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ABSTRACT

A new process for an additional protection of integrated circuit (I.C.) chips at T.A.B. (Tape automated bonding) film level has been developed by CII-HONEYWELL BULL. This article presents analyses and tests required for the resin qualification and the equipment used since last year in the ANGERS plant.

Successful utilization of this chip protection process confirms that T.A.B. technology is a satisfactory and available approach for the assembly of complex hybrid microcircuits.

INTRODUCTION

For two years now, CII-HB has been using, for its new line of DPS-7 computers, a new family of integrated circuits with a high level of integration, interconnected through new techniques known as micropackaging. These techniques have already been described (1.2) ; they are mainly based on multi-layers ceramic substrates and T.A.B. (Fig. 1.2.)

One characteristic of micropackaging is the use of I.C.'s without any package at the chip and substrate level. Chip protection has to be carefully done by our I.C. suppliers.

A very tight specification defines environmental tests to be performed on these chips. The nature of protective layers is the responsibility of each supplier, the effectiveness of the protection is tested by CII-HB.

A big advantage of T.A.B. compared to conventional wire bonding is the hermeticity of chips at the pad level due to gold bumps ; so there is no further need for encapsulation. However, it appeared useful to have an additional protection, mainly to prevent chips from being mechanically damaged during micropackage assembly and handling. This coating will also act as first barrier against moisture and contamination.

So, a process was developed along with the corresponding automatic equipment to protect chips on tape by a drop of epoxy. One of the problems was the resin selection according to process requirements. Many experiments, analyses and qualification tests were performed to make sure the selected resin was really effective and without risk for chips.

The first aim of this presentation is to give a general insight into the work involved in selecting a suitable resin for chip protection and in defining a qualification procedure. The second aim is to describe the automated equipment developed by CII-HB.

A) - MATERIAL

1) MATERIAL CHOICE

At first, materials were selected according to the following process requirements :

- Handling convenience and ease of application for automatic processing. A liquid resin with a pot life longer than one day is a solution.
- Cost and thermomechanical properties CII-HB uses a mylar tape which does not allow temperatures higher than 110° C.
- Good solvent resistance. Several cleaning processes are necessary during micropackage assembly. The solvent resistance of silicone resin for example is not sufficient for our application.

All these requirements, particularly pot life and curing temperature, greatly restrict the choice of material. In the end, an electrically insulative two-component liquid epoxy resin was found to be suitable. Its main properties are (supplier data) :

- . Mixing ratio (parts by weight or volume)
 - Part A (Resin + filler) : 1
 - Part B (Hardener + filler) : 1
- . Curing schedule :
 - 5 mn at 150° C to 1H30 mn at 80° C
- . Thermal conductivity : 0.012 W/cm.s.°C
- . Thermal expansion coefficient : $34 \cdot 10^{-6}$ cm/cm °C
- . Volume resistivity : $1.5 \cdot 10^{13}$ Ω.cm

The next step was to qualify the protective properties of the resin such as ionic purity, moisture and contaminant resistance, thermo-mechanical behavior. The risks are the following :

Corrosion can appear if ionic purity, moisture and pollution resistance are not sufficient.

Connections can be broken if the thermal expansion coefficients of the chip and the coating are too different.

2) MATERIAL QUALIFICATION

The three following investigations were considered as essential : Ionic Purity Measurements, Thermal Analysis and Qualification Tests.

Ionic purity

To be sure of the resin compatibility with I.C. chip and micropackage, the resin must not contain any ionic contaminant such as chloride which will cause corrosion or electrical leakage between I.C. conductors (3). Two different methods were used.

a) Chloride content

Because chloride may be introduced in epoxy resin during manufacturing, it is very important to determine chloride content. The method used is a direct titration with silver nitrate, before and after sample polymerization.

The values obtained are lower than 2 µg/g which correspond for a cured sample (10 g - 50 cm²) to a concentration lower than 0.4 µg/cm².

b) Ionograph measurements

Many other ions can cause contamination, so chloride analyses had to be completed by conductivity measurements. The ionograph method was used : it's a dynamic measurement of ionic conductivity of a rinse solution (water or 50/50 water - alcohol mixture) which extracts ions from the sample.

The experiments showed no ionic contaminant on part A before mixing (chloride equivalent $\leq 1 \mu\text{g/g}$) but, on part B, contamination was important (3000 µg/g). This was due to the amine ionization. It was then interesting to measure the ionic purity of the resin after polymerization for different mixing ratios of parts A and B :

For part A / part B Ratio ≥ 0.75
ionic contamination $\leq 1 \mu\text{g} / \text{g}$

For part A / part B Ratio < 0.75
ionic contamination increases when this ratio decreases.

Although the manufacturer recommendation is 50/50, a part A / part B ratio of 3/2 by weight was chosen to avoid the risk

of hardener excess. With this 3/2 ratio, the chloride content of a cured sample is always lower than 1 µg / g or 0.2 µg / cm² chloride equivalent.

Thermal analysis

Differential scanning calorimetry (D.S.C.) is very useful for studying epoxy resin polymerization (4). The properties of cured resin are strongly affected by the curing schedule and the resin / hardener ratio (5). It's important to know the effect of these parameters on the glass transition temperature (Tg).

All the following D.S.C. experiments were carried out in a DU PONT Instruments 1090 Thermal Analyser (sample size : 40 ± 10 mg Scanning Rate : 20° C / mn).

a) Determination of the curing schedule

Table 1 illustrates relationships between curing schedule and Tg (Part A / Part B = 3/2). Optimum curing temperature is about 120° C.

Table 1 - Temperature, Time, Tg

Temperature	Gel Time	Polymerization*	Tg**
100° C	12 mn	15 H	85° C
125° C	3 mn	10 mn	80° C
150° C	1 mn	4 mn	75° C

* Time for complete polymerization (D.S.C. thermograms without residual curing exotherm).

** Tg values after complete polymerization.

b) Influence of mixing ratio on Tg

On Fig. 3 Tg values are plotted versus part B per cent (sample curing schedule : 10 mn at 125°). Results show that Tg is strongly affected by hardener concentration. The lower the part B percentage is, the higher the Tg is. But glass transition is less pronounced when there is too much or not enough hardener. Suitable values for the part A / part B ratio are between 1 and 3.

c) Thermal degradation

To check thermal stability of the resin T.G.A. measurements on cured sample were carried out. T.G.A. curves are plotted on Fig. 4. No noticeable thermal degradation occurs before 250° C and weight loss is lower than 5 % at 350° C.

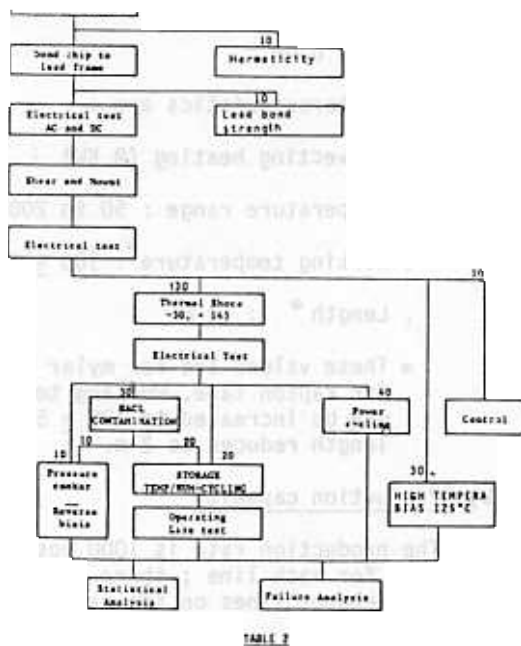
Resin qualification on chips

It was necessary to perform environmental testing on chips protected with epoxy resin in order to check the compatibility of the resin. We mainly have to verify two important points.

- Its mechanical behavior during thermal shocks. Differences in thermal expansion coefficients can cause defects, even cracks in the coating or defective bonds.
- The effectiveness of protection during humidity and contamination tests.

In our specification for chips on wafers, a qualification program is defined which includes thermal shocks, pressure cooker with NaCl contamination, humidity cycling (Table 2). Firstly, this program was performed on chips with resin bonded on single chip substrates. As the results were correct, other tests were done in much severer conditions. The following table 3 gives an idea of the results we obtained with the selected resin.

Table 2 Qualification flow-chart



It's important to notice that during previous investigations some bad results were obtained with certain hard resins. They were cracked during thermal shocks and the chips were corroded during humidity testing.

Table 3 Results of qualification tests

- Thermal shocks air to air between - 30° C and + 145° C.
10 cycles → 0 failure
- Pressure cooker : $2.1 \pm 0.1 \text{ Kg/cm}^2$

	16 H	32 H	48 H	64 H
Pressure cooker	0	0	0	0
Pressure cooker after NaCl contamination	0	0	0	0

0 failure related to conformal coating

- 85/85 storage : after 1000 hours → 0 failure
- Humidity cycling : according to MIL STD 883 method 1004 : 10 cycles of 24 hours
Temperature : 25 to 65° C -
Relative humidity : 90 to 98 % at 65° C
0 failure

3) MATERIAL CHARACTERIZATION

For a better understanding of the material behavior, it was necessary to obtain a detailed knowledge of the resin.(6). So a complete chemical characterization was carried out.

a) Thermogravimetric analysis (T.G.A.)

Thermal analysis methods have been described in detail by different authors (7). T.G.A. curve, expressing the dependence weight change on temperature, gives informations on the filler content. Curves corresponding to part A and part B measurements are plotted on Fig. 5 and 6.

b) Filler composition

The following methods were used :

- X-Ray Fluorescence Spectrometry
- Atomic Absorption Spectrometry (A.A.S)
- Scanning Electronic Microprobe (S.E.M)

All these methods give elementary analysis of the filler - Results are summed up in Table 1 and 2.

Filler contains mainly alumina, silica, copper and chromium oxides (in part A) Silica could be the thixotropic agent and metallic oxides the colorant.

c) Size of filler particles

Measurements were made on a Coulter Counter after gravimetric experiments. Fig. 7 shows the particle size distribution. The average is about 6 μm with a minimum less than 1,3 μm and a maximum about 25 μm.

d) Resin characterization

The type of epoxy resin was determined by Nuclear Magnetic Resonance (N.M.R.)

and Infra-Red spectrometry (I.R.)
It was found that this resin was a
NOVOLAC and not a Bisphenol A
(as we had originally thought).

e) Curing agent characterization

Characterization of the curing agent was more difficult because it is a complex system. Mass spectrometry, I.R. spectrometry, N.M.R. were used. These analyses show that the curing agent contains an amine hardener with another compound inhibiting hardener reactivity at low temperature.

Table 4 Filler elements of part A

Element Method	Na	Mg	Al	Si	K	Ca	Ti	Cr	Mn	Fe	Cu	Zn
X-Ray			(X)	(X)		X		(X)	X		(X)	
A.A.S.	X	X	(X)	(X)		X		(X)	X	X	(X)	X
S.E.M.		X	(X)	(X)		X	X	(X)	X	X	(X)	

(X) Main element X Trace of element

Table 5 Filler elements of part B

Element Method	Na	Mg	Al	Si	K	Ca	Ti	Cr	Mn	Fe	Cu	Zn
X-Ray			(X)	(X)								
A.A.S.	X	X	(X)	(X)	X				X	X		
S.E.M.		X	(X)	(X)		X				X		

(X) Main element X Trace of element

B) PROCESS AND EQUIPMENT

1) PROCESS CHARACTERISTICS

The principal steps of the process are

- After mixing and outgassing, resin is poured into a syringe which is fixed on the equipment.
- A controlled drop of epoxy is put on each chip at the tape level. The amount of resin is adjusted to the die size. The height of epoxy is greater on large chips due to the spheric shape of the drop.
- The resin is then precured in line, the tape moving step by step through a tunnel oven during 12 mn at $105 \pm 5^\circ \text{C}$.
- Complete curing is obtained by an additional storage of the reel in an oven (2 hours at 90°C).

Fig. 8 shows a chip after coating, the active surface of the die and the Inner Lead

Bonds are protected. There is no risk of overflowing during prepolymerization.

2) EQUIPMENT

a) Description

Equipment (Fig. 9) includes three main parts :

- Tape handling system (Fig. 10)
Winding and rewinding of tape and spacer are automatic. Each reel is driven by an independant motor. The tape moves under the resin dispenser and through the furnace with two tape steppers. The first one, just after the resin deposition, is mainly used to pull the tape under the dispenser syringe and the second one, at the end of the tunnel oven, pulls the tape out of the furnace.
- Resin dispenser (Fig. 11)
The tape moves step by step under the resin dispenser. The syringe holder moves down until the end of the needle comes close to the chip. A calibrated drop of resin is put on it. The syringe holder moves up and then the tape moves to the next position.

- Tunnel oven

Its characteristics are :

- . Convecting heating (8 KW)
- Temperature range : 50 to 200°C
- . Working temperature* : $105 \pm 5^\circ \text{C}$
- . Length* : 4 m

* These values are for mylar tape but, for Kapton tape, working temperature may be increased to $125 \pm 5^\circ \text{C}$ and length reduced to 2 m.

b) Production capacity

The production rate is 1000 positions/hour for each line ; there are two independant lines on the same equipment.

The cost of this operation is :

- For material $< 0.002 \text{ US } \$/ \text{ chip}$
- For labour $\approx 1.5 \text{ sec} / \text{ chip}$

TO SUMMARIZE

- Our process requirements restrict the choice of the resin. In spite of the differences of properties between the resin selected and those used for conventional chip encapsulation, results are satisfactory. So this kind

of coating, along with the excellent robustness of T.A.B. connections and the good wafer protection we require, is a suitable solution for our reliability aims. This approach may be available for other applications like L.S.I. chip packaging, for example.

- b) All this resin selection work has allowed us to choose a suitable material but, also, to increase our knowledge in I.C. protective material, to define a qualification procedure for new protective resin and incoming inspection for the epoxy used.
- c) For one year now, this process has been satisfactorily used in our Angers production plant (chip protection efficiency, process and equipment reliability).

REFERENCES

1 - "Economic Considerations in multi-layer thick film hybrid" by J. LOUGHRAN, K. KURZWEILL - IEEE Transactions - Vol. PHP 10 (June 1974).

- 2 - "Tape Automated Bonding Moving in Production" by G. DEHAINE, K. KURZWEILL - Solid State Technology (October 1975).
- 3 - "Evaluation of Electrically Insulative Adhesives for Use in Hybrid Microcircuit Fabrication" by J.J. LICARI, K. L. PERKINS, S.V. CARUSO - IEEE Transactions, Hybrids and Packaging - Vol. PHP 9 (December 1973)
- 4 - "Differential Scanning Calorimetry of Epoxy Resins" by R.A. FAVA - Polymer 9, p. 137 (1968).
- 6 - "Materials and Curing Characterization of Conductive Epoxide Adhesives" by D.M. SHEMFIELD - ISHM Los Angeles (1979).
- 5 - "The Significance of Glass Transition Temperature on Electrically Conductive Epoxy Resins in Hybrid Microelectronics" by F.W. KULESZA ; J.F. SAUNDERS - ISHM Los Angeles (1979).
- 7 - "Thermal Analysis" - by A. BLAZEK edited by R.A. CHALMERS - Van Nostrand Reinhold Company.

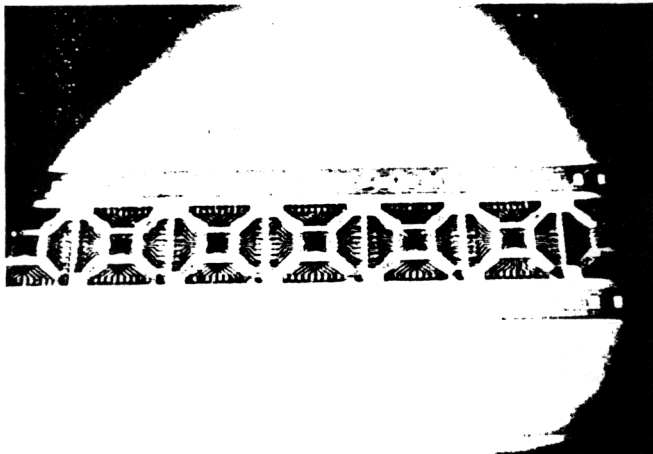


Fig. 1 Chips on T.A.B. film

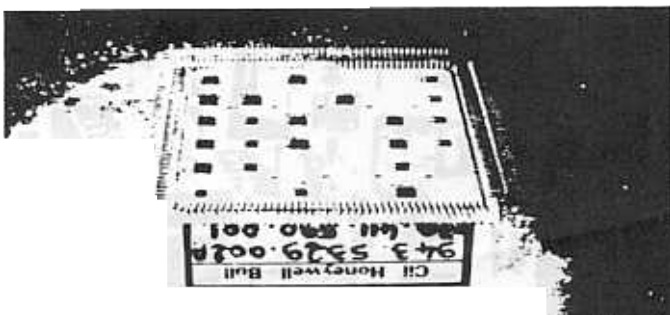


Fig. 2 Finished module micropackage

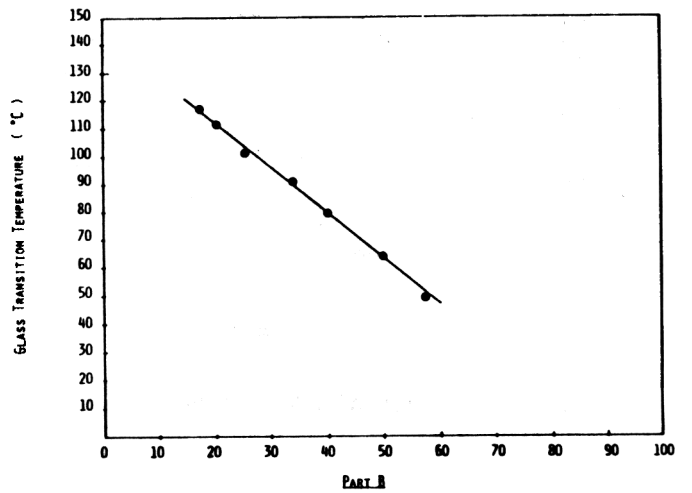
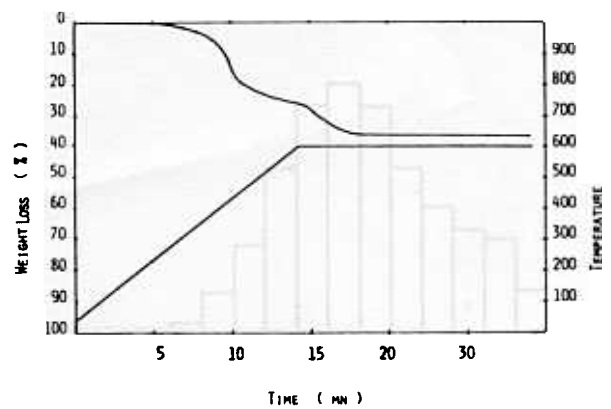
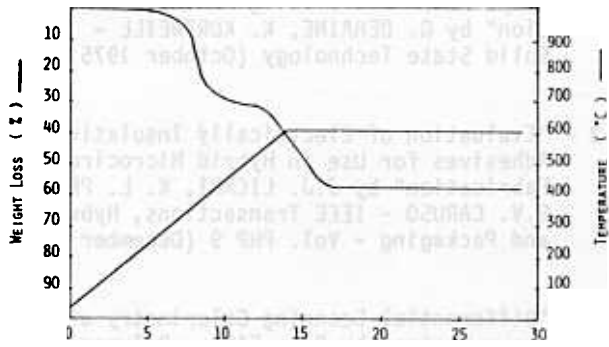


Fig. 3 Relationship between Tg and mixing ratio

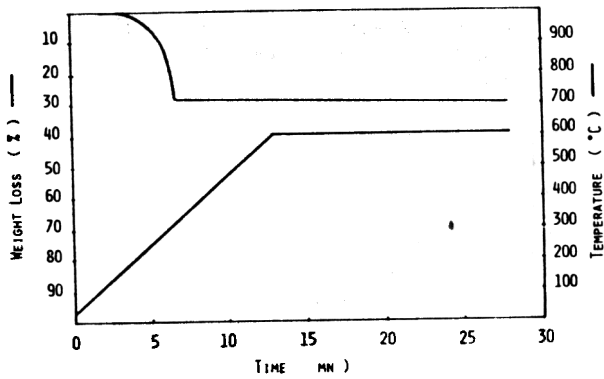


4 Thermal degradation



FILLER 42 %
RESIN 58 %

Fig. 5 T.G.A. curve of part A



FILLER 71 %
HARDENER 29 %

Fig. 6 T.G.A. curve of part B

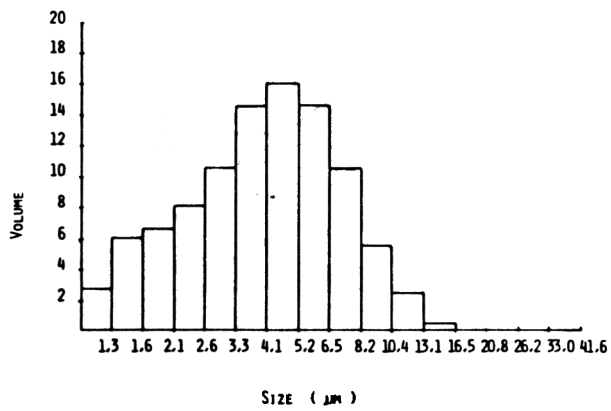


Fig. 7 Filler particle size

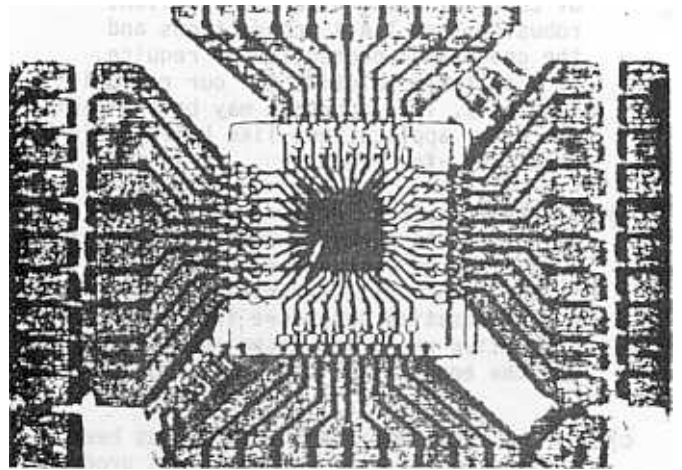


Fig. 8 Chip after coating

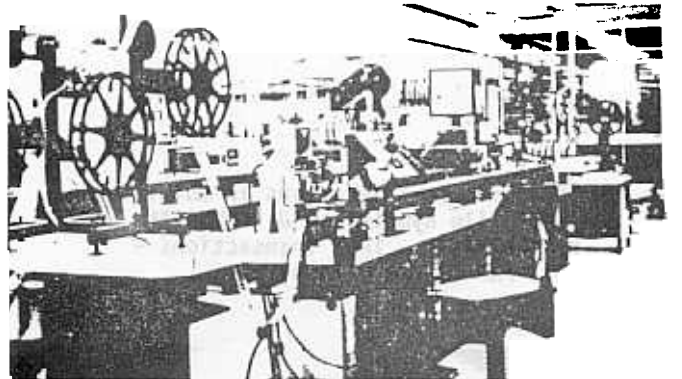


Fig. 9 General view of the equipment

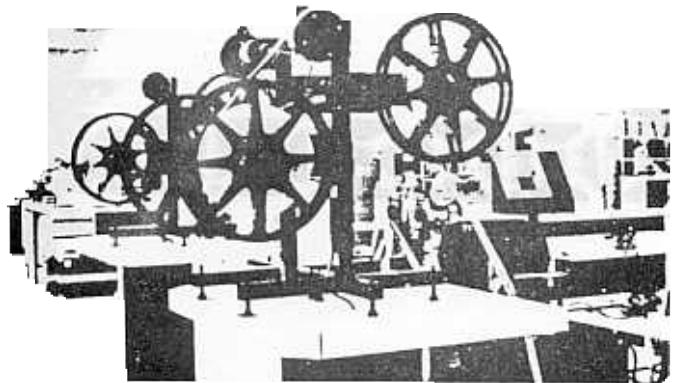


Fig. 10 Tape winding system

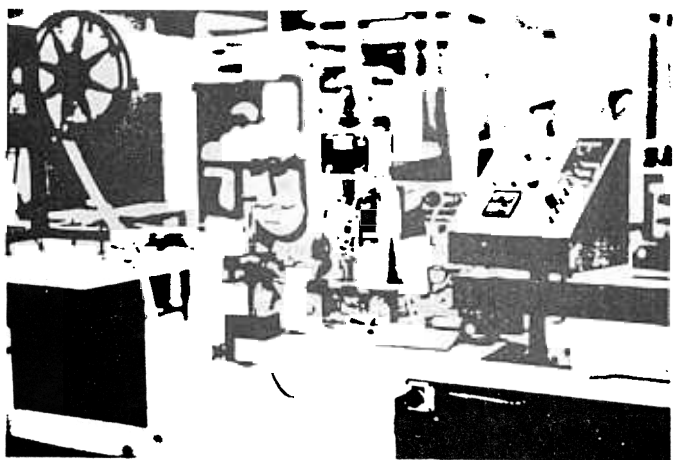


Fig. 11 Resin dispenser