STUDY OF BONDING METHODS FOR FLIP CHIP AND BEAM LEADED DEVICES

NASA CONTRACT NO. NAS8-25615

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INTRODUCTION

A. OBJECTIVE

Under Contract No. NAS8-25615 Electronic Communications, Inc., has performed a program with the objective of a comprehensive study and evaluation for the bonding of "flip chip" and "beam leaded devices" onto hybrid microcircuit substrates used in high reliability space applications. The program included the evaluation of aluminum flip chips, solder (silver/tin) bump chips, gold beam leaded devices, and aluminum beam leaded devices.

1.0 General Requirements

Develop and conduct a program to collect, generate, and evaluate data and information necessary, to establish design, quality, and reliability standards and screening techniques, recommended and mandatory, for the joining methods used in mounting "flip chips" and "beam leaded devices" onto hybrid microcircuit substrates. The areas of investigation shall include controls related to fabrication, methods, design constructions, environmental capabilities, material compatibility, failure modes and mechanisms, and screening techniques that are most effective in detecting failure mechanisms that may exist.

2.0 Mechanical Specifications

The individual devices after initial screening were mounted on test substrates and sealed in flat packages for the evaluation program.

3.0 Environmental Specifications

Thermal Shock: -55°C to +85°C (25 cycles)

Vibration (sine): 50 g. peak 20 - 2000 Hz in three axis (4 cycles/axis)

Thermal Scan: -65°C to +125°C

Vibration Scan: 70 g: max 20 - 2000 Hz

Step Stress Test: -65°C to +125°C with simultaneous vibration from 20 g. to 70 g. maximum in 8 steps

4.0 Fabrication Processes

Aluminum Flip Chip:

- Device - 2N930 (Intersil)
- Substrate - Alumina (glazed)
- Metallization - Aluminum Thin Film
- Device bonding - ultrasonic

Gold Beam Lead:

- Device - RM709 (Raytheon)
- Substrate - Alumina (glazed)
- Metallization - Gold Thin Film
- Device bonding - individual beam thermal compression

Solder Bump Chip:

- Device - GAZ8075 (Hughes)
- Substrate - Alumina (unglazed)
- Metallization - Palladium gold thick film
- Device bonding - solder reflow

Aluminum Beam Lead:

- Device 20TBL (Amperex)
- Substrate - Alumina (glazed)
- Metallization - Aluminum thin film
- Device bonding - individual beam ultrasonic

B. RESULTS

A total of two hundred and sixty-five (265) devices were included in the final evaluation phase of the program. Twenty (20) device failures were recorded from the initial electrical screening through final step stress testing. The summary of the failures is included in Section C. 2.

C. PROGRAM DEVELOPMENT

The program was divided into two phases. The first phase was the development of the bonding techniques. The final phase was the reliability evaluation program. The bonding techniques are as follows:

1. 0 Gold Beam Lead Bonding

Gold beam lead devices were designed with the thermocompression bonding processes as the method for interconnecting these devices into hybrid circuits. An extension of this design is to utilize gold film metallization to maintain a monometallic bonding system which is ideal for thermo-compression bonding. The film used for the studies was a 6000 Å thick gold film over a 200 Å nichrome film used for adhesion. The films were vacuum desposited onto a glazed alumina substrate using an electron-beam gun for evaporation of the films. All bonding studies were made with Raytheon RM 709BL beam lead devices fabricated by the planar process. Silicon nitride is used as a hermetic passivation layer with a Pt-Ti-Pt-Au metallization system. The RM 709BL, shown in Figures 1 and 2 is an integrated circuit having fourteen (14) beam leads uniformly distributed around its perimeter. The beams are 3 mils wide and extend 4 mils beyond the edge of the chip with 7 mils between adjacent beams. The beams are electroplated to a final thickness of 0. 5 mils in a controlled gold plating bath.

The devices are received from the manufacturer in two inch (2") square plastic boxes sandwiched between a glass plate and thin sheet of plastic material. A foam material makes up the remainder of the box allowing little or no movement of glass slide, devices, or plastic sheet. The devices are positioned on the glass slide in such a manner that inspection of the devices is possible without removing them from the box. The lot of devices received for this program came 5 devices per box. Mechanical samples were received 25 per box. After receiving the devices at ECI, they were stored in a dry nitrogen atmosphere.

Handling of devices required the use of vacuum pickup methods. Again, the most efficient and simplest approach was used. A simple vacuum pickup system with a hand manipulated probe was chosen. The vacuum tip is a syringe needle type instrument having a flat rather than angled end. Various sizes of vacuum tips were evaluated for this device; the #18 vacuum tip was chosed (OD = .050"; ID = 0.30"). The vacuum tip is approximately two inches long and has been angled some 15 - 20 degrees in the middle for ease of device manipulation. To remove a device from the glass slide, it is necessary to first remove the plastic sheet over the top of the devices. In many instances the vacuum tip must be applied at an angle approximately 30 - 45 degrees to the plane of the glass slide in order to pick the device up. In most cases, however, the vacuum tip can be positioned on top of the device perpendicular to the plane of the device body. Care must be taken and some training is necessary in order to become proficient at this task. Once the device is held by the vacuum tip, it may be transferred and positioned elsewhere.

Testing of the beam lead 709 was accomplished by building a test fixture which consisted of the typical package/substrate system to be used in the program less the bonded device. The substrate was T.C. bonded to the package pins and the package then put into breadboard test setup. The beam lead devices were removed from their containers by vacuum tip as previously described and placed on the bonding pads of the substrate in proper orientation. Very slight or no pressure was required to obtain sufficient contact to test the devices. After test data was taken, the device was returned to the glass slide of the container and properly identified. This method afforded rapid beam lead testing without the expense of sophisticated equipment. No damage to devices occurred. An alternate method was used in laboratory test; this consisted of a similar test setup except a hole was abraded in the substrate in the center of the device pattern, as shown in Figure 3, and vacuum applied from the bottom. The vacuum used to hold the device in place was found to be unnecessary. The vacuum also caused positioning and device removal problems. Probing the top of the device beams was also attempted, but was found to be time consuming and hazardous to device reliability. The first method described was found to be the most applicable. Smaller beam lead devices have also been tested in this manner with little difficulty. Unless thousands of devices require testing, it appears unnecessary to purchase special handling and test equipment.

One of the main goals of the program was to investigate various methods of assembly techniques used to fabricate hybrid circuits utilizing beam leaded devices. The two bonding techniques of single beam bonding and simultaneous beam bonding were investigated with the most effort placed on the least tried method of thermocompression bonding a single beam at a time.

This method, when using pulsed heated tips, has the least effect on other devices on the hybrid circuit. The pulse heated tip may be the only way to bond beam leads on hybrid circuits having temperature sensitive devices since wobble head bonding utilizes a heated stage during bonding. A

Weltek pulsed tip bonder, model 100/2 bonding head with a model AC-10A power supply, was used to make the single beam bonding studies.

Another important goal was to compare the various methods of testing the bond strength developed by the various bonding techniques. The air-blast method was refined by the Bell Telephone Laboratories and is well documented in published technical literature. It was decided that more information would be obtained for comparison by concentrating on a method where the beam leaded device was either pushed or pulled off of the bonded substrate. Either of these methods are more practical to most hybrid companies without any large capital expenditures.

The mechanical testing of aeam lead devices for the purpose of choosing a bonding schedule is most valuable if used properly. By proper use, it is meant that the bond strength be reviewed carefully and not interpreted as being the only deciding factor. Visual inspection after the device has been removed from the substrate metallization is most important. The bond strength data figures and failure mechanism along with a good visual inspection are necessary for evaluating the bonding of beam lead devices.

Several types of mechanical tests were evaluated. The first to be discussed is that of shearing the device from the metallization with a tool moving parallel to the plane of the substrate. The tool travel is one inch per minute. Special fixturing had to be fabricated in order to have confidence in the test data. The shearing tool is similar to a milling tool and it is held stationery perpendicular to the substrate. Shear values run from 200 to 400 grams in most cases with an average of approximately 300 grams. These values are for the fourteen lead beam lead integrated circuit bonded with a .0007" capillary tip pulse heated to 350°C and using a bonding force of 40 grams. In most cases the shear test will cause failure of the bonds edge. It is very seldom seen that a bond will fail once the proper bond schedule is achieved. The beams opposite the side of the device where the tool started are usually doubled back over and failure occurs at the beam/silicon interface. As the tool passes over the bonding pads, the gold beam material remaining is usually scraped and this sometimes causes loss of important bonding information.

The second test method is that of pushing the device off through a pre-drilled hole in the substrate. Before bonding the device to the substrate, a hole is mechanically abraded through the substrate, Figure 3, in the middle of the bonding pattern. In order that this hole be drilled, a protective coating such as photoresist must first be put over the metallization. After the hole is made, the substrate must be thoroughly cleaned before bonding. The bond is then made as previously described.

The push test is made by supporting the substrate edges with the metallization side down as shown in Figure 4.

A test gage with arm was designed to accept a needle type probe which would clear the pre-drilled holes. The probe is placed directly over the hole perpendicular to the plane of the substrate. The gage is held stationary while the substrate holder moves at one inch per minute. The probe goes down through the hole and contacts the beam lead chip NEAR the middle. As the holder continues to move, the beams are stressed and failure occurs. The failure mechanism is generally that of the beam fracturing at the bonds edge. It is usually found that the beams on one side of the device do not fail at all; this is due to the probe not being centrally located on the chip body. Some drag may occur, also, since scratch marks are almost always seen on the substrate metallization. The average push strength of the fourteen lead devices are approximately

75 grams. If only ten of the fourteen beams fail, it would average out to 7.5 grams per beam. One advantage of this test is that the devices are not lost nor are they damaged to the extent that bonding information is lost. Since the device is usually left hanging to the substrate by 2 to 4 beams, the sample can be filed for future use.

The third test method is that of attaching a small diameter wire to the device body and pulling until failure. The basic problem involved with this technique is that of attaching a wire to the top of the device body. Several different adhesive compounds were tried with little success. Pressure sensitive compounds were also used; the low viscosity and low bond strength to silicon gave poor results. The wire used was gold .005" and .006" in diameter with a ball formed on the end. When results were obtained, they corresponded very well with those obtained from the "push" test.

The fourth method used to mechanically test beam lead devices was the "air gun" test. This method was not evaluated extensively due to the additional equipment necessary for calibrating the air flow required.

Another aim of the project was to determine what the failure mechanism would be for the beam lead devices. It was important to note the frequency of each type of failure and to try to understand what caused each type of failure. Once this data were obtained, the bonding parameters would be studied to determine how they relate to each failure mechanism. Finally a bonding schedule would be derived that would result in an optimum bond for a high reliability hybrid circuit.

The advantage of cold substrate bonding is obtained by pulsing a tungsten alloy tip with a controlled pulse of energy. The type of bond formed will depend on the bonding pressure, temperature, pulse duration and the configuration of the bonding tip. The widest range of satisfactory metallurgical bonds are achieved when the bonding temperature is 350°C ± 25± and the pulse width is 1.7 sec ± 0.2 sec. These two parameters were maintained in their respective range while the bonding pressure was varied for each type of bonding tip. The three bonding tips

1. Slotted Wedge
2. Rounded Wedge
3. 0.007" Capillary

were investigated to determine the most compatible type for bonding beam devices, Figures 5, 6, and 7. Satisfactory bonds were achieved with all three types of tips. The amount of bonding force was much lower for the rounded wedge and the capillary tips. This is due to the type of beam deformation caused by the shape of the tip that comes into contact with the beam. The rounded wedge and the capillary tips were optimized at a bonding force of 40 gms ± 5 gms. The amount of diffusion was decreased as the force was decreased and if lowered enough would result in a weak bond or no bond, as shown in the photograph in Figure 8. As the force is increased much above 45 gms the beam becomes pinched off at the heel of the tip and develops a weak point in the beam, Figure 9. Corresponding effects occur with the slotted wedge tip at forces of 60 gms ± 10 gms, Figure 10.

All three types of tips caused the chip to raise up, called "bugging," when the first beam was bonded. The degree of bugging depended on the bonding force and the type of tip. The higher the bonding force the more deformation of the beam and therefore resulting in more bugging. The more narrow the bonding tip the worse was the bugging. Too much bugging occasionally causes beams to fail, as shown in Figure 11, because of stresses when the device is realigned to the substrate. Since the capillary tip creates a circular deformation coplanar with the beam, the degree of bugging is decreased, Figure 12. The best processing control was obtained when the first two bonds were made on beams that were diagonally opposite each other on the chip. This prevented an excessive amount of bugging during the remaining bonds and prevented any alignment problem that might otherwise exist. Figure 13 shows a device bonded with the cap8llary tip and the device having good registration with the metallization pattern.

The improper location of the bond on the beam with respect to the chip will frequently cause failures. If the bond is made too close to the chip, the beam may break at the chip periphery. Thermal shock may occur to the thin film on the substrate if the bond tip extends much beyond the outer end of the beam. The optimum location for a bond made with a capillary tip is several tenths of mil from the outer edge of the beam, as shown in Figure 14.

The number of repairs that can be successfully performed depend on the film metallization and the type of substrate used for the hybrid. Bonds with beam diffusion into aluminum films are difficult to remove. The beams are easier to remove from a gold thin film and results in higher yields. Hybrid substrates with the thin film on a glazed surface are more difficult to remove the beams because of possible high stresses created in the glaze at time of beam removal. Occasionally the glaze will chip out of the substrate and create a discontinuity in the circuit, Figure 15. If the beams are not completely removed the alignment of the next beam lead device may be difficult.

A difference in bonding pad heights occurs where some beams are removed and some beams are allowed to remain on the substrate. This often causes some beams on the replacement device to break off at the chip during bonding.

Some bonding experience was developed with a Micro-Tech beam lead bonder using the multiple beam bonding process. The model 1190 Wobble Head Bonder was used for all the testing. This bonding uses a heated substrate stage and a constant heat bonding tip (cullet). The best bonds visually were bonded at the following settings:

1. Substrate temperature - 125°C
2. Cullet temperature - 390°C
3. Bonding force - 275 gms
4. Number of cycles - 2 or 3
5. Wobble speed - slow

Bond strengths comparable to the bonds made with a capillary tip were achieved with a minimum of effort.

The bond strength and type of failure mechanism depends on the method of mechanical testing used to remove the devices.

The main two methods of testing bond strengths are where the device is sheared or pushed off the substrate. The shear-test is performed with a force applied along the plane of the beams. This test provides readings which range from 200 to 400 gms for a 14 beam leaded device. The shear-test appears to be less sensitive to bonding parameters since the bond strength is essentially the same for bonds made with 40 to 80 gms bonding force.

The "push-test" is achieved by applying a force perpendicular to the chip on the bonding face of the device. This is accomplished by inserting a

10 mil diameter needle through a 20 mil hole in the substrate. A pushing force is applied on the device until a catastrophic failure occurs. The push-test appears to be more sensitive to bonding parameters and gives bond strength readings approximately one-quarter the value of the shear-test or an average of 75 gms. The explanation for both of these results is the type of failure mode is entirely different for the push-test than that for the shear-test. The four main modes for bond failure are[1]:

1. The peel strength of the bond - the force required to peel the beam from the substrate or silicon chip at an angle to the plane of the bond.

2. The buckling strength - the force required to buckle the beam.

3. The shear strength of the bond - the force required to shear the beam from the substrate or silicon chip.

The peel strength is given by Elftherion at an angle of 90 degrees (90°). Buckling and tensile strengths are several times stronger than the peel strength. Shear strengths are an order of magnitude stronger than the peel strength. The main mode of failures for the shear-test is tensile strength while the main mode of failures for the push-test is a combination of peel and tensile strength. Most beam failures occur at the bonds edge where the beam has a reduced cross-section, Figures 9, 10 and 16, but the difference in the failure modes causes the push-test to fail at lower strength readings.

Beam lead devices can be bonded to unheated substrates by various pulse heated tips. The capillary tip creates a slightly stronger bond and has a higher yield than the wedge tips. The higher yield is mainly because the

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Ref. (1) Handling and Bonding of Beam-Lead Sealed-Junction Integrated Circuits - M. P. Elftherion round capillary tip does not have the excessive bugging that occurs in the wedge bonds. The multi-beam bonders (wobble head) are more repeatable and much faster once the equipment is aligned and calibrated. It is recommended that for large quantities of beam lead devices that a multibeam bonder be used for bonding.

The method of testing the bonds, as indicated earlier, will depend on the amount of equipment available. In theory the Bell System's air-blast test is the best method of testing bonded devices. This test stresses each beam uniformly and can be used as a non-destructive test. However, this equipment is extremely expensive and not commercially available. The most readily available equipment can be used to test beam lead bonds satisfactorily by either the shear or the push-test method. Either method cannot easily be used as a non-destructive test because the test visually creates some permanent damage to the device. The shear-test is the easiest and the less expensive but is not quite as sensitive a test as the push-test.

The common mode of failure for both the shear-test and push-test are broken beams occurring at the bond edge. This is due to the weakened area caused by the head of the bonding tip. Occasionally failures occur in the beam at the chip periphery and the bond frequently fails at the chip to beam interface, Figures 9, 11, 16 and 17. Whenever the bonding parameters are not kept within their range, the beams may break anywhere during the bonding process or a weak bond may result. The optimum bonding parameters for a capillary tip thermo-compression bond, Figure 18, are:

1. Temperature - 350 - ±25-C
2. Force - 40 ± 5 gms
3. Pulse width - 1.7 ± 0.2 sec
4. Bond made within a few tenths of a mil of the beam end.

The above parameters were used to bond approximately 150 Raytheon RM 709 BL integrated circuits with satisfactory results.

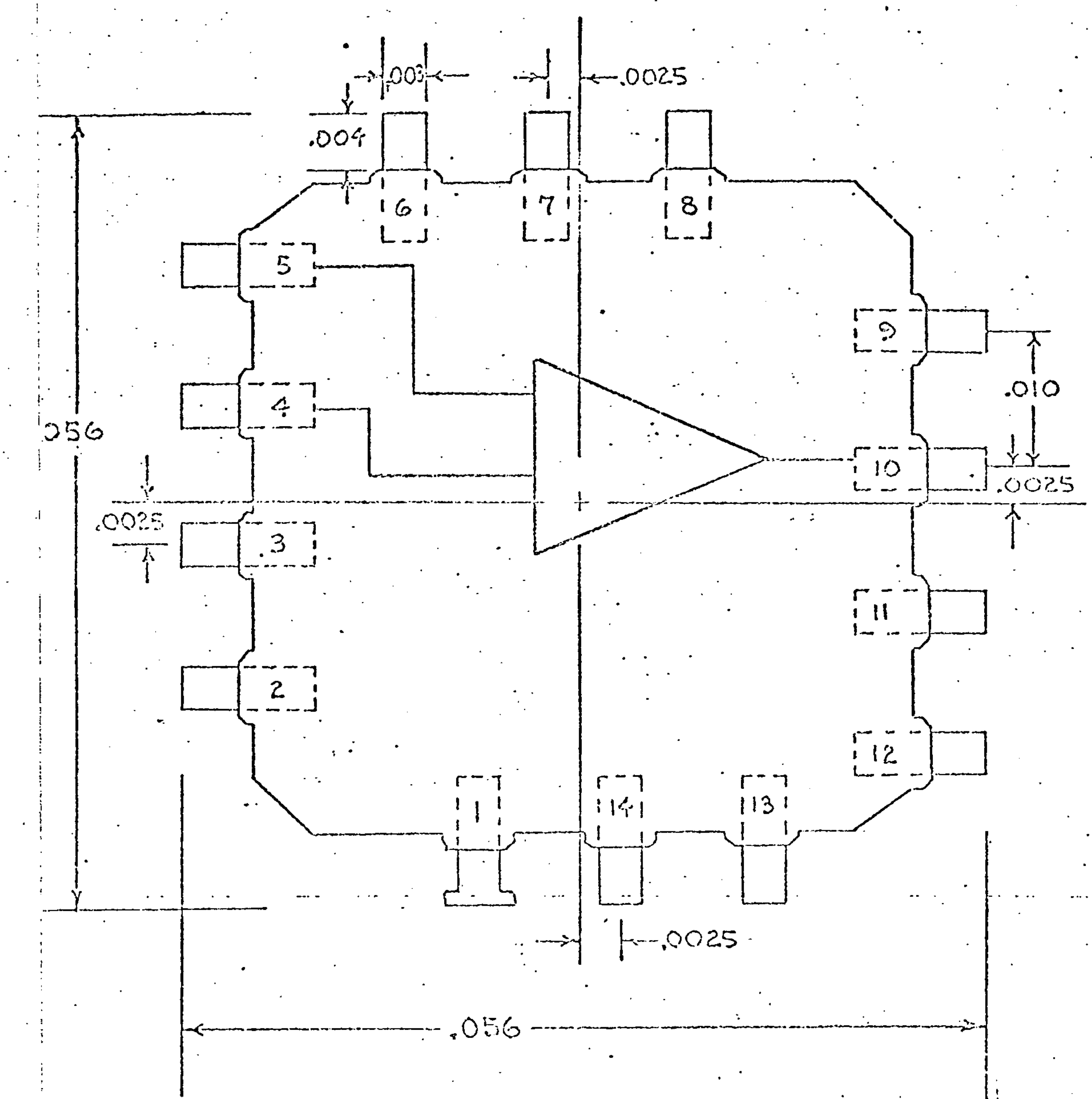
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FIG. 1

FIGURE 2

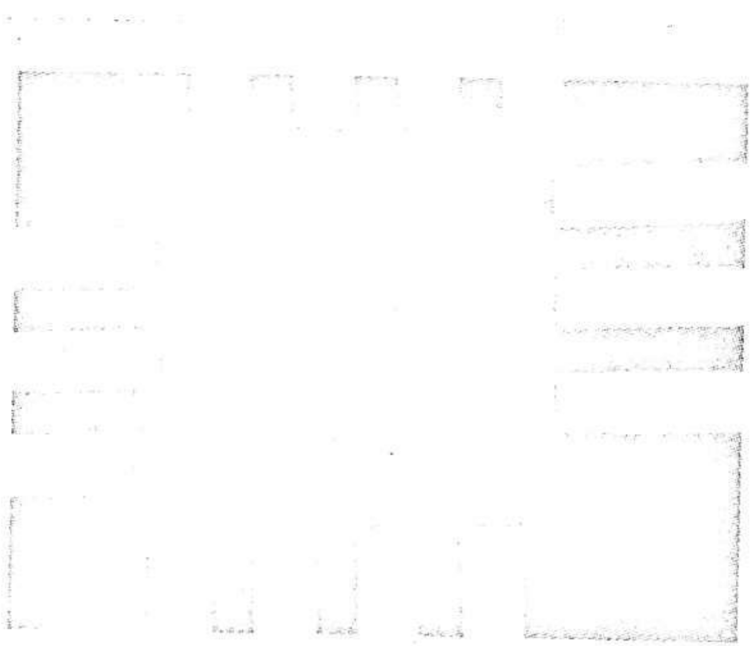
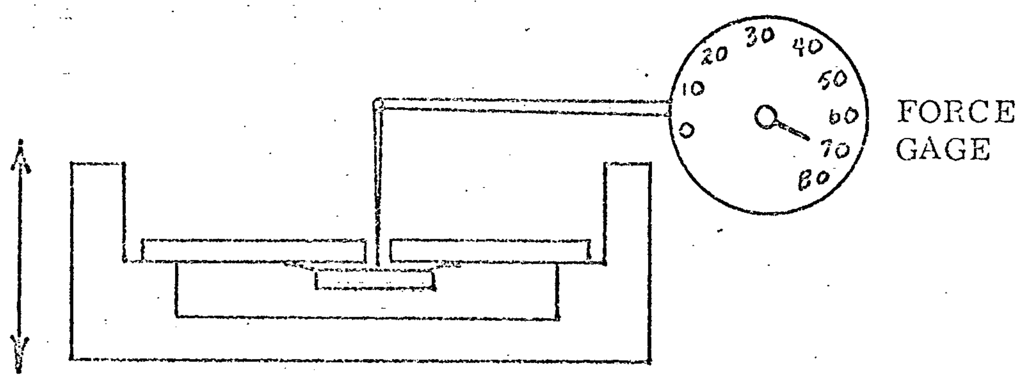


FIGURE 3



PUSH TEST APPARATUS

FIGURE 4

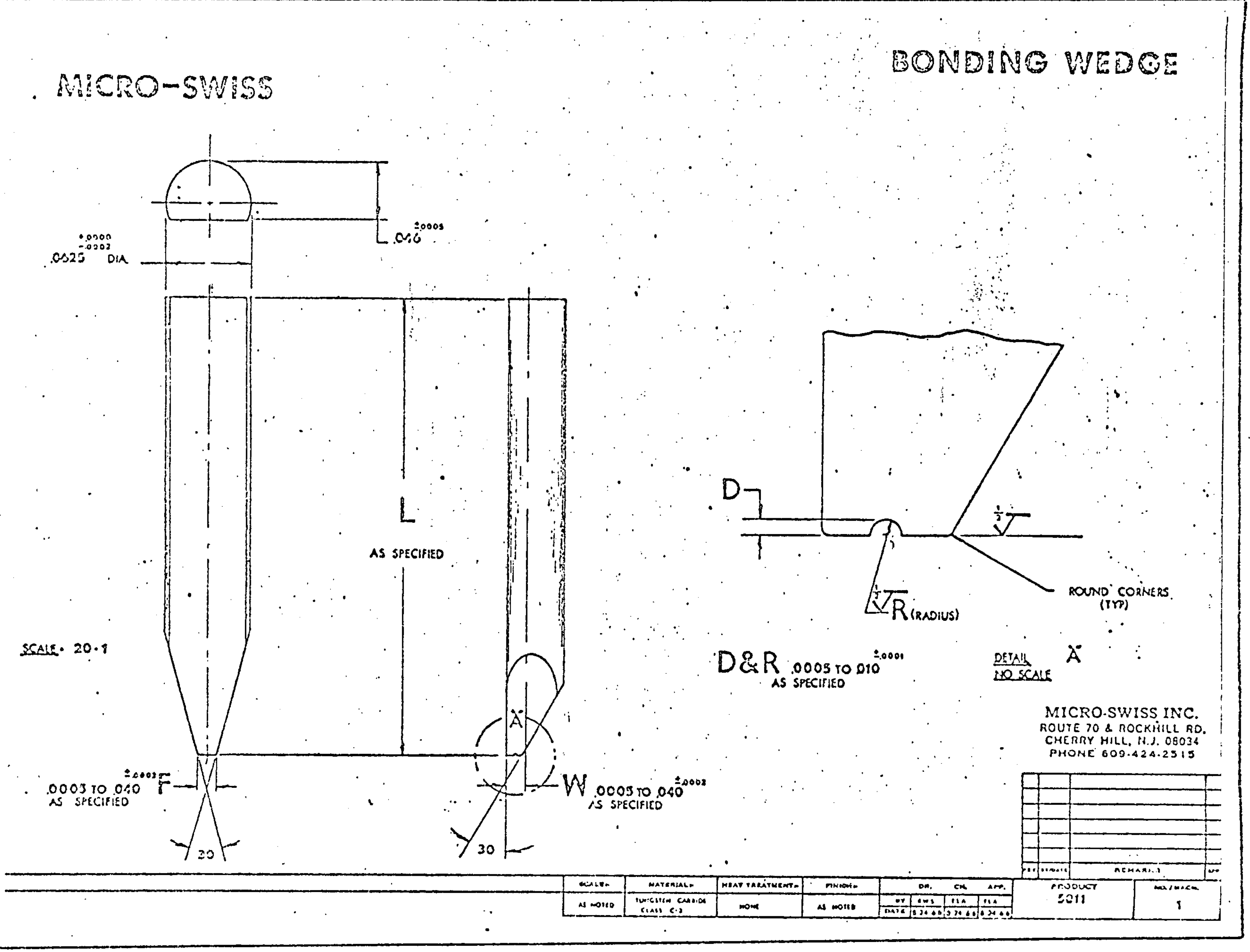


FIGURE 5

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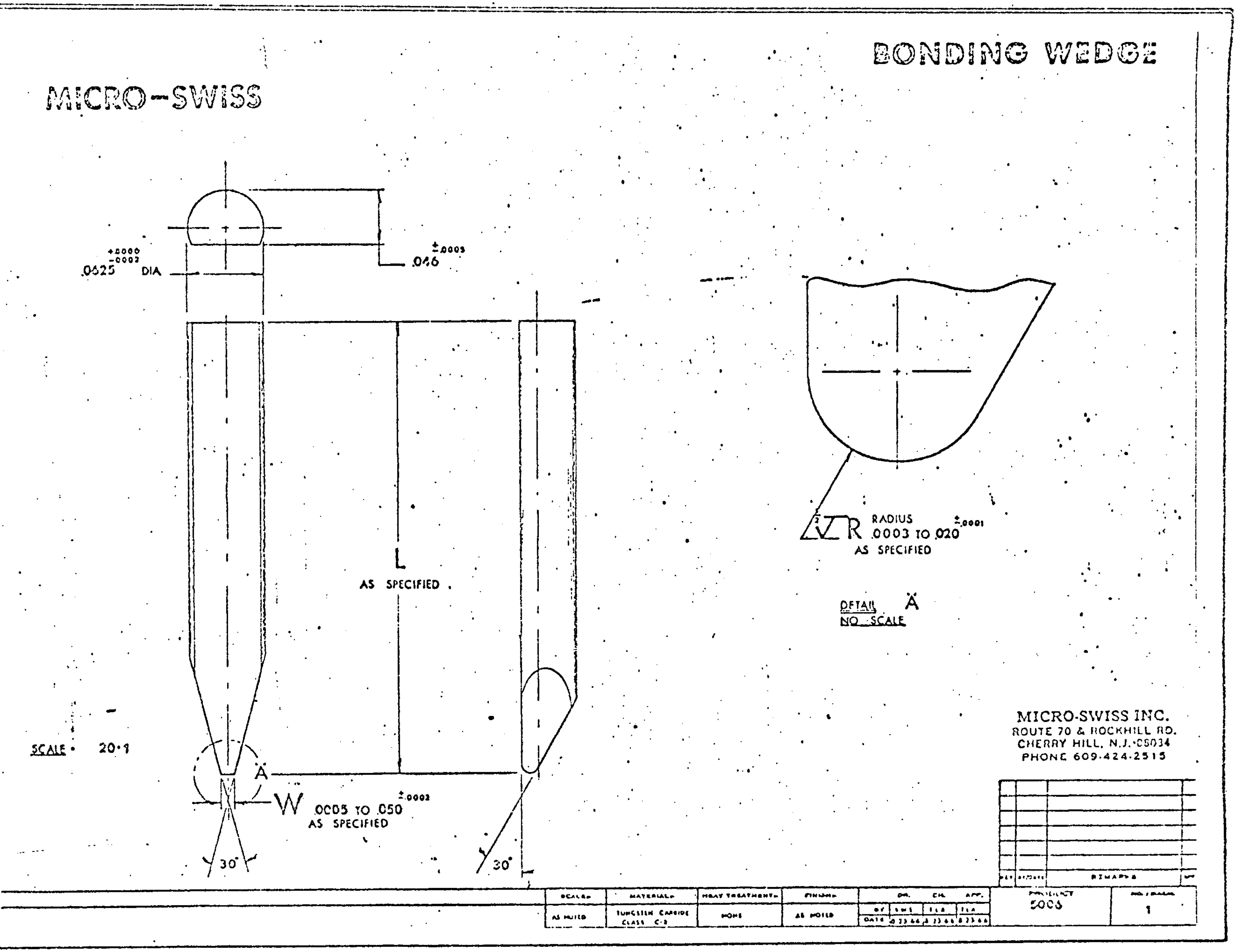
FIGURE 6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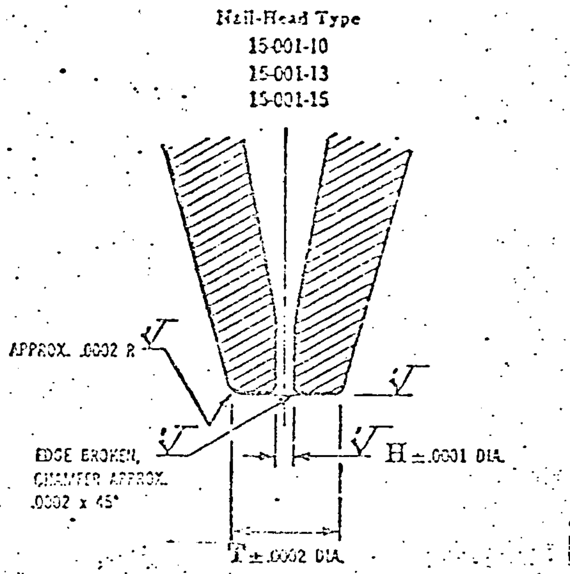

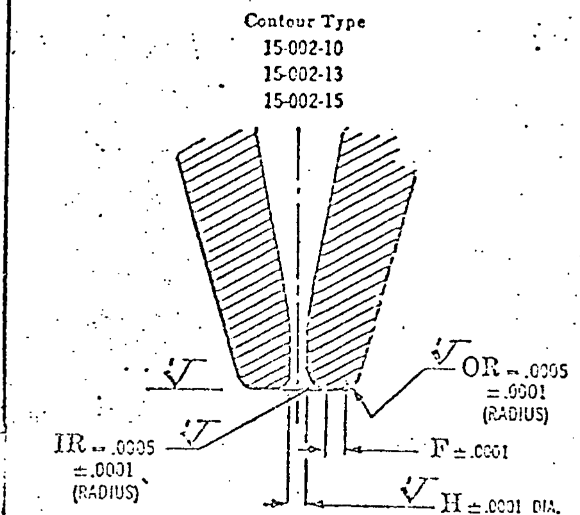

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FIGURE 7

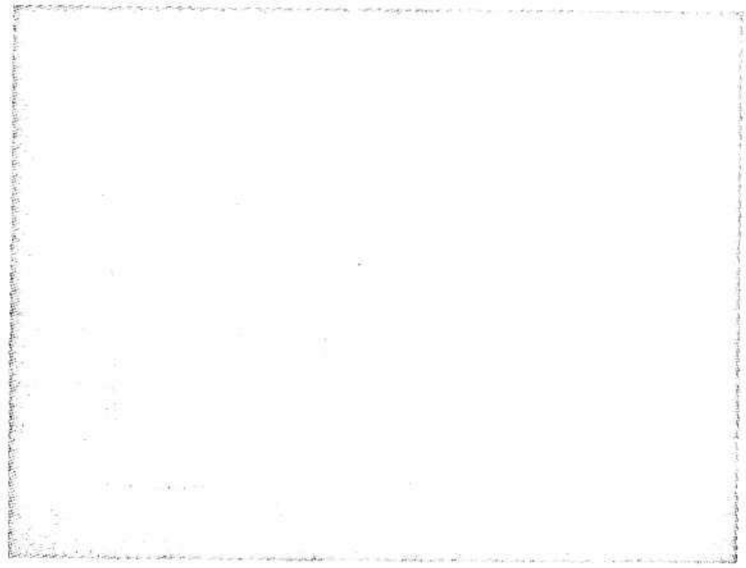


Figure 8

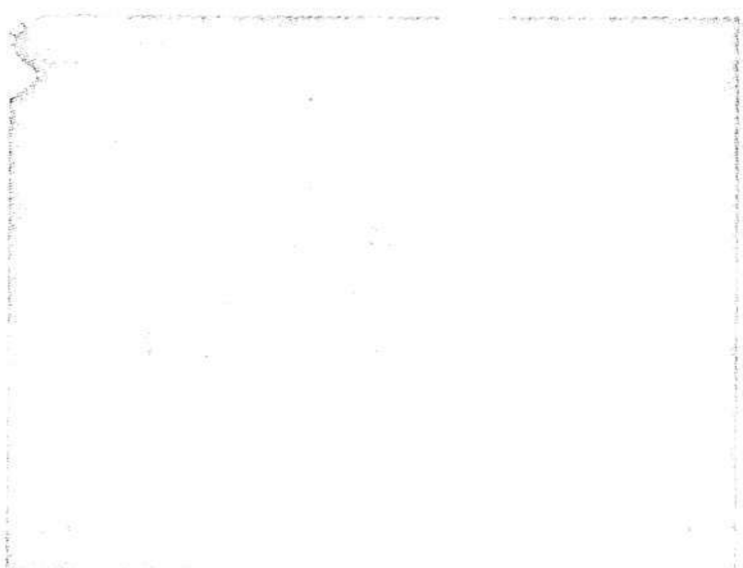


Figure 9

Figure 10

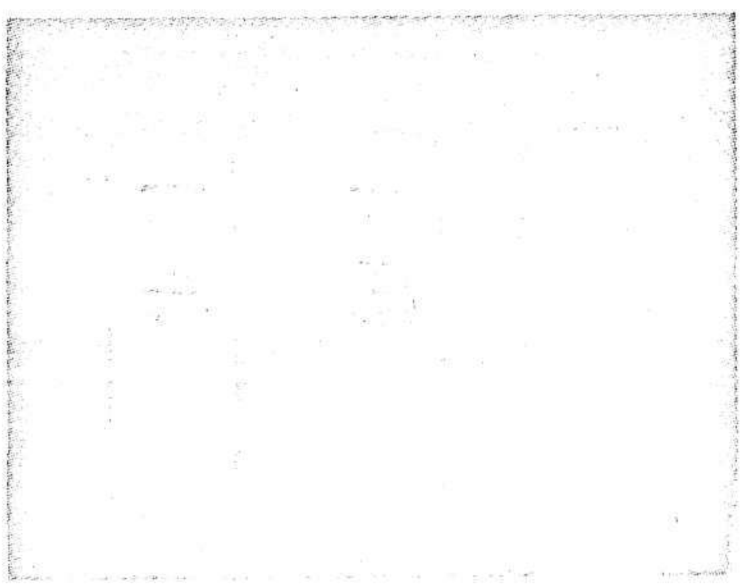


Figure 11

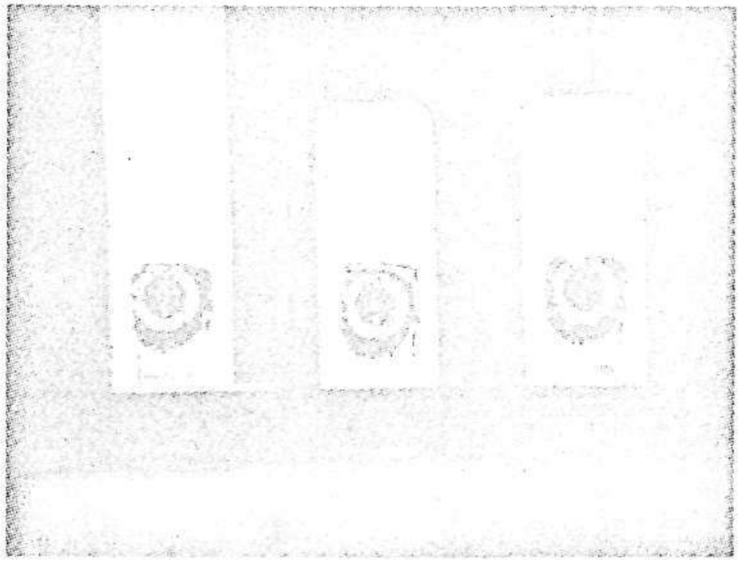


Figure 12

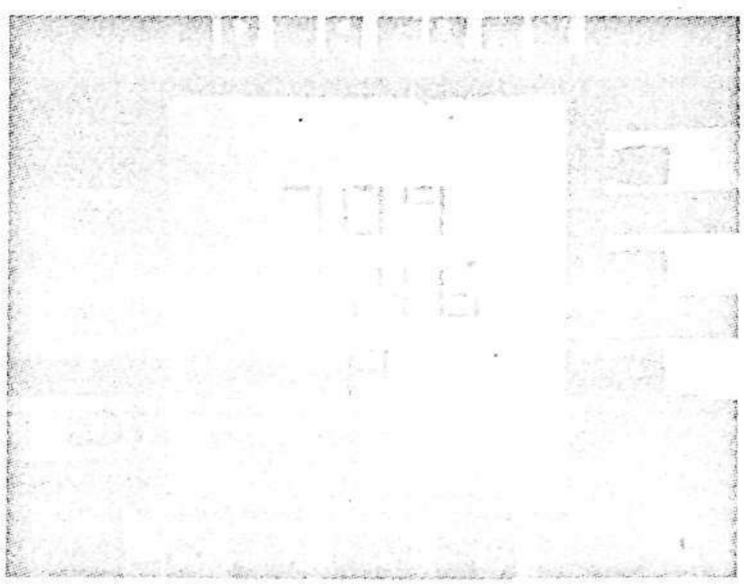


Figure 13

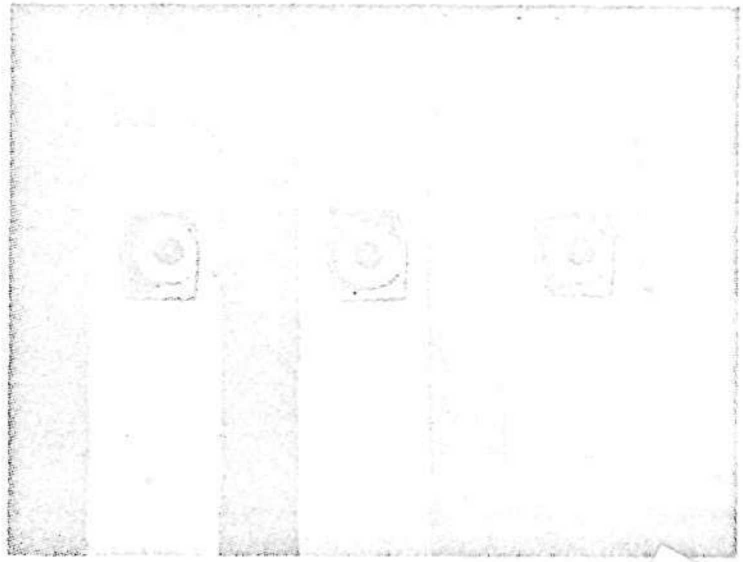


Figure 14

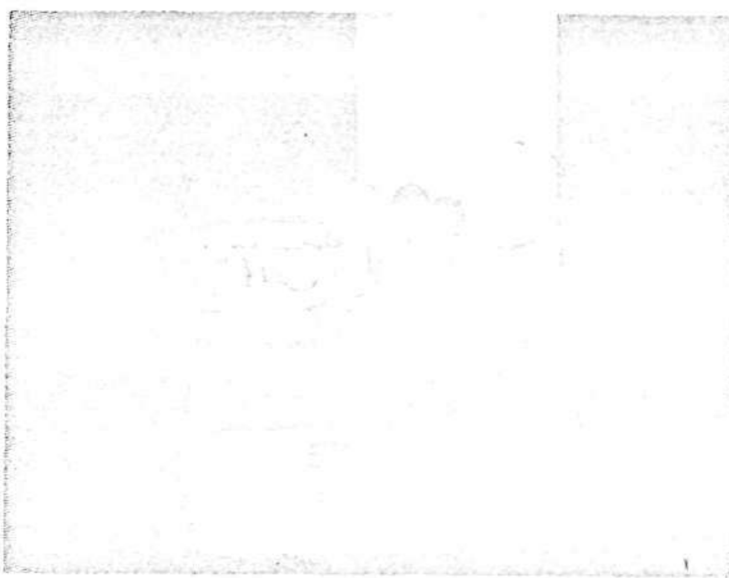


Figure 15

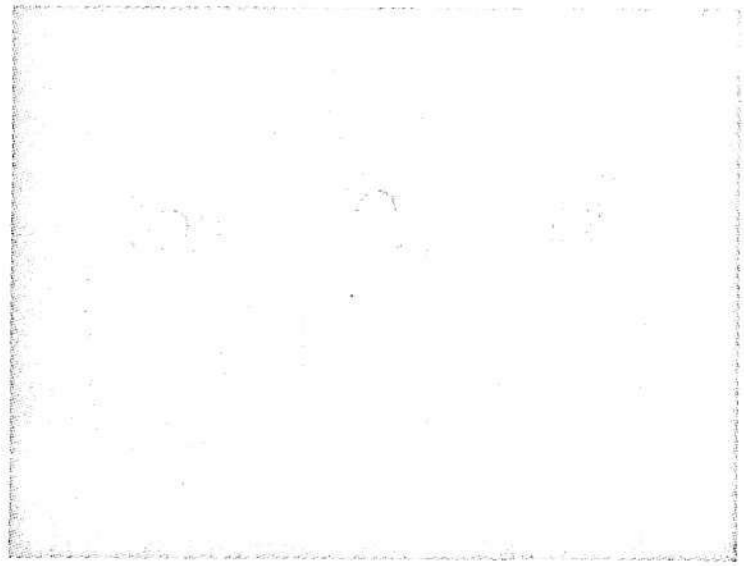


Figure 16

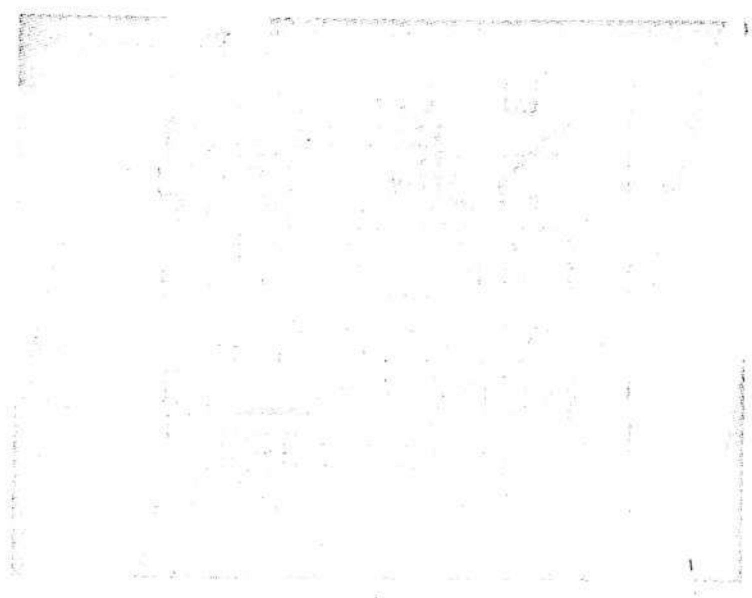


Figure 17

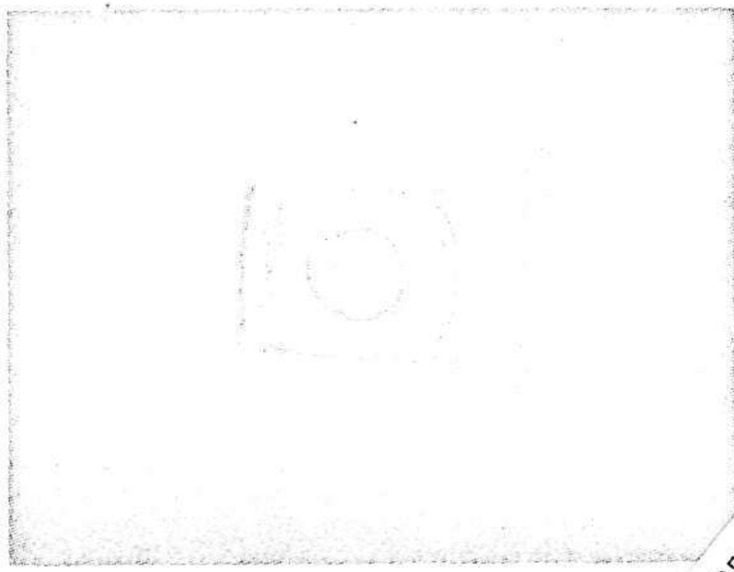


Figure 18

2.0 Aluminum Flip Chip Devices

Flip chip devices generally have three bumps for diodes and four bumps for transistors, while integrated circuits have 14 to 48 bumps. A four-bump device (Intersil IT 930), shown in Figure 19, was chosen as the test vehicle because it would have some of the alignment problems and could be tested electrically and mechanically with a reasonable amount of effort.

The first goal was to investigate the alignment problem and develop methods to alleviate the problem. The method would then be utilized to study the parameters of ultrasonically bonding the chip to a 6000Å aluminum film pattern on a glazed substrate. The pattern, shown in Figure 20, was designed to have each bump electrically isolated, so that electrical continuity of each bond could be tested on a bonded device. This was later used to determine which bonds failed and became open. The outside edges of the pattern was designed to aid in the alignment of the bumps to the bonding pads. Figures 21 and 22 show a top view and a bottom view of a bonded device. The bottom view was obtained from a device bonded to a metallized glass substrate. The strengths of the ultrasonic bonds would be measured and used to determine the optimum bonding parameters. The effects of typical flaws in the bumps would be investigated using the optimum bond schedule. The final objective was to determine if circuits using flip chips could be repaired.

The method of bonding the aluminum bump devices to the aluminum film would be to use a swept ultrasonic power supply, Buyfield Model 201. This type of supply sweeps over a frequency range (centered at 60 kilohertz) that will pass through the self-resonance frequency of the bonding system. This in turn, eliminates the critical tuning of the power supply to the bonding tool.

The alignment problem was investigated initially so that it would be resolved before the bonding parameters were studied. Misalignment of the bonded bumps would effect the outcome of the results. The parallelism of the bumps to the substrate was difficult to determine visually. An angle of approximately one degree to two degrees is sufficient to have one bump not making contact with the substrate pad after bonding. A film of silicone mold release was sprayed on a substrate and used to initially align the bonding tool with the substrate. This was done by making a depression in the silicone film and adjusting the bonding tool until a uniform pattern was made in the silicone film by the bumps on the device. This method also was used to select the best types of pick-up and bonding tools. A die brazing type of cullet, Figure 23a, would not always pick up the chip in the same plane and would produce partial bonds and no bonds, as evident in Figure 24. The planarity of the bumps on the Intersil devices appeared to be controlled and the bump heights were within 0.1 mil on any one device. The substrates were glazed ceramic from Coors and were sufficiently flat to cause very little alignment problems.

The best type of tool used to bond the flip chips would be one that could also be used for picking up the devices. This would eliminate many handling problems, such as, tedious handling and time consuming hand alignment. Several ultrasonic tools were tried that did not have a vacuum pickup capability to determine if there were any other problems characteristic of this type of tool. One problem that frequently occurred with a rounded dowel tip with a radius of 5 mils or less (Figure 23c), was that the device would crack where the tip made contact with the chip. This generally occurred when high bonding forces ($>$400 gms) were used to get a satisfactory bond.

The best type of bonding tip was a Micro-Swiss 400-10 die cullet, Figure 23b, with a vacuum hole for picking up the devices. The face of the tool is the form of a flat ring with a 20 mil outside diameter and a 5 mil inside diameter hole. When the tip is aligned by the silicon film method, it will provide bonds with a very few parallel alignment problems. The face of the tip must be cleaned frequently to prevent a build-up of foreign matter. The foreign matter can cause excessive movement between the tool and the chip during ultrasonic bonding. A capillary tip, Figure 23d, gives similar results but is more difficult to use.

The vertical alignment depends almost entirely on the skill of the operator. Where the chips are precisely scribed, the outer perimeter of the chip can be used as an alignment guide. This guide when used on a thin film pattern that matches the chip dimensions can result in good vertical alignment after bonding, as shown in Figures 21 and 22. Another technique, "reflective method," uses the bumps for alignment by observing the reflection of the bumps on the reflective thin film on the substrate. This method relies on the operator's skill and also can only be used on thin films that are reflective enough to see the image. The advantage is that the chip need not be scribed as accurate as in the first method. Another advantage is that the orientation can be checked just prior to the bonding. The reflective method was found to be the most practical and easiest to implement and produce satisfactory results. Another method of using infrared techniques to observe the alignment through the substrate, was not tried. This method would have the advantage of seeing where the actual bond was made.

The main parameters in ultrasonic bonding are ultrasonic power, time, and applied to weight to the chip. The applied weight was varied from 125 gms to 600 gms with diffusion occurring over the whole range. It was found that the weight had to be near the top of the range to prevent the chip from rotating during bonding. The pattern in Figure 25 is a good example of a device that rotated during bonding. The rotation could be as much as 45 degrees and make if impossible to maintain alignment between the chip and the thin film circuit. This was especially true with the round bonding tools, typically shown in Figure 23c. An impression of the tool would be evident on the chip's backside when the weight was correctly set for a good bond; see Figure 26. A weight of 400 gms was optimized when the Micro-Swiss 400-10 tip was used for bonding. Excessive weight would cause excessive deformation of the bumps and could cause the devices to short out electrically. The electrical shorts could be caused by the flattened bump bridging the thin film pattern on some devices, Figure 27, or the bumps shorting two adjacent bonding pads.

The amount of ultrasonic power will depend on the number of bumps on the device, the size of each bump, the type of bonding tool used and the type of power supply. The swept frequency power supply was used with the Micro-Swiss 400-10 bonding tool to bond the IT 930 devices. The power was varied from two watts to 20 watts. A minimum power of 3.5 watts was necessary to get the devices to adhere well enough to make shear test on them. The most consistent shear bond strengths were obtained with a power range of 7.5 watts to 16 watts. The optimum power was a function of time (pulse width). The lower the power the longer the time required to get a strong bond. The higher the power the shorter the time required to get a strong bond. While too short a pulse time would give a poor bond, too long a pulse time would cause the bump to shear from the device, Figure 28, or the thin film may shear or remove some glaze from the substrate, Figure 29. The optimum power and time settings were determined by the consistency of the shear bond strengths. An average bond strength of 150 gms was achieved for an optimum setting of 13 watts for 400 milliseconds.

A vacuum hold-down is necessary to prevent the substrate from moving during bonding. At the higher power settings it is also necessary to keep the substrate holder clean to prevent movement of the substrate.

The flip chip devices require considerable care in parallel and perpendicular alignment. The silicone film method or a similar method can be used to align the chip's bumps to the tink film substrate. The perpendicular alignment can be made by one of several methods that rely on the skill of the operator. It is important that the alignment be maintained and periodically checked during a bonding program.

The best bonding tool is one that can be used for device handling as well as bonding. The ring faced tip that is smaller than the device provides satisfactory bonds. This type of tool must be kept clean during bonding to maintain the proper frictional force between the device and the tip face.

The bonding force must be sufficient to prevent the device from spinning (rotating) and yet low enough to prevent damage to the device or an excessive deformation of the bumps. The amount of power will depend on the number of bumps and the size of the bumps. A four-bump device with five (5) mil diameter bumps requires approximately 13 watts from a swept frequency power supply. The pulse time must be sufficiently long enough to allow diffusion but not too long to prevent damage to the bond after diffusion is complete. The photo in Figure 30 shows bonds having a minimum amount of diffusion to the ideal amount of diffusion between the films.

The strength of the bonds can easily be measured by a shear-test. An average of 150 gms was achieved for the four-bump Intersil device. A minimum of 20 gms/bump should be easy to acquire.

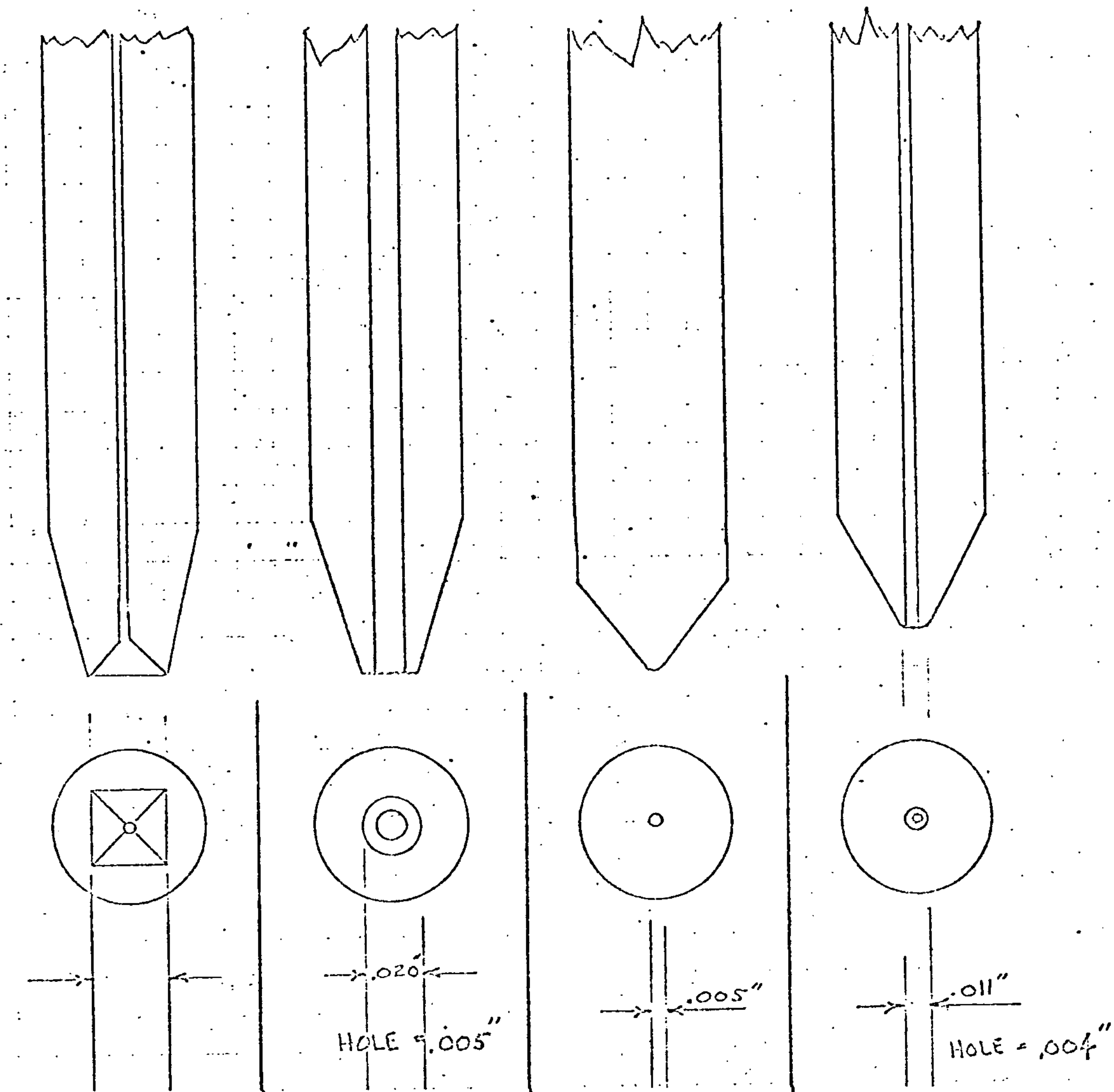
Devices that were bonded at the optimum bonding schedule can be removed without damage to the bonding pads, as was the case in Figure 30. Another new device could then be bonded into the same bonding pads using the same optimum bonding schedule. The strength of these bonds were then measured and found to be about 10 percent higher than the initial device. This is most likely due to the increase in diffusion as evident in Figure 31. Generally the devices could be removed four to six times without any detrimental damage to the substrate. Also the bond strength would maintain an average of 150 gms.

Intersil IT 930
Figure 19

Substrate Metallization Pattern
Figure 20

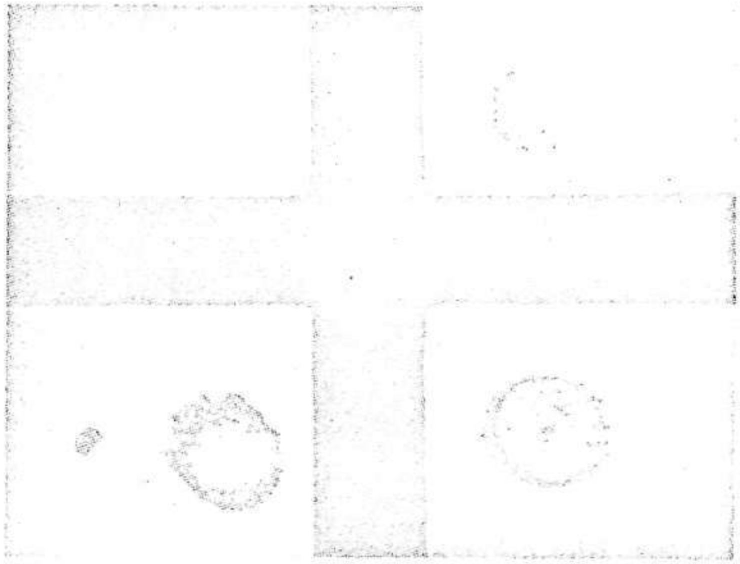
Bonded Device-Top View
Figure 21

Bonded Device-Bottom View
Figure 22

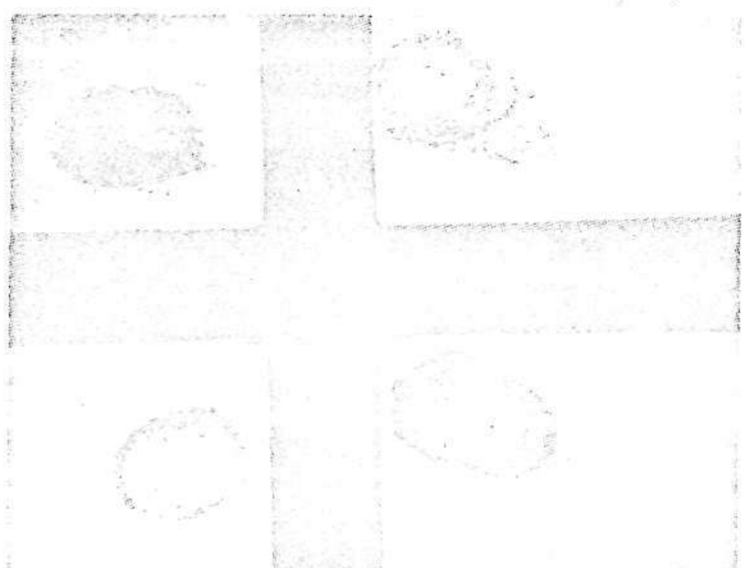


(a)	(b)	(c)	(d)
Die Braze Cullet	Micro-Swiss #400-10	Dowel Pin	Capillary tip - 3 mil
1. Poor	1. Best	1. Good	1. Good
2. Inconsistant bonds	2. Consistent bonds	2. Consistent bonds	2. Consistent bonds
3. Difficult to align	3. Easy alignment	3. Easy alignment	3. Easy alignment
4. Device must have straight edges	4. Easy pick-up	4. No pick-up	4. Easy pick-up
	5. Clean frequently	5. High pressure causes chip to crack frequently	5. High pressure
			6. Too short

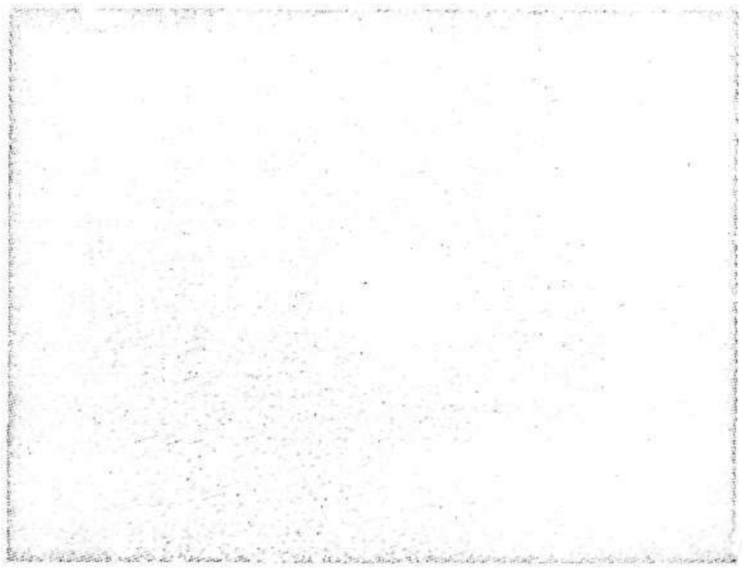
FIGURE 23



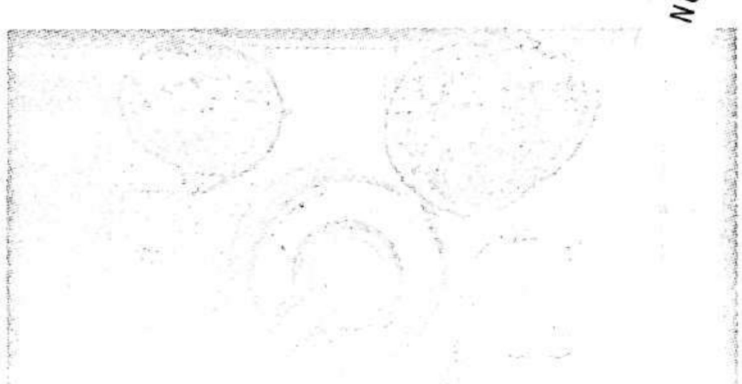
No Bond - Poor Parallism
Figure 24



Device Rotated During Bonding
Figure 25



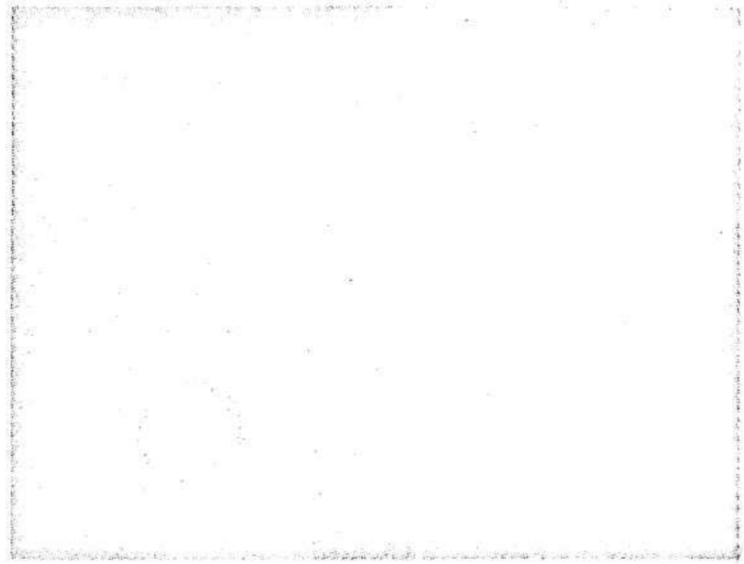
Tool Mark on Chip
Figure 26



Bump Shorting Device Metallization
Figure 27

Bumps Sheared From Device
Figure 28

Film and Glaze Damage
Figure 29



Acceptable Diffusion Range
Figure 30

First and Second Bond Patterns
Figure 31

3.0 Aluminum Beam Lead Devices

The device used to study aluminum beam lead bonding was a discrete transistor from North American Phillips. The 1.5 mil thick silicon chip, shown in Figures 32 and 33, is 8.5 mils square having four beams with a width of 2.5 mils, a length of four mils and a thickness of 0.25 mils. The devices were shipped in a package, Figure 34, consisting of two 0.4"x 0.4" glass plates held together with a special spring clip. The photo in Figure 34 also shows the devices in small cavities in one of the glass plates. A larger view of a cavity with a device is shown in the photo of Figure 33. One of the main objectives of the program was to investigate various techniques for handling these devices prior to bonding. Any technique developed must not only be able to handle the very small devices but must be delicate enough not to damage the sensitive aluminum beam leads.

After the best handling tool was determined, the next goal was to determine what types of tools could be used for ultrasonically bonding the aluminum beams to aluminum thin film substrates. The devices were bonded to the pattern etched in a 6000Å aluminum film shown in Figure 35. A bonding schedule would then be developed for each bonding tool that appeared satisfactory.

The minute size of the silicon chip makes the handling of the device extremely difficult. Many manual and semi-automatic systems were used without obtaining a method that gives consistent satisfactory results. A very fine vacuum needle was initially used to position the device onto the bonding pads for bonding. Alignment was difficult and very time consuming. A semi-automatic tool consisting of a capillary bonding tip with a 10 mil outside diameter and a 5 mil hole for the vacuum was satisfactorily used for positioning the device. This holder made it easy to align the device with the bonding pads and could be done quickly. The rotational alignment was the most difficult because the substrate had to be rotated. This type of positioning tool would require the device to be temporarily attached at time of positioning to prevent movement until the beams were bonded permanently. It might also have been possible to use a turret type head (cOntaining the pickup tool and the bonding tool), to make the bond right after device alignment to the substrate. This was not tried because of the complex tooling design required for the coupling of the ultrasonic energy to the bonding tool.

A handling tool that could be used for both positioning and bonding, such as die brazing cullets, was investigated. Several types of cullets were used with some success but the results were not consistent. Several cullets were too large and the vacuum would draw the chip into the cullet and bend the aluminum beams. The most appropriate tool was a 10 mil x 10 mil x 3 mil die brazing cullet from Micro-Swiss. Some difficulty was noticed in always picking up the device in the center of cullet such that all the beams were lying on the outer perimeter of the cullet. This misalignment could cause pinched-off bonded beams.

The method of bonding the beams depended on what method was used to position the devices on the substrates. When the capillary tip was used to position the devices, a resin was used to temporarily hold the device in place. After the beams were ultrasonically bonded the resin was removed by dissolving it with alcohol and then flushing with filtered alcohol. Once the device was temporarily attached, the aluminum beam leads were bonded individually with the following types of tips:

1. 1 mil capillary
2. 5 mil capillary
3. Rounded probe with radius 1 mil

4. Rounded dowel pin with radius 2 mils
5. Rounded wedge (Micro-Swiss #5006)
6. Flat wedge (Micro-Swiss #5007)
7. Slotted wedge (Micro-Swiss #5011)

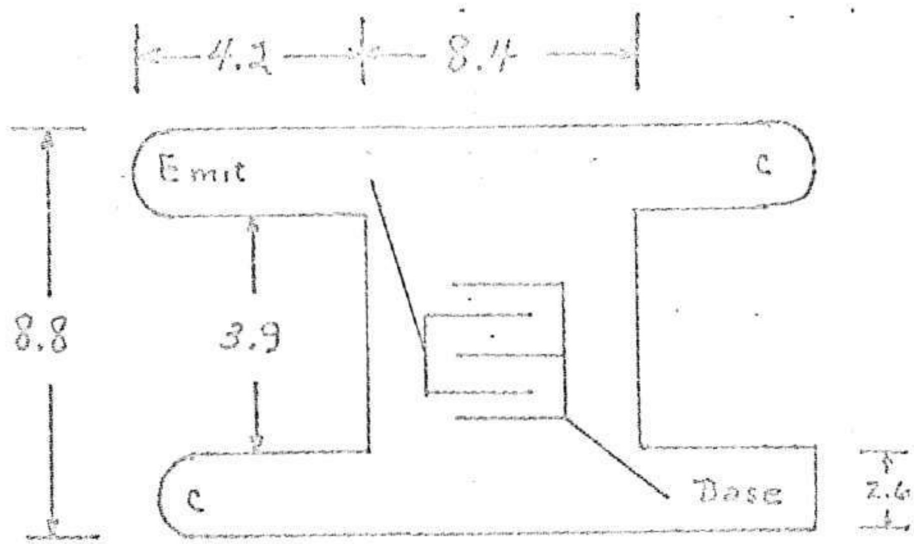
The capillary tips and the wedge tips generally gave poor to fair bonds mainly because of the non-parallelism of the bonding tip face and the bonding pad. Bugging of the chip would occur when the temporary resin bond was not sufficient to hold the device during bonding. The rounded tips gave fair to good bonds, two of which are shown on Figures 36 and 37. This type of tool does not rely on an alignment of bonding faces since it has a hemispherical bonding face. The probe tip produced a small bonding area and resulted in weaker bonds, Figure 36, The 2-mil rounded dowel pin gave the best single beam bonding and was the most consistent, Figure 37.

Multibeam bonding was performed with a Micro-Swiss 10 x 10 x 3 die brazing culler (#604-TC). This tool provided relatively easy handling and positioning and also the capability of multi-beam bonding. Good consistent bonds could not be made because of the non-parallelism of the bonding tool face and the substrate bonding pads. The limited amount of bonding indicated that the bonding parameters were:

1. Bonding - 20 to 30 gms
2. Ultrasonic energy - 300 to 500 m watts
3. Bonding time - 200 to 400 milliseconds

The difficulty in the handling of the devices was the major problem with the aluminum beam lead device. Special tools would need to be designed for each device which might become very expensive. The approach taken by North American Phillips appears to have been well thought out. The equipment that they use for handling and bonding appears to have been designed to alleviate the problems that were encountered in the present program.

A rounded hemispherical tipped) tool appears to be the best type of tool for bonding one beam at a time. The die brazing type of cullet would be satisfactory for multibeam bonding if both bonding surfaces were kept parallel during bonding or if the wobble head system would be adapted for these small devices. The North American Phillips approach is very similar to a two-sided die cullet with particular emphasis put on the parallel alignment of the bonding surfaces.



Device Sketch

Figure 32

Packaged Device

Figure 33

Device Package

Figure 34

Bonding Pads

Figure 35

Probe-Tip Bond

Figure 36

2-Mil Rounded Tip Bond

Figure 37

4.0 Solder Bump Flip Chip

The solder bump flip chip which was chosen for the program was a GAZ8075 Zener Diode from Hughes. The device has three silver/tin bumps on a 20 mil square chip, as shown in Figure 38.

The objectives necessary to successfully bond this type chip are as follows:

1. The chip must be located on the circuit geometry and held in place until the actual soldering is started.

2. Temperature control is necessary for stress relief of bond.

3. Atmosphere must be controlled to reduce oxidation.

4. The solder used must be compatible to the device bumps and the circuit conductor material.

5. Removal of parts and repair of circuit is necessary.

6. Inspection of bonds is necessary.

The chips are accurately scribed so alignment was fairly easily accomplished by operator by aligning outer dimensions of chip to circuit pattern. A mirror system was tried that enabled the operator to see all sides of the chip at once, but was discarded later as being unnecessary. If irregular chips are used it might be necessary to use a mirror system.

The chips were placed bump-side down on a mirrored chip dish and oriented by rotating the dish. The chip was picked up by vacuum using a flat faced round rool and positioned on the circuit, then ultrasonically pulsed at a low power level for a short time duration. A standard die cullet was tried, but due to flux being on the circuit, the cullet had to be cleaned too frequently.

The overall test pattern used for the program is given in Figure 39. The pattern consists of:

1. gold pads for connecting to the flatpack,
2. conductors leading to the flip chip bonding pads,
3. glass dam overlays between the conductors and the bonding pads,
4. and the chip bonding pads.

The photo in Figure 40 shows a magnified view of the glass dams and the bonding pads (using strong back lighting). The bonding pads are pre-tinned with solder and is restricted to the bonding pads by the glass dams, see Figure 41. Initially the glass dams were not used and, therefore, the conductors would leach away the solder from the bonding pads. During the bonding of the devices the solder bumps on the device would frequently be leached away also; therefore, it was necessary to include the glass dams in the test pattern. Figure 42 shows a sample device where the bumps were leached completely off the device. The glass dams were essential to be able to control the amount of solder on the bonding pads. The pads were pretinned with an excess of solder and then ground to a level and smooth surface to a thickness that was one-half to one times the thickness of the thick film conductor. Palladium gold, DuPont 8451 conductors were used for the bonding pads. The solder ECI previously used with this conductor was tried and proved good; it was a (low melting point) 62/36/2 AG wolder; 60/40, and 63/37 solders were tried and were fair, more leaching occured, so they were discarded. A 96 (SN)/4(AG) solder was selected. It provided strong bonds, and was compatible with the solder bumps on the chip. However, more leaching of the solder occurred when repairs were attempted. The main reason for its selection was a higher melting point solder was required because of package sealing temperature. The sealing temperature must be lower than the device solder temperature or reflow could occur and might cause the device to become unbonded.

All methods tried in pretinning the pads were awkward. Following are comments on the various methods tried:

> Dip Tinning - a good method but difficult to control the amount of solder on pads, also the areas of conductor that are to be used for other types of bonding had to be masked off.
>
> Solder Paste - not a good solder. The solder did not flow but separated and formed small balls on pads.
>
> Solder Cream - a good method. The solder flowed easily. The solder cream might be applied by screening the material on to the circuit in the required areas.

For limited production, applying the solder with a small soldering iron worked satisfactorily and was used for this program.

After each method of applying solder it was necessary to mechanically polish and level the solder to provide a smooth and flat surface.

After solder was applied to the substrate, flux was applied to provide a means of holding the chips in place after chip placement and to aid the solder reflow process. Spray coating the substrate was used to apply the flux; a brush was also used when it was desirable to apply flux to a small area such as, when repairing or replacing one chip on the circuit. Both methods worked good when properly applied. A thin coating of flux is needed to prevent the flux from boiling during reflow and floating the chip away from its position.

A dri-nitrogen atmosphere was provided on all reflow methods to reduce oxidation during reflow.

Reflow Methods Tried

1. Placing substrate on preheated hot plate in glove box: - Reflow was accomplished easily with the entire substrate heated. The substrate was removed from hot plate as soon as the solder reflowed and the substrate was then rapidly cooled. The rapid cooling might cause some stress at the solder bond. The rapid rise in temperature when the substrate is placed on the hot plate initially might also stress the substrate. Repair or replacement of a single chip could not be done without reflowing all the devices.

2. Reflow of solder using a flat pack sealing machine: - This method worked good as we were able to control the atmosphere, the time at temperature, the rise time to maximum temperature and the cooling rate after reflow. A machine could be designed with these capabilities and would be desirable for a high production quantity.

3. Hot gas jet reflow: - Hot jet reflow was the method selected as best in all instances. The substrate was placed on a heated stage at 175°C and pre-heated; then each dhip was passed under the heated nitrogen jet and reflowed, the jet temperature was approximately 320° centigrade.

4. Removal of chip: - Removal of a chip was easily accomplished by re-heating under the gas jet and replacement was easily accomplished.

Infrared reflow was not tried as the equipment was not available, but might be a good method if the expense incurred in obtaining the equipment could be justified.

Removal of flux after reflow was done by soaking the circuit in alcohol or DWR solvent, then spray cleaning with the same solvent.

Visual inspection under a microscope was possible. The visual inspection was backed up by radiographic inspection which worked very well as the solder bumps and circuit outline could be easily defined.

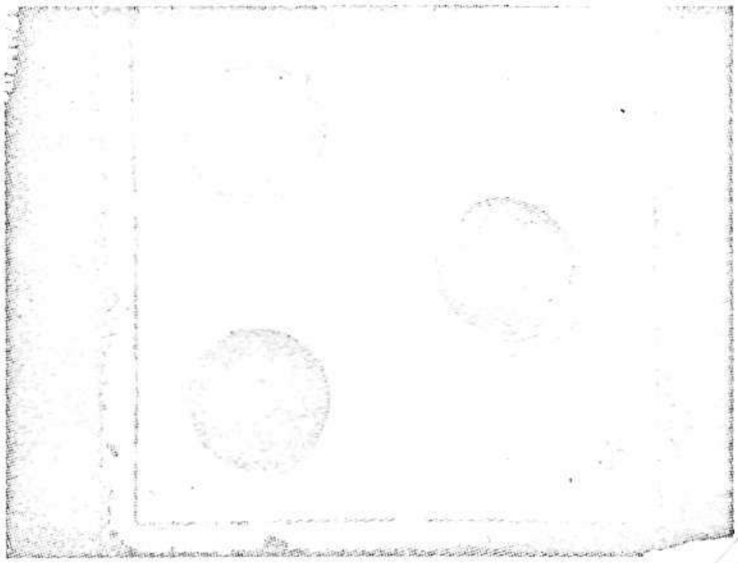
The isostrength diagram samples were shear-tested initially, after humidity and after thermal shock. The initial shear values averaged 359 gms with a low of 55 gms and a high of 660 gms. After humidity the average was 390 gms with a low of 100 gms and a high of 640 gms. After thermal shock the average was 539 gms with a low of 320 gms and a high of 770 gms.

The three main failure mechanism observed when the devices were destructively shear tested are:

1. Solder bumps not reflowing due to insufficient heat, Figure 43.
2. Thick film metallization pulling from the substrate, Figure 44.
3. Bumps sheared from the devices, Figures 45 and 46.

The first mechanism can and should be eliminated by the proper application of heat. A bond of sufficient strength (60 gms or more) should either shear the bumps from the device or pull the metallization from the substrate as shown in Figures 44, 45 and 46. Occasionally the device will crack and chip out as shown in Figure 47. A well aligned and bonded device is shown in Figure 48.

Although the results of the solder bump chips seem to indicate very good bonds, ECI feels that for long term reliability the solder crack problems which have been investigated in printed circuit boards on the Apollo program may limit long term reliability results with solder bump chips.



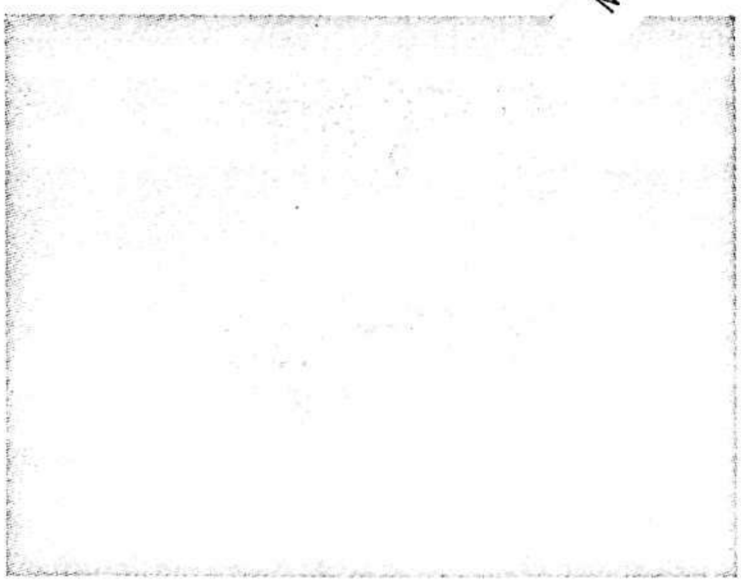
Flip Chip Device
Figure 38

Test Pattern
Figure 39

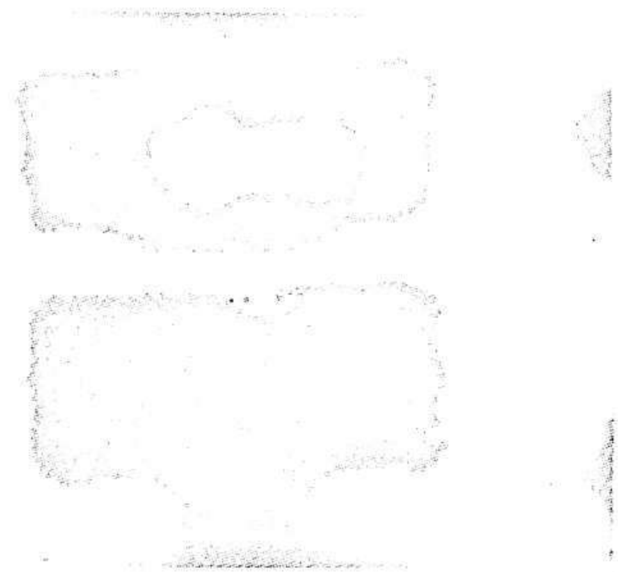
Thick Film Bond Pads
Figure 40

Tinned Bond Pads
Figure 41

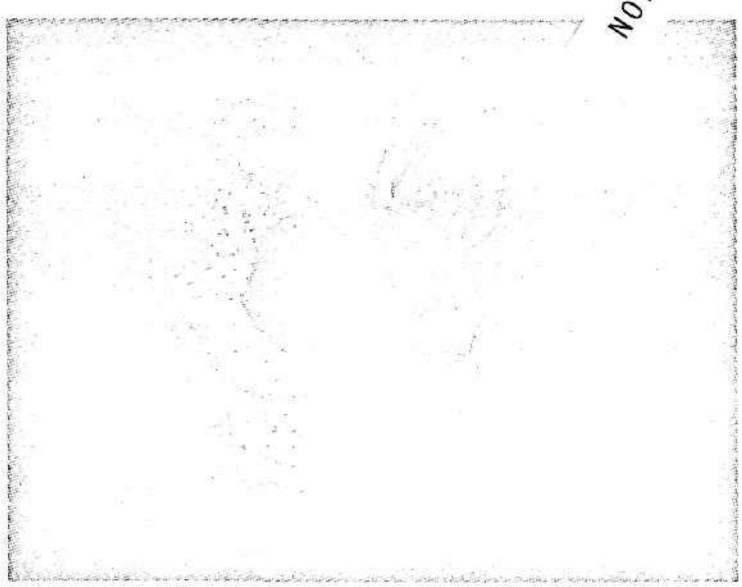
Bumps Leached From Device
Figure 42



Insufficient Heat
Figure 43



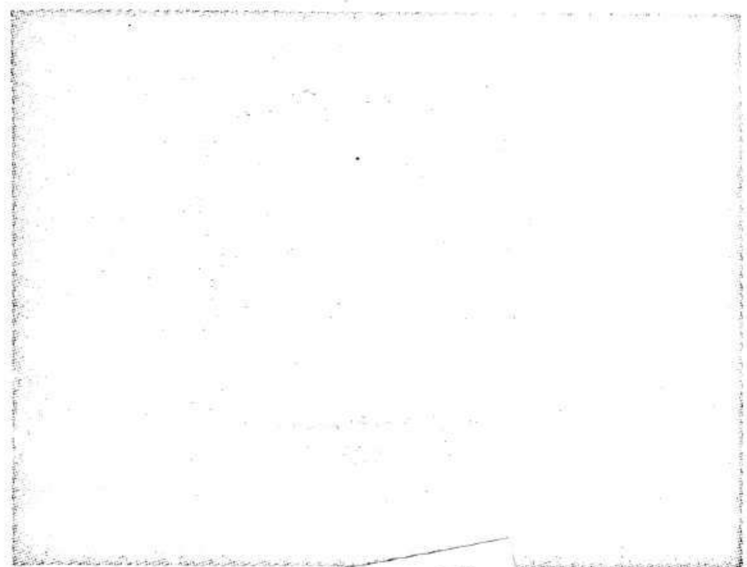
Thick Film Failure
Figure 44



Bump Sheared From Device
Figure 45

Failed Device
Figure 46

Cracked Device
Figure 47



Ideal Bond
Figure 48

REPORT SUMMARY SHEET

1. COMPONENT/PART NAME PER GENERIC CODE	Parts Mounting & Bonding Study, Hybrid Microcircuits
2. PROGRAM OR WEAPON SYSTEM	NASA
3. TEST COMPL. (DAY / MO. / YR.)	23 / 7 / 71
REPT. COMPL. (DAY / MO. / YR.)	23 / 8 / 71
4. ORIGINATOR'S REPORT TITLE	Section C.2 of Report of Test on "Study of Bonding Methods for Flip Chip and Beam Leaded Devices"
5. ORIGINATOR'S REPORT NO.	1-2348
6. TEST TYPE, ETC.	Environmental and Temp/Vib. Step Stress Testing
7. THIS TEST (SUPERSEDES) (SUPPLEMENTS) REPORT NO:	

8 ITEM	8A. PART TYPE, SIZE, RATING, LOT, ETC.	9. VENDOR	10. VENDOR PART NO.	11. IND./GOV. STD. NO.	12 TOTAL TESTED
1	Beam lead devices used in Op Amp circuit in hybrid pkg. 3 circuits per pkg. 30 pkgs. Amp is RM709BL	ECI			90
2	Aluminum bump flip chip mounted transistors (2N930) mtd in flat pack. 6 transistors per pack. 16 packs. 11 transistors not installed	ECI			85

(OVER)

13. INTERNAL SPECS.ETC REQ'D TO UTILIZE REPT.		ENCL	SENT WITH REPORT NO.
A	GO-00001		
B	REM 10160		
C	REM 10165		
D	CER 30234		

14. MIL. SPECS./STDS. REFERENCED IN 15C	
E	MIL-STD-883

15A. TEST OR ENVIRONMENT	B ITEM	C PER SPEC	D SPEC. PARAGRAPH/ METHOD/CONDITION	E TEST LEVELS, DURATION AND OTHER DETAILS	F NO. TESTED	G NO. FAILED
Initial Electrical	1			7.0 VPP input	90	3
Initial Electrical	2			I_B = 5 ua, V_{CE} = 5V	85	7
Initial Electrical	3			V_Z = 7.5V @ 16 ma	90	1
Thermal Shock	1	A E	para. 3.3.3.2 Method 1010 Cond. A	-55°C↔+85°C; transfer time 15sec; elec. after 15 cycles & 25 cycles.	30	4
Thermal Shock	2	A E	para. 3.3.3.2 Method 1010 Cond. A	-55°C↔+85°C; transfer time 15 sec; elec. after 15 cycles & 25 cycles.	28	1
Thermal Shock	3	A E	para. 3.3.3.2 Method 1010 Cond. A	-55°C↔+85°C; transfer time 15 sec; elec. after 15 cycles & 25 cycles.	30	0
Vibration Sine	1	A E	para. 3.3.3.3 Method 2007 Cond. A	20-2000-20Hz in 4 min. 3 axes. elec. after each axis. 4cycles/axis	30	3
Vibration Sine	2, 3	A E	para. 3.3.3.3 Method 2007 Cond. A	20-2000-20Hz in 4 min. 3axes 4cycles/ axis.elec.after each axis (30T&30D)	60	0
Thermal Scan	2	B C,D		+25°C, -65°C, +125°C, +25°C; 1 cycle; elec. test 5°C/min. change	27	1

(OVER)

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN: This report discusses the effects of various environments on three different bonding techniques: beam lead, aluminum bump flip chip, and solder reflow flip chip. The beam lead devices were in an operational amplifier configuration and were tested for output null voltage and output peak-to-peak voltage (27.5VPP). A failure was classified as a device which did not switch on an input square wave signal. This would result in having only the positive or negative half of the 27.5VPP output voltage. There were ten (10) total failures of the beam lead devices. The transistors (OVER)

21 REPT NO. 347.23.00.00-M4-01

17. TESTED BEYOND VENDOR CATALOG SPECIFICATIONS	18. VENDOR INFORMATION / COPY OF REPT / QUAL	19. SIGNED	20. CONTRACTOR	SUBCONTRACTOR
YES [ ]	[ ] [X] [X]			

SPE 407 28

8 ITEM	8A. PART TYPE, SIZE, RATING, LOT, ETC.	9. VENDOR	10. VENDOR PART NO.	11. IND./GOV. STD. NO.	12 TOTAL TESTED
3	Solder reflow flip chip mtd diodes (GAZ8075) in hybrid flat pack. 15 packs. 6 diodes per pack.	ECI			90

15A. D ITEM	TEST OR ENVIRONMENT	C PER SPEC	D SPEC. PARAGRAPH/ METHOD/CONDITION	E TEST LEVELS, DURATION AND OTHER DETAILS	F NO TESTED	G NO FAILED
1,3	Thermal Scan	B C,D		+25°C, -65°C, +125°C, +25°C, 1 cycle; 30 beam lead & 30 diodes; 5°C/min.	60	0
1,2,3	Vibration Scan	B C,D		70G max or 0.06 in DA. 1 cycle= 20-2000-20Hz(30beam,11T, 12Diodes)	53	0
1,2,3	Temp.Vib Step Stress Test	A B C D	para. 3.3.3.4	(12 beam lead,11 trans. 12 diodes) Step 1: -55°C 20 G Sine	35	0
				Step 2: +85°C 20 G Sine	35	0
				Step 3: +85°C 30 G Sine	35	0
				Step 4: -55°C 30 G Sine	35	0
				Step 5: -60°C 50 G Sine	35	0
				Step 6: +100°C 50 G Sine	35	0
				Step 7: +125°C 70 G Sine	35	0
				Step 8: -65°C 70 G Sine	35	0
				Step 7: +125°C 70 G Sine	35	0
				Step 8: -65°C 70 G Sine	35	0
				Step 7: +125°C 70 G Sine	35	0
				Step 8: -65°C 70 G Sine	35	0

16. SUMMARY OF REPORT, NATURE OF FAILURES AND CORRECTIVE ACTIONS TAKEN: and diodes mounted as components using aluminum bump flip chip and solder reflow flip chip techniques, resp, were tested as piece parts. The transistors and diodes were considered failures only if the continuity to the component elements (collector,base,emitter on transistor; anode and cathode on diode) opened; not if the component parameters failed. There were nine (9) transistor failures and one (1) diode failure.
Failures which seem to have been actually caused by environments are as follows: four(4) beam lead and two(2) aluminum bump in thermal shock; three(3) beam lead in sine vibration; and one(1) aluminum bump in thermal scan prior to actual step stress testing.

21 REPT. NO. 347.23.00.00.M4.01

cont'd

16. For the mechanisms of the failures, conclusions, and any appropriate corrective actions see the "Summary and Conclusions" Section D of the Final Design Report "Study of Bonding Methods for Flip Chip and Beam Leaded Devices" of which this report is a part.

SPE-15A

TABLE OF CONTENTS

SPE-154

1.0 Reason for Test: To evaluate microelectronic bonding techniques and processes of the following bonding methods:

a. Beam Lead
b. Aluminum Bump
c. Solder Reflow

2.0 Description of Test Samples

2.1 Beam Lead: These active devices were bonded in an operational amplifier configuration (RM709BL). There were thirty (30) flat packs each of which had three (3) circuits. S/N's for the flat packs were 404-413, 415-422, 427-438.

2.2 Aluminum Bump: These units were 2N930 transistors mounted in an aluminum bump flip chip configuration. Leads were brought directly out of the flat pack so that transistor parameters could be measured. There were sixteen (16) flat packs with positions for six (6) transistors in each pack. Eleven (11) positions were not filled. S/N's for the flat packs were 101-111, 113-116, 119.

2.3 Solder Reflow: These units were GAZ 8075 7.5 volt zener diodes mounted in a solder reflow flip chip configuration. Leads were brought directly out of the flat pack so that the diode parameters could be measured. There were fifteen (15) flat packs with positions for six (6) diodes in each pack. All positions were filled. S/N's for the flat packs were 204, 205, 207-219.

3.0 Disposition of Parts: All parts were returned to the Project Engineer in Space Instrumentation Design Engineering.

4.0 Abstract, Conclusions, Recommendations

4.1 Abstract: This report describes the effects of thermal shock, sine vibration (vibration fatigue), and temperature/vibration step stress tests on beam lead, aluminum bump flip chip and solder reflow flip chip mounting methods. Since the objective is to evaluate mounting techniques and processes rather than piece parts, a "failure" was

defined as an electrical open circuit. Parameter shifts or device shorts did not constitute a failure. An "open" was assumed if the operational amplifiers in which the beam lead devices were mounted did not switch output voltage polarity with a switch in input voltage polarity.

The initial electrical readings were taken to give a base for comparison of data on future tests.

The beam lead devices were tested in the circuit shown on page 33.

The following is a list of tests and the failures which occurred:

	Beam Lead		Alum. Bump		Solder Reflow	
Test Performed	No. Tested	Failure S/N	No. Tested	Failure S/N	No. Tested	Failure S/N
Initial Electrical	90	427-2 436-2 437-2	85	101-1 104-5 109-6 110-3 113-5 114-2 115-5	90	210-6
Thermal Shock	30	416-3 431-1 434-2 434-3	28	106-3 109-6 110-3	30	210-6
Vibration Fatigue	30	405-3 408-2 427-2 428-1	30	101-1 104-5	30	
Temp./Vib. Step Stress Test						
a. Thermal Scan	30	437-2	27	111-2 113-5 114-2 115-5	30	
b. Vibration Scan	30	437-2	11	113-5	12	
c. S. S. T.	12		11	111-2 113-5	12	

SPE-154

	Beam Lead			Alum. Bump			Solder Reflow		
Test Performed	No. Tested	Failure S/N	*	No. Tested	Failure S/N	*	No. Tested	Failure S/N	*
Summary (Failed S/N's counted only once)	90	405-3	3	85	101-1	1	90	210-6	1
		408-2	3		104-5	1			
		416-3	2		106-3	2			
		427-2	1		109-6	1			
		428-1	3		110-3	1			
		431-1	2		111-2	4			
		434-2	2		113-5	1			
		434-3	2		114-2	1			
		436-2	1		115-5	1			
		437-2	1						
Totals	90	10		85	9		90	1	

*Notes:

1. This part first failed during initial electrical tests and was considered a control failure throughout the remainder of the test program.

2. This part failed thermal shock.

3. This part failed vibration fatigue.

4. This part failed thermal scan prior to step stress testing.

4.2 Conclusions and Recommendations: For the mechanisms of the failures, conclusions and recommendations see the "Summary and Conclusions" Section D of the Final Design Report "Study of Bonding Methods for Flip Chip and Beam Leaded Devices" of which this report is a part.

OPE-15A

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED INITIAL ELECTRICAL (PRE TEMP SHOCK) DATE 4-5-71 → 5-12-71
E.C.I. PART NO. — TESTED BY C.M.C. /
MFR. NAME ECI WITNESSED BY
PART NAME ALUM BUMP FLIP CHIP (2N930) APPROVED BY

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M. COOK
PAGES 31 & 32

S/N↓	#1	#2	#3	#4	#5	#6		
101	DEF	OK	OK	OK	OK	OK		
102	OK	OK	OK	OK	OK	OK		
103	OK	OK	OK	OK	OK	OK		
104	OK	OK	OK	OK	OPEN	OK		
105	OK	OK	OK	OK	OK	OK		
106	OK	OK	OK	OK	OK	OK		
107	OK	OK	OK	MISSING	OK	OK		
108	MISSING	OK	MISSING	OK	OK	OK		
109	MISSING	MISSING	MISSING	MISSING	OK	INTER-MITTENT		
110	MISSING	OK	OPEN	OK	OK	OK		
111	OK	OK	OK	OK	OK	MISSING		
113	OK	OK	OK	OK	OPEN	OK		
114	OK	OPEN	OK	OK	OK	MISSING		
115	OK	OK	MISSING	OK	OPEN	OK		
116	OK	OK	OK	OK	OK	OK		
119	OK	OK	OK	OK	OK	OK		

Measurements made with Tektronix 575 Curve TRACER
Transistors tested for: A BETA(β) AT $I_B = 5\mu a$ + $V_{CE} = 5V$

(1) "DEF" MEANS ACTIVE DEVICE NOT GOOD AS RECEIVED.
(2) "MISSING" MEANS ACTIVE DEVICE NOT INSTALLED.
(3) "OPEN" MEANS ACTIVE DEVICE WAS INSTALLED BUT THERE IS NO CONTINUITY TO THE TRANSISTOR ELEMENTS.

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED INITIAL ELECTRICAL (PRE TEMP SHOCK) DATE 4-27-71
E.C.I. PART NO. — TESTED BY C.M.C.
MFR. NAME ECI WITNESSED BY
PART NAME FLIP CHIP SOLDER REFLOW (DIODES) APPROVED BY

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M. Cook page 19

S/N	CONDITION							
204	OK							
205	OK							
207	OK							
208	OK							
209	OK							
210	#6 DEFECTIVE							
211	OK							
212	OK							
213	OK							
214	OK							
215	OK							
216	OK							
217	OK							
218	OK							
219	OK							

MEASUREMENTS MADE ON TEKTRONIX 575 CURVE TRACER

DIODES TESTED FOR BREAKDOWN VOLTAGE OF 7.5V @ 16 ma

(1) "OK" MEANS ALL DIODES HAD CONTINUITY TO TERMINALS AND TESTED ELECTRICALLY GOOD.

(2) "DEF" MEANS DEVICE PARAMETERS NOT IN SPEC BUT CONTINUITY TO LEADS STILL EXISTS.

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED INITIAL ELECTRICAL (PRE TEMP SHOCK). DATE 12-22-70 & 1-20-71
E.C.I. PART NO. — TESTED BY C.M.C./BL
MFR. NAME ECI WITNESSED BY [signature]
PART NAME BEAMLEADED OP. AMPS. Rm 709 BL (3/FLATPAK) APPROVED BY [signature]

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M.COOK PAGES 24,25,26 + 27

S/N & OUT. TERM.	(mV) Null V	(27.5VPP) OUT. V.	S/N & OUT TERM	(mV) Null V	(27.5VPP) Out. V.	S/N & OUT. TERM.	(mV) Null V.	(27.5 VPP) Out. V.
404-1	-0.04	OK	411-1	-7.79	OK	419-1	-5.58	OK
-2	-1.60	OK	-2	-10.69	OK	-2	-19.93	OK
-3	+1.52	OK	-3	+0.90	OK	-3	+3.68	OK
405-1	-0.91	OK	412-1	-5.29	OK	420-1	-11.20	OK
-2	-2.18	OK	-2	-3.80	OK	-2	+2.30	OK
-3	+0.13	OK	-3	-3.00	OK	-3	+2.10	OK
406-1	+12.15	OK	413-1	-18.59	OK	421-1	-1.28	OK
-2	+7.58	OK	-2	-0.37	OK	-2	+10.11	OK
-3	+26.7	OK	-3	+0.93	OK	-3	+1.89	OK
407-1	-13.00	OK	415-1	+3.53	OK	422-1	-1.95	OK
-2	-2.35	OK	-2	+10.47	OK	-2	-1.85	OK
-3	-5.60	OK	-3	-4.02	OK	-3	+18.28	OK
408-1	-19.40	OK	416-1	+14.60	OK	427-1	+2.55	OK
-2	+10.24	OK	-2	+0.30	OK	* -2	—	-13.8V
-3	+1.64	OK	-3	-7.30	OK	-3	+1.80	OK
409-1	-2.18	OK	417-1	+3.60	OK	428-1	+3.40	OK
-2	-2.07	OK	-2	-20.00	OK	-2	+0.35	OK
-3	+4.83	OK	-3	+5.00	OK	-3	-0.76	OK
410-1	-1.28	OK	418-1	-6.95	OK	429-1	-2.68	OK
-2	-3.34	OK	-2	-2.70	OK	-2	+13.00	OK
-3	+5.19	OK	-3	+2.29	OK	-3	-35.00	OK

1) Vin = 7.0 VPP, V+ = +15.00V; V- = -15.00V, R_L = 10K, G = 4, R_S = 10K, R_{FB} = 40K
2) SEE SHEET FOR TEST FIXTURE CIRCUIT
3) * DEFECTIVE DEVICE

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED: INITIAL ELECTRICAL (PRE TEMP SHOCK)
DATE: 12-22-70 & 1-20-71
E.C.I. PART NO.: —
TESTED BY: C.M.C. /[illegible]
MFR. NAME: ECI
WITNESSED BY:
PART NAME: BEAM LEADED OP. AMPS. RM 709 BL (3/FLAT PAK)
APPROVED BY: [signature]

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M. COOK, PAGES 24, 25, 26 & 27

S/N & OUT. TERM	Null V. (mV)	Out. V. (27.5 VPP)	S/N & OUT. TERM	Null V. (mV)	Out. V. (27.5 VPP)			
430-1	+2.24	OK	437-1	-4.30	OK			
-2	+7.64	OK	* -2	+14.19V	—			
-3	-4.18	OK	-3	-8.90	OK			
431-1	-4.90	OK	438-1	+3.60	OK			
-2	-5.90	OK	-2	+1.50	OK			
-3	+5.00	OK	-3	-1.40	OK			
432-1	-18.31	OK						
-2	-0.60	OK						
-3	-4.40	OK						
433-1	+0.50	OK						
-2	+1.29	OK						
? -3	-1560	OK						
434-1	+0.45	OK						
-2	-5.47	OK						
-3	-4.49	OK						
435-1	-5.90	OK						
-2	-5.83	OK						
-3	+13.38	OK						
436-1	+4.55	OK						
* -2	OSC	—						
-3	-4.58	OK						

(1) V_{in} = 7.0 VPP; V+ = +15.00V; V- = -15.00V; R_L = 10K; R_S = 10K; R_{FB} = 40K
(2) SEE SHEET FOR TEST FIXTURE CIRCUIT
(3) * DEFECTIVE DEVICE

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

ST. PETERSBURG 10, FLORIDA

TEST PERFORMED THERMAL SHOCK
E.C.I. PART NO. 60-00001
MFR. NAME ECI
PART NAME BEAM LEAD & FLIP CHIP

DATE 5-6-71
TESTED BY D.Z.[illegible]
WITNESSED BY
APPROVED BY [signature]

1. Requirement

2. Test Conditions
Relative Humidity AMBIENT Temperature PER SPEC'S

3. Results

4. Equipment Used

Instrument	Mfr.	Model	Ser.	Cal. Date
TEMP. CHAMBER	ATC	2LH8	1036	6-15-70

SPE 255

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED THERMAL SHOCK
E.C.I. PART NO. GO-00001
MFR. NAME —
PART NAME BEAM LEAD & FLIP CHIP

DATE 5-6-71
TESTED BY D. Walters
WITNESSED BY
APPROVED BY [illegible]

CYCLE #		-55°C		+85°C				
1		✓		✓				
2		✓		✓				
3		✓		✓				
4		✓		✓				
5		✓		✓				
6		✓		✓				
7		✓		✓				
8		✓		✓				
9		✓		✓				
10		✓		✓				
11		✓		✓				
12		✓		✓				
13		✓		✓				
14		✓		✓				
15		✓						
ELECTRICAL TESTS: 5/7/71								
16		✓		✓	CONTINUED 5/10/71			
17		✓		✓				
18		✓		✓				
19		✓		✓				
20		✓		✓				
21		✓		✓				
22		✓		✓				
23		✓		✓				
24		✓		✓				
25		✓		✓				

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED: POST 15 + 25 CYCLES THERMAL SHOCK ELECTR.
DATE: 5-7-71 + 5-12-71
E.C.I. PART NO.: —
TESTED BY: C.M.C.
MFR. NAME: ECI
WITNESSED BY:
PART NAME: ALUM BUMP FLIP CHIP 2N 930
APPROVED BY:

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M. COOK page 32

POST 15 cycles

S/N ↓	#1	#2	#3	#4	#5	#6
106	OK	OK	*OPEN	OK	OK	OK
107	OK	OK	OK	MISSING	OK	OK
108	MISSING	OK	MISSING	OK	OK	OK
109	MISSING	MISSING	MISSING	MISSING	OK	**OPEN
110	MISSING	OK	① OPEN	OK	OK	OK
116	OK	OK	OK	OK	OK	OK

POST 10 ADDITIONAL CYCLES

S/N	#1	#2	#3	#4	#5	#6
106	OK	OK	*OPEN	OK	OK	OK
107	OK	OK	OK	MISSING	OK	OK
108	MISSING	OK	MISSING	OK	OK	OK
109	MISSING	MISSING	MISSING	MISSING	OK	**OPEN
110	MISSING	OK	① OPEN	OK	OK	OK
116	OK	OK	OK	OK	OK	OK

MEASUREMENTS MADE ON THE TEKTRONIX 575 CURVE TRACER.

UNITS TESTED FOR a β @ $I_B = 5\mu a$ + $V_{CE} = 5V$.

① OPEN ON INITIAL ELECTRICAL.

* = FAILURE

** = FAILURE BUT WAS INTERMITTENT ON INITIAL ELECTRICAL

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST 15 + 25 CYCLES THERMAL SHOCK ELECTRICAL
DATE 5-7-71 + 5-12-71
E.C.I. PART NO. —
TESTED BY C.M.C. [signature]
MFR. NAME ECI
WITNESSED BY
PART NAME FLIP CHIP SOLDER REFLOW (DIODES)
APPROVED BY [signature]

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M. COOK PAGE 19.

POST 15 CYCLES

S/N	CONDITION
210	#6 DEFECTIVE, REST OK
211	OK
212	OK
213	OK
214	OK

POST 10 ADDITIONAL CYCLES

S/N	CONDITION
210	#6 DEFECTIVE, REST OK
211	OK
212	OK
213	OK
214	OK

MEASUREMENTS MADE ON TEKTRONIX 575 CURVE TRACER

DIODES MEASURED FOR A VOLTAGE BREAKDOWN OF 7.5V @ 16 ma

"OK" means UNITS HAD VOLTAGE BREAKDOWN OF ≈7.5V @ 16 ma

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED Post 15 CYCLES, THERMAL SHOCK ELECTRICAL — DATE 5-13-71
E.C.I. PART NO. — TESTED BY C.M.C./[illegible]
MFR. NAME ECI — WITNESSED BY [illegible]
PART NAME BEAM LEADED OP.AMPS RM709 BL(3/FLATPACK) — APPROVED BY [illegible]

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M.COOK PAGE 27

S/N# OUT.TERM	(mV) Null V.	(27.5VPP) Out.V.	S/N# OUT.TERM	(mV) Null V.	(27.5VPP) Out.V.			
410-1	-1.40	OK	432-1	-18.40	OK			
-2	-3.30	OK	-2	-8.50	OK			
-3	+5.40	OK	-3	-4.40	OK			
411-1	-7.90	OK	433-1	+0.40	OK			
-2	-10.90	OK	-2	+1.10	OK			
-3	-0.70	OK	? -3	-243	OK			
412-1	-12.00	OK	434-1	+0.40	OK			
-2	-10.30	OK	*-2	-14.00	-14.0			
-3	-9.50	OK	-3	-7.00	OK			
413-1	-20.00	OK						
-2	-0.40	OK						
-3	+0.80	OK						
415-1	+3.40	OK						
-2	+10.50	OK						
-3	-4.30	OK						
416-1	+14.20	OK						
-2	+0.20	OK						
*-3	-13.91V	-13.92V						
431*-1	+13.91V	+13.9V						
-2	-6.10	OK						
-3	+4.70	OK						

* = FAILURE
? = UNUSUALLY HIGH NULL VOLTAGE
SEE SHEET FOR TEST FIXTURE CIRCUIT

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST 10 ADDED CYCLES THERMAL SHOCK ELECT.
DATE 5-13-71
E.C.I. PART NO. —
TESTED BY C.M.C.
MFR. NAME ECI
WITNESSED BY
PART NAME OP. AMPS. RM 709 BL (3 DEVICES PER FLAT PACK
APPROVED BY

EXTRACTED FROM ENGRG NOTEBOOK #4845 C.M.COOK PAGE 28

S/N+↓	(mv)	(27.5 Vpp)	S/N+↓	(mv)	(27.5 Vpp)			
Out. Term.	Null V.	Out. V.	Out. term.	Null V.	Out. V.			
410-1	-1.4	OK	432-1	-18.7	OK			
-2	-3.3	OK	-2	-8.5	OK			
-3	+5.4	OK	-3	-4.5	OK			
411-1	-8.03	OK	433-1	+0.2	OK			
-2	-11.10	OK	-2	+1.1	OK			
-3	+0.54	OK	? -3	-508	OK			
412-1	-11.2	OK	434-1	+0.2	OK			
-2	-9.3	OK	*2	-13.1V	—			
-3	-9.1	OK	*3	-13.4V	—			
413-1	-22.7	OK						
-2	-0.5	OK						
-3	+0.6	OK						
415-1	+3.3	OK						
-2	+10.5	OK						
-3	-4.3	OK						
416-1	+14.9	OK						
-2	+0.2	OK						
*-3	-13.7V	-13.7V						
431*1	+13.89V	+13.8V						
-2	-6.1	OK						
-3	+4.9	OK						

* = FAILURE
? = UNUSUALLY HIGH NULL VOLTAGE
SEE SHEET FOR TEST FIXTURE CIRCUIT

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST VIBR ELECTRICAL
E.C.I. PART NO. –
MFR. NAME ECI
PART NAME ALUM BUMP FLIP CHIP (2N930)

DATE 5-12-71, 5-17-71, 5-28-71
TESTED BY C.M.C., R. WALTERS
WITNESSED BY
APPROVED BY [signature]

POST VERT AXIS DATA EXTRACTED FROM ENGRG NOTE-BOOK # 4845, C.M. COOK, PAGE 32

POST VERT AXIS VIBR.						
S/N ↓	#1	#2	#3	#4	#5	#6
101	ORIG DEFECTIVE	OK	OK	OK	OK	OK
102	OK	OK	OK	OK	OK	OK
103	OK	OK	OK	OK	OK	OK
104	OK	OK	OK	OK	ORIG OPEN	OK
105	OK	OK	OK	OK	OK	OK
POST MAJ. HORIZ. AXIS VIBR.						
101	ORIG DEFECTIVE	OK	OK	OK	OK	OK
102	OK	OK	OK	OK	OK	OK
103	OK	OK	OK	OK	OK	OK
104	OK	OK	OK	OK	ORIG. OPEN	OK
105	OK	OK	OK	OK	OK	OK
POST MIN. HORIZ. AXIS VIBR.						
101	ORIG. DEFECTIVE	OK	OK	OK	OK	OK
102	OK	OK	OK	OK	OK	OK
103	OK	OK	OK	OK	OK	OK
104	OK	OK	OK	OK	ORIG. OPEN	OK
105	OK	OK	OK	OK	OK	OK

MEASUREMENTS MADE ON TEKTRONIX 575 CURVE TRACER.
UNITS TESTED FOR β @ $I_B = 5\mu a$ & $V_{CE} = 5V$

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST VIBR. ELECTRICAL
E.C.I. PART NO. —
MFR. NAME ECI
PART NAME FLIP CHIP SOLDER REFLOW (DIODES)

DATE 5-12-71, 5-17-71, 5-28-71
TESTED BY GMC., R. WALTERS
WITNESSED BY
APPROVED BY

POST VERT AXIS VIBR. EXTRACTED FROM ENGRG NOTEBOOK #4845 G.M. COOK PAGE 19

POST VERT AXIS VIBR								
S/N	CONDITION							
204	OK							
205	OK							
207	OK							
208	OK							
209	OK							
POST	MAJ.	HORIZ	AXIS	VIBR.				
204	OK							
205	OK							
207	OK							
208	OK							
209	OK							
POST	MIN.	HORIZ.	AXIS	VIBR.				
204	OK							
205	OK							
207	OK							
208	OK							
209	OK							
MEASURED ON TEKTRONIX 575 CURVE TRACER								

"OK" MEANS ALL DIODES HAD CONTINUITY TO TERMINALS AND TESTED ELECTRICALLY GOOD.

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST VERT AXIS VIBR ELECTRICAL
DATE 5-12-71
E.C.I. PART NO. –
TESTED BY C.M.C., R. WALTERS
MFR. NAME ECI
WITNESSED BY
PART NAME BEAM LEADED OP. AMPS, RM 709 BL. (3/FLATPACK)
APPROVED BY

POST VERT AXIS VIBR DATA EXTRACTED FROM ENGRG NOTE-BOOK # 4845, C.M. COOK, PAGE 28

S/N+ OUT. TERM ↓	(mv) Null V.	(27.5VPP) Out. V.	S/N+ OUT. TERM ↓	(mv) Null V.	(27.5VPP) Out. V.			
404-1	-36.8	OK	428 *-1	-13.7V	-13.7V			
-2	-4.2	OK	-2	+0.1	OK			
-3	+13.0	OK	-3	-1.1	OK			
? 405-1	416.3	OK	429 ?-1	-120.2	OK			
-2	-31.9	OK	?-2	-149.7	OK			
*-3	-13.76V	-13.79V	-3	-62.9	OK			
406-1	-11.8	OK	430-1	+1.9	OK			
-2	+7.2	OK	-2	+7.4	OK			
-3	+26.9	OK	-3	-3.9	OK			
407-1	+6.9	OK						
-2	-2.5	OK						
-3	-5.5	OK						
408-1	-8.1	OK						
*-2	-13.74V	-13.73V						
-3	+1.3	OK						
409-1	-2.3	OK						
-2	-2.2	OK						
-3	-4.6	OK						
427-1	+1.7	OK						
**-2	-13.76V	-13.74V						
-3	+1.6	OK						

SEE SHEET FOR TEST FIXTURE CIRCUIT.
* FAILURE.
** = DEFECTIVE WHEN PART RECEIVED.
? = EXCEPTIONALLY LARGE NULL VOLTAGE.

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED ELECT, POST V.B.
E.C.I. PART NO. (HORIZ MAJ)
MFR. NAME ECI
PART NAME BEAM LEAD (3/FLAT PACK) OP. AMPS RM709 BL

DATE 5/17/71
TESTED BY D. Z. [illegible]
WITNESSED BY [illegible]
APPROVED BY [illegible]

S/N	DEVISE #	OFFSET (MV.)	SWITCH.		S/N	DEVISE #	OFFSET (MV.)	SWITCH.
404	1	-29.1	ok		409	1	-2.6	ok
	2	-4.0	ok			2	-2.5	ok
	3	+12.4	ok			3	+4.4	ok
405	1	-381.7	ok		427	1	+1.4	ok
	2	-29.2	ok		**	2	-13.73 V.	-13.74 V
*	3	-13.72V	-13.72V			3	+1.3	ok
406	1	+11.4	ok		428*	1	-13.69V.	-13.65V
	2	+6.9	ok			2	0.0	ok
	3	+26.1	ok			3	-1.6	ok
407	1	+6.7	ok		429	1	-118.2	ok
	2	-2.7	ok			2	-145.9	ok
	3	-5.8	ok			3	-62.3	ok
408	1	-80	ok		430	1	+1.9	ok
*	2	-13.69V	-13.71V			2	+7.1	ok
	3	+1.2	ok			3	-4.3	ok

* FAILED ON VERT AXIS PREVIOUSLY.
SEE SHEET FOR TEST FIXTURE CIRCUIT.
** FAILED ON INITIAL ELECTRICAL

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST MIN HORIZ. VIBR. ELECT.   DATE 5/21/71
E.C.I. PART NO. —   TESTED BY D. Walton
MFR. NAME ECI   WITNESSED BY
PART NAME BEAM LEAD (3/FLATPACK) OP. AMPS. RM 709 BC   APPROVED BY [signature]

S/N	DEVICE #	OFFSET (MV.)	SWITCH		S/N	DEVICE #	OFFSET (MV.)	SWITCH
404	1	-37.4	ok		409	1	-2.3	ok
	2	-4.4	ok			2	-2.1	ok
	3	+13.8	ok			3	+4.6	ok
405	1	-479.9	ok		427	1	+1.8	ok
	2	-35.6	ok		**	2	-14.06 V.	-14.04 V.
*	3	-14.03 V.	-14.05 V.			3	+1.7	ok
406	1	+11.9	ok		428 *	1	-13.98 V.	-13.97 V.
	2	+7.4	ok			2	+0.3	ok
	3	+26.9	ok			3	-0.9	ok
407	1	+7.1	ok		429	1	-121.6	ok
	2	-2.4	ok			2	-154.1	ok
	3	-5.5	ok			3	-64.1	ok
408	1	-8.2	ok		430	1	+2.2	ok
*	2	-14.01 V.	-13.9 V.			2	+7.5	ok
	3	+1.4	ok			3	-3.7	ok

* FAILED ON VERT AXIS PREVIOUSLY.
SEE SHEET FOR TEST FIXTURE CIRCUIT.
** FAILED ON INITIAL ELECTRICAL

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

ST. PETERSBURG 10, FLORIDA

TEST PERFORMED S.S.T	DATE 6-7-71 → 7-23-71
E.C.I. PART NO. —	TESTED BY D. Walters
MFR. NAME ECI	WITNESSED BY
PART NAME —	APPROVED BY [signature]

1. Requirement

2. Test Conditions
   Relative Humidity PER S.S.T. SPEC Temperature PER S.S.T. SPEC.

3. Results

4. Equipment Used

Instrument	Mfr.	Model	Ser.	Cal. Date
VIBRATION EXCITER	MB	C60	643	4-28-71
CHARGE AMPL.	UNHOLTZ-DICKIE	D11	452	5-6-71
ACCELEROMETER	CRL	302-S	3354	1-22-71
DIGITAL V.M.	H/P	3440A	1778	5-6-71
CURVE TRACER	TEKTRONIX	575	7465	6-23-71
POWER SUPPLY	POWER DESIGNS	TW-4005	512092	N.C.R.
FUNCTION GEN.	WAVETEK	103	1967	N.C.R.

SPE 255

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST TEMP SCAN ELECT. TEST — DATE 6/3/71
E.C.I. PART NO. — — TESTED BY D. [illegible]
MFR. NAME ECI — WITNESSED BY
PART NAME ALUM BUMP FLIP CHIP (2N930) — APPROVED BY [signature]

4 FLIP CHIP SOLDER REFLOW (DIODES)

#111	#2 - OPEN EMITTER, #6 not installed, REST OF UNITS OK
113	#5 OPEN ON INITIAL ELECT. REST OF UNITS OK
114	#2 initially open, #6 not installed, REST OF UNITS OK
115	#3 not installed, #5 initially open, REST OF UNITS OK
119	ok
215	ok
216	ok
217	ok
218	ok
219	ok

TESTED ON TEKTRONIX 575 CURVE TRACER.

* = FAILURE

"OK" MEANS ALL DIODES OR TRANSISTORS MET THERE ELECTRICAL REQUIREMENTS.

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST TEMP SCAN ELECTRICAL — DATE 8 JUNE 71
E.C.I. PART NO. — — TESTED BY D. [illegible]
MFR. NAME ECI — WITNESSED BY
PART NAME BEAM LEAD (3 PER FLAT PACK) OP. AMP. RM709 BL — APPROVED BY [signature]

S/N	DEVISE #	OFFSET (MV.)	SWITCH		S/N	DEVISE #	OFFSET (MV.)	SWITCH
417	1	+3.54	ok		422	? 1	-170.2	ok
	2	-20.18	ok			? 2	-134.4	ok
	3	+5.09	ok			3	+18.29	ok
418	1	-6.75	ok		435	1	-7.31	ok
	2	-2.24	ok			2	-5.51	ok
	3	-2.38	ok			3	-0.41	ok
419	1	-5.56	ok		436	1	+4.56	ok
	2	-19.99	ok			? 2	+349.5	ok
	3	+3.51	ok			3	-4.57	ok
420	1	-0.78	ok		437	1	-68.72	ok
	2	+2.39	ok		*	2	+14.21 V.	+14.20 V
	3	+1.95	ok			3	-14.57	ok
421	1	-1.44	ok		438	1	+3.78	ok
	2	+10.05	ok			2	-2.89	ok
	3	+1.76	ok			3	-1.35	ok

? = LARGE OFFSET SHIFTS FROM PREVIOUS READINGS
* = DEFECTIVE (FROM INITIAL READING ALSO)

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST VIBRATION SCAN ELECT — DATE 6-9-71

E.C.I. PART NO. — — TESTED BY R. Walters

MFR. NAME ECI — WITNESSED BY

PART NAME ALUM BUMP & SOLDER REFLOW FLIP CHIPS — APPROVED BY

S/N								
111	#6 MISSING; OTHER OK							
113	#5 INITIALLY OPEN; OTHERS OK							
215	OK							
216	OK							

"OK" MEANS ELECTRICALLY IN SPEC

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

TEST PERFORMED POST VIBRATION SCAN ELECTRICAL
DATE 9 JUNE 71
E.C.I. PART NO. —
TESTED BY D. Walters
MFR. NAME ECI
WITNESSED BY
PART NAME BEAM LEAD (3) (FLAT PACK) OP. AMP. RM709 BL
APPROVED BY

S/N	DEVISE #	OFFSET (MV)	SWITCH		S/N	DEVISE #	OFFSET (MV.)	SWITCH
417	1	+3.44	ok		422	? 1	-173.4	ok
	2	-20.33	ok			? 2	-134.7	ok
	3	+4.99	ok			3	+18.32	ok
418	1	-7.06	ok		435	1	-7.55	ok
	2	-2.27	ok			2	-5.51	ok
	3	+2.32	ok			3	-0.96	ok
419	1	-5.84	ok		436	1	+4.65	ok
	2	-19.94	ok			? 2	+398.4	ok
	3	+3.78	ok			3	-4.54	ok
420	1	-0.98	ok		437	1	-68.19	ok
	2	+2.42	ok		*	2	+14.21V.	+14.20
	3	+1.89	ok			3	-14.71	ok
421	1	-1.47	ok		438	1	+3.73	ok
	2	+10.09	ok			2	+2.87	ok
	3	+1.81	ok			3	-1.35	ok

? = HIGH change in OFFSET VOLT.
* = DEFECTIVE (ALSO AT INITIAL ELECT)

SPE 257

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.

ST. PETERSBURG 10, FLORIDA

TEST PERFORMED ~~SST-AL BUMP~~ SOLDER BUMP

E.C.I. PART NO. —

MFR. NAME ECI

PART NAME ALUM BUMP & SOLDER REFLOW FLIP CHIPS

DATE 22 JUNE 71

TESTED BY D. [illegible]

WITNESSED BY

APPROVED BY [illegible]

STEP#		S/N 111	S/N 113	S/N 215	S/N 216			
1		OK	OK	OK	OK			
2		OK	OK	OK	OK			
3		OK	OK	OK	OK			
4		OK	OK	OK	OK			
5		OK	OK	OK	OK			
6		OK	OK	OK	OK			
7		OK	OK	OK	OK			
8		OK	OK	OK	OK			
7		OK	OK	OK	OK			
8		OK	OK	OK	OK			
7		OK	OK	OK	OK			
8		OK	OK	OK	OK			

"OK" MEANS NO CHANGE FROM "POST VIBR. SCAN ELECT"

SPE 257

TEST DATA SHEET
ENGINEERING LABORATORY
ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG, FLORIDA

SUBJECT: BEAM LEAD - S.S.T. (3/FLAT PACK) OP. AMP. RM 709 BL

DATE: 21 JUNE 71 WITNESSED BY: [signature]
TESTED BY: D. Walton APPROVED BY: [signature]

S/N	STEP #1		STEP #2		STEP #3		STEP #4		STEP #5		STEP #6		STEP #7		STEP #8	
	NULL	SWITCH	NULL	SWITCH	NULL	SWITCH	NULL	SWITCH	NULL	SWITCH						
417																
1	+3.54	ok	+3.50	ok	+3.51	ok	+3.59	ok	+3.40	ok	+3.45	OK	+3.46	OK	+3.44	ok
2	?-88.01	ok	-20.06	ok	-20.11	ok	-20.04	ok	-20.14	ok	-20.12	OK	-20.19	OK	-20.17	ok
3	+5.19	ok	+5.12	ok	+5.11	ok	+5.07	ok	+4.78	ok	+5.03	OK	+5.05	OK	+4.99	ok
418																
1	-6.51	ok	-6.94	ok	-6.71	ok	-6.70	ok	-6.71	ok	-6.74	OK	-6.77	OK	-6.71	ok
2	-2.13	ok	-2.21	ok	-2.15	ok	-2.22	ok	-2.27	ok	-2.20	OK	-2.26	OK	-2.26	OK
3	+2.29	ok	+2.28	ok	+2.28	ok	+2.37	ok	+2.31	ok	+2.21	OK	+2.52	OK	+2.35	OK
419																
1	-5.66	ok	-5.62	ok	-5.65	ok	-5.73	ok	-5.60	ok	-5.70	OK	-5.62	OK	-5.55	OK
2	-19.95	ok	-20.11	ok	-20.02	ok	-20.05	ok	-20.12	ok	-20.13	OK	-20.06	OK	-20.46	OK
3	+3.74	ok	+3.66	ok	+3.72	ok	+3.62	OK	+3.61	ok	+3.52	OK	+3.34	OK	+3.88	OK
420																
1	-0.76	ok	-0.82	ok	+0.71	OK	-0.64	ok	-0.84	ok	-0.73	OK	-0.77	OK	-0.66	ok
2	+2.36	ok	+2.33	ok	+2.38	OK	+2.29	OK	+2.31	ok	+2.30	OK	+2.36	OK	+2.13	ok
3	+1.78	ok	+1.87	ok	+1.78	OK	+2.36	OK	+2.38	ok	+2.32	ok	+2.27	OK	+2.38	ok

? = UNUSUALLY HIGH CHANGE OF NULL FROM POST VIBR SCAN ELECT & TO 2ND STEP OF SST.

TR-112-3

TEST DATA SHEET

Engineering Laboratory

ELECTRONIC COMMUNICATIONS, INC.
ST. PETERSBURG 10, FLORIDA

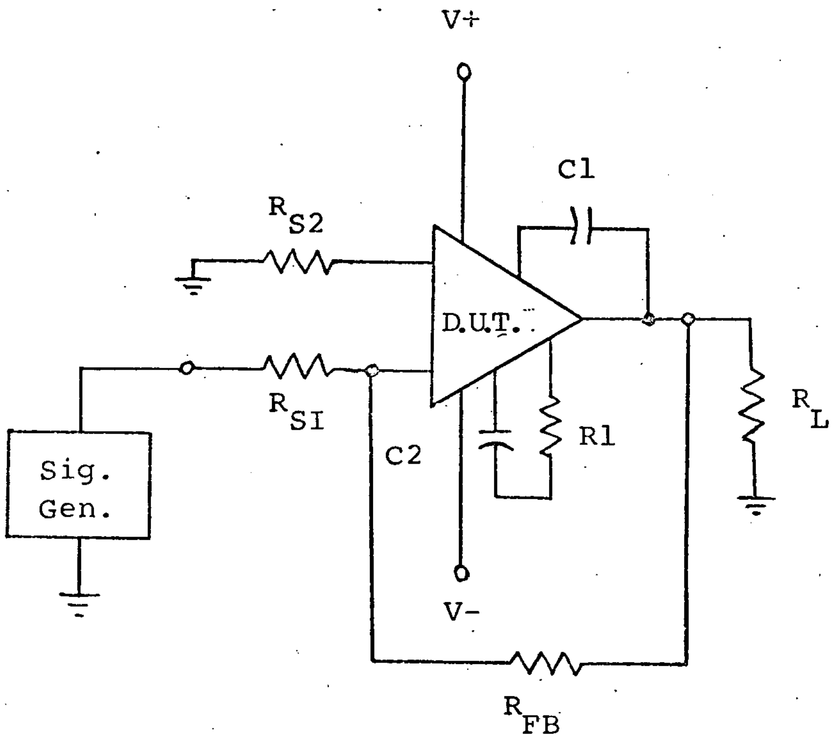
TEST PERFORMED SST
E.C.I. PART NO. —
MFR. NAME ECI
PART NAME BEAM LEADED (3/FLAT PACK) OPAMP. RM709 BL

DATE 7-23-71
TESTED BY R. WALTERS
WITNESSED BY
APPROVED BY

	STEP #7		STEP #8		STEP #7		STEP #8	
S/N	NULL	SWITCH						
417	+3.57	OK	+3.59	OK	+3.44	OK	+3.70	OK
	-20.27	OK	-20.20	OK	-20.23	OK	-20.02	OK
	+5.05	OK	+4.99	OK	+5.08	OK	+5.17	OK
418	-6.81	OK	-6.82	OK	-6.37	OK	+6.29	OK
	-2.23	OK	-2.28	OK	-6.85	OK	-6.82	OK
	+2.24	OK	+2.36	OK	-1.74	OK	+1.38	OK
419	-5.61	OK	-5.67	OK	-5.54	OK	-5.59	OK
	-19.91	OK	-20.09	OK	-19.26	OK	-20.06	OK
	+3.88	OK	+3.91	OK	+3.92	OK	+3.86	OK
420	-0.59	OK	-0.68	OK	-0.74	OK	-0.58	OK
	+2.33	OK	+2.26	OK	+3.13	OK	+2.35	OK
	+2.32	OK	+2.38	OK	+2.40	OK	+2.48	OK

SPE 257

Test Circuit for Testing
Beam Lead Flat Packs
Circuit is RM709BL



V+ = +15.00 volts
V- = -15.00 volts
D.U.T. = Device Under Test
R_{S1}, R_{S2}, and R_L = 10K ohms
C1 = 56 pf
C2 = 500 pf
R1 = 1.5K ohms
R_{FB} = 40K ohms
R_L = 10K ohms

SPE-154

D. CONCLUSIONS AND RECOMMENDATIONS

With the exception of the aluminum beam lead device, ECI has been able to provide handling, bonding, inspection and screening guidelines for flip chips and beam leaded devices. Due to time and funding limitations the environmental testing phase of the program was limited to approximately 50 percent of the total number of devices which were originally planned. Even with a limited sample lot, ECI has been capable of formulating meaningful conclusions for the various devices.

The gold beam leaded devices appear to be very reliable with respect to bonding techniques. The failures which were sustained during step stress testing were traced to device related failures. Careful handling of the beam leaded devices prior to attachment is essential for insuring reliable assemblies. The "wobble head" bonding procedure is the optimum technique for attaching this type of device.

As described in previous sections the aluminum beam leaded device requires special handling equipment which was not available during the program. It is recommended that further work is accomplished on this device since it may be a key element for radiation hardened assemblies. Also, it may prove to be the most economical approach on a long term basis.

The solder bump chip appears easy to handle and results in a very simple attachment procedure. The only anticipated problem with this device may be long term reliability from a known history of solder cracking problems which has been investigated on other programs relating to high reliability space applications.

The aluminum flip chip, although easy to handle, presents a problem of establishing a consistent bonding schedule. The failures which were sustained during step stress testing had resulted from a separation between the bump and the substrate metallization. The indication is that although an optimum schedule was established on the ultrasonic bonder, a control problem was encountered which could not be predicted. An investigation into ultrasonic bonding problems has been accomplished by the National Bureau of Standards during a recent two year study. The results of that study substantiate some of the problems which were encountered on this program.

The following table is an attempt to indicate relative factors of the devices which were included in this program.

	ALUM. FLIP CHIP	SOLDER BUMP CHIP	GOLD BEAM LEAD	ALUM. BEAM LEAD
Uniformity of product	Fair	Good	Excellent	Excellent
Handling Ease	Excellent	Excellent	Fair	Poor*
Bondability	Fair	Excellent	Good	*
Inspectability	Poor	Fair**	Excellent	*

* Further study will be necessary before any meaningful conclusions can be reached.

** Inspection of the solder bump devices is enhanced by the utilization of x-ray techniques.