EVALUATION OF ALTERNATIVE MATERIALS EFFECTIVENESS IN CLEANING SURFACE MOUNT ASSEMBLIES

by

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INTRODUCTION

Surface Mount Assemblies(SMAs) present additional cleaning problems that do not exist in normal through hole PWBs. They have a higher density of components on the boards along with the clearance between component and the board being very small. Any cleaner used must be able to address these areas effectively in order for it to be of use in cleaning SMAs. In addition to the above cleaning requirements, the cleaner/equipment must be adaptable to the manufacturing process of the assemblies and must be able to complete the cleaning task in a reasonable time.

The current cleaner being used at Westinghouse is a Chlorofluorocarbon(CFC) mixture with Alcohol. This material is being federally controlled and it's use must be phased out beginning immediately. Since one of the largest areas of CFC use at Westinghouse is PWB cleaning, alternatives need to be identified for PWB cleaning. These alternatives must provide equal or superior cleaning to the present process in use.

This study will identify possible cleaning alternatives and attempt to evaluate their effectiveness in cleaning test boards built at Westinghouse. A variety of cleaners and equipment will be tested and recommendations will be made as to the direction this study should take.

TEST BOARDS

A double sided SEM-E test board was designed and built at Westinghouse which included components that provided a range of clearances from the board. The board material was epoxy/glass. Seven types of components to include leaded, leadless, and discrete devices were placed onto the board. Each component was assigned a find number to properly identify it. For a listing of the actual components placed onto the boards, see Table 1. A drawing of the test board with the positions of each component can be seen in Figure 1.

An Alpha Metals solder paste (63Sn/37Pb, RMA384, 90% metal, mesh 2, 650K-800K CPS) was used to attach the components to the board. An RF3M RMA Flux was used as part of the test for cleaning effectiveness under components.

The parts for the boards were cleaned using a vapor degreaser and then stored in a Nitrogen environment until they were needed for assembly. Solder paste was printed onto the board using equipment in the AITL Lab. After the paste was printed, additional flux was applied beneath certain component body areas on the board. The components were then placed using the Zevatech Place Mat 460 instrument in the AITL Lab. The 124 I/O Leaded Chip Carrier components (4) were hand placed last. The alignment of the components was checked and then the entire assembly was baked for 15 minutes at 125.in a nitrogen environment to drive the volatiles from the paste. The boards were allowed to cool to room temperature and then the solder paste was reflowed using a pre-determined profile on the IR furnace. After the results of the IR reflow operation were inspected, the boards were allowed to cool to room temperature and then placed in a clean ESD bag and packaged to be sent out for cleaning. See Figure 2 for a flow chart of the Assembly/Test procedure.

<u>CLEANERS/SOLVENTS</u>

The following is a brief description of the materials that were used to clean the test boards in this study. An analysis of the virgin material was done by running a Fourier Transform Infrared Spectrum on each material. The results can be found in Figures 3 through 8.

<u>Prelete Defluxer Solvent</u> is manufactured by Dow Chemical Company. It is a mixture of 1,1,1 Trichloroethane, Nitromethane, 2-Butanol, 1,4-Dioxane, 2-Methyl-3-butyn-1-ol, and 1,2-Butylene Oxide. Prelete is a constant boiling blend which is used at a temperature of 164^{O}F.

<u>BioAct EC-7</u> consists of 65-95% Terpene hydrocarbons. It is manufactured by Petroferm, Inc. The cleaner contains a surfactant/solvent system to allow the advantages of both solvent and aqueous cleaning. It is advertised to be a biodegradable, non-toxic cleaner that removes rosin and water soluble flux even in tight clearances. It can be spray or brush applied and has an operating temperature of 80-115^{O}F.

<u>Genesolv 2010</u> is a combination of two Hydrochlorofluorocarbons(HCFCs) and Methanol. It is manufactured by Allied Signal/Baron-Blakeslee Engineering Solvent Systems. The two HCFCs contained in this cleaner are HCFC-141b, which has a good cleaning ability, and HCFC-123 for it's low ozone depleting qualities.

Marclean is a proprietary cleaner which contains a combination of Esters and surfactants developed by Martin Marietta Research Laboratories. It has been developed to specifically clean PWAs and is currently being tested by IPC.

X-33 No-Residue Flux is advertised to produce no residue when used in properly controlled solder operations and will pass Mil-P-28809 cleanliness tests without additional cleaning. It is manufactured by Multicore.

Re-Entry KNI Solvent is a Terpene based solvent manufactured by Envirosolv Incorporated. It is designed to clean metals, glass, and ceramics by a variety of methods including immersion. KNI may be used in existing vapor degreasing equipment that has been modified.

CLEANING EQUIPMENT

The following is a brief description of the different types of equipment that were used to clean the test boards in this study.

Detrex PCBD-18BS1-2ER-W Inline Cleaner is manufactured by the Detrex Chemical Industries, Incorporated. This equipment was designed to be used with a solvent cleaner and includes a combination of spray and immersion cleaning methods as the boards run through the cleaner along the conveyer belt. The machine settings are as follows:

Spray Nozzle	Spray Pressure (PSI)	Flow Rate (GPM)
Pre-Clean Top	18	10
Pre-Clean Bottom	13	10
Immersion Left	29	23
Immersion Right	29	23
Distillate Top	23	10
Distillate Bottom	16	10

Belt Speed = 3.0 feet per minute

The Microcel Centrifugal Cleaning equipment is a semi-automatic system which is manufactured by Accel Corporation. The boards are manually loaded into the holding fixture and lowered into the cleaning chamber, which is then sealed from the outside environment before the cleaning process begins. The printed wiring board is spun inside this chamber about it's center of gravity. The cleaning, rinsing, and drying cycles can all be programmed and all take place inside the one chamber without having to destroy the environmental seal. The equipment is compatible with water based cleaners, Chlorofluorocarbons, and Terpenes. Dual solvent systems may also be used with the Microcel.

The GRAM EC-1850 is an inline cleaner specifically designed for use with BioAct EC-7 by the Vitronics Corporation. The system has a stainless steel conveyer belt that runs horizontally through the equipment. The conveyer may be interfaced with other systems such as solder reflow lines and the speed of the conveyer is fully programmable. Five process stages are built into this cleaner. The stages are the Load Stage, First Wash Stage, Second Wash Stage, Removal Stage, and the Off Load Stage. The boards may be loaded manually or automatically at the load stage. This end is equipped with a vapor trap to prevent cleaner escape. The first wash stage is three feet long and has twelve upper and twelve lower spray nozzles. The cleaner is recirculated and it shares a common sump with the second wash cycle. The second wash stage is a high pressure stage to insure high impingement on the board surface. The removal stage includes compressed air blowers to rid the board of excess cleaner. At the off load stage, a vapor trap is installed to prevent odors from entering the work area. The board can be removed manually or automatically and sent to an aqueous rinse system.

The CBL-24Le is an inline cleaner manufactured by Baron-Blakeslee. It does not allow for immersion cleaning, only spray cleaning.

The Hydro-Kleen 5 is used for aqueous cleaning of printed circuit boards manufactured by Unique Industries Incorporated. The system includes a microprocessor which has been programmed to control all the devices of a standard dishwasher in order to clean the boards. An operator control panel allows the operator to control different aspects of the cleaning operation. The aspects are the starting or stopping of the machine cycle, control of rinse and wash cycles and cycle reset to allow for the drainage of the machine. There is also a supervisor's control panel to allow the supervisor/engineer to control the number of wash cycles (1-15) during the cleaning process, the length of each wash cycle (1-15 minutes), the number of two minute rinse cycles in the cleaning process (1-15), the amount of cleaner replenishment that needs to be added during a wash cycle, and the selection of a ten minute drying cycle with or without heat. The cleaner must be manually loaded into the washer, but it is automatically drained out the back of the unit into a holding container.

The XL-1200 ia a two tank vapor degreaser with ultrasonics manufactured by Crest and modified by Envirosolv Inc. for use with Re-Entry KNI Solvent.

CLEANING METHODS

The cleaning method of each group of test boards varied depending on the cleaner and equipment used. In most of the cases, the manufacturer of the cleaner gave recommendations on the proper cleaning method for their cleaner. This recommendation was followed in order to obtain the best cleaning performance out of each cleaner/equipment system. Refer to Tables 2 through 7 for a complete listing of the cleaning parameters.

The test boards for the control lot were cleaned at Westinghouse-ESG in the AITL using the Detrex Inline cleaner with Prelete as the solvent.

Accel Corporation cleaned a set of test boards using the Microcel Centrifugal equipment and BioAct EC-7 cleaner. The wash cycle was 15 minutes at a speed of 600 RPM. The EC-7 was maintained at 82°F during the wash stage. The rinse cycle was run at 750 RPM for 2 minutes. The rinse solution was tap water heated to 130°F The drying agent was filtered air(20 psig static) at 160°F. This cycle was run for 2 minutes at 900 RPM. All of the test boards were cleaned face down.

Vitronics Corporation cleaned a set of boards using the GRAM EC-1850 inline cleaner along with BioAct EC-7. The conveyer speed was 3 feet/minute. The EC-7 temperature was maintained at 65°F. A tap water rinse heated to 120°F was followed by a drying stage with air heated to 275°F.

Allied Signal/Baron-Blakeslee cleaned a set of boards with the CBL-24Le inline cleaner using Genesolv 2010. The cleaning cycle consisted of three spray stages, each designed to attempt to match the corresponding Detrex stage. The first stage used a 19 psi upper spray and a 13 psi lower spray. The second stage used a 25 psi upper spray and a 20 psi lower spray. The pressures were lower than normally run in this equipment to simulate the Detrex immersion stage. The final stage included a 2.2 psi upper spray and a 1.9 psi lower spray.

Martin Marietta Laboratories cleaned a set of boards using the Hydro-Kleen 5 equipment and Marclean as the cleaner. All of the boards went through two 15 minute wash cycles, between which the board was flipped, followed by a 5 minute cool tap water hand rinse, a 2 minute Deionized water hand rinse, a 5 minute cool air dry, and finally a 3 minute warm air dry. In addition, two of the boards were soaked in Marclean for 60 minutes prior to the wash cycle.

Envirosolv Inc. cleaned the three test boards using the modified XL-1200 Vapor Degreaser with Re-Entry KNI Solvent. Each board was subjected to a 3 minute immersion in the KNI Solvent at 36^{o}C followed by a 3 minute immersion in static DI water at 98^{o}C and finally a 10 second steam column ambient air dry.

After the cleaning process was completed, each of the boards was placed into a new ESD bag and returned to Westinghouse for storage in a nitrogen environment until the inspection and testing began.

TESTING METHODS

Five different tests were used to test the boards for cleanliness. They were weight gain/loss, visual inspection around the components, an ionic contamination test, a visual inspection under certain components, and instrumental analysis of any unusual findings.

Each test board was weighed immediately before it was sent out to be cleaned and immediately upon it's return to Westinghouse. The boards were handled only with clean gloves and stored at all times in an ESD bag. Any weight change would be attributed to trapped contaminates, trapped cleaner, or a degradation of some material on the test board.

The visual inspection around the components was actually a two-part test. All inspections were done using a magnification of 10x. The initial inspection was done to the requirements of Mil-P-28809. The boards were judged as to whether they could pass the normal inspection criteria that actual boards at Westinghouse are required to pass. The second part of the inspection involved rating the area around each component on a scale of 0-4, with 0 being the lowest rating. For a detailed explanation of the criteria for each rating on the scale, see Table 8. After all the ratings had been made, the ratings for each type of component were averaged for each lot of test boards. This was to give an indication of how different cleaning methods performed on the different components. Finally, a weighted average was calculated to give a final rating for each cleaning method's effectiveness. The ratings were weighed according to the percentage area that each component represented on the board. Photographs were taken which give an example of some of the obtained results.

An ionic contamination test was performed in the Circuit Card Assembly Lab of Westinghouse using an Omega Meter 600 instrument. This test meets the requirements of Mil-P-28809 4.7.2.1 and IPC test requirements. The ceiling limit for ionic contamination is 14 micrograms/inch. One test board from each lot was subjected to this test.

Following the ionic contamination test, the components which originally had the extra flux placed beneath them were removed from the boards and the area under the components was inspected using a magnification of 10x. A rating scale similar to the one used for the visual inspection above was used along with the same analysis calculations which took into account the percentage of area under each component type. Photographs were taken which give an example of some of the obtained results.

Instrumental analysis was used on any areas where the contamination was not readily identified as dried flux or residue. This was required for only one group of test boards, the Marclean group. Both Scanning Electron Microscopy (SEM) and Fourier Transform Infared Analysis (FTIR) was used in the analysis. The results of the analysis will be reported later in this paper.

TEST RESULTS

Weight Gain/Loss data obtained in this study showed that none of the boards had any appreciable weight gain or loss that could have been caused by the cleaning methods.

The first inspection was made according to the criteria of Mil-P-28809. The results would determine whether the board could pass normal Westinghouse inspection criteria for production parts. The results from this inspection test showed that none of the test boards would be allowed to pass Westinghouse inspection. The second test involved rating the area around each component and averaging the results for each component type and then making a weighted average score for the entire board. For the percentage breakdown of the components, see Table 9. The results of the inspection can be found in Tables 10 and 14. On average, all of the cleaners seemed to show better cleaning around the leaded chip carriers than around the leadless chip carriers. Only Marclean and KNI Solvent gave uniformly poor results over the entire board. These poor results may have been the result of poor equipment or lag time between reflow and cleaning rather than the ability of the cleaner.

All of the boards passed the ionic contamination test that was performed. The actual results can be seen in Table 11 of this report. The test boards cleaned at Vitronics and Accel showed the lowest contamination readings while the Multicore No-Clean fluxed boards gave the highest reading, but all were well below the pass/fail ceiling value.

The rating method was again applied to the areas under the components removed from the test boards. The breakdown of the percentages used for the weighted rating can be found in Table 11. The ratings can be seen in Tables 13 and 14. Once again, the expected results were obtained. All cleaners seemed to remove most of the extra flux form under the leaded chip carriers and did not remove the extra flux from under the leadless chip carriers. All the final ratings for the cleaners were very similar to each other. Appendix I of this report includes photographs of the areas underneath these components.

Analytical inspection was performed on some contamination found on the Boards cleaned with Marclean. The residue can be seen in Figure 9. It appears to have been the product of a reaction between the Marclean and the solder paste. Analysis done by FTIR picked up some evidence of flux residue, but no inorganic material can be identified using this method. A SEM analysis identified the presence of Tin in the residue, indicating the probability of a Tin oxide. No further analysis was performed since it was obvious that the boards would not pass with this residue present. If Marclean is pursued further, it is recommended that this residue be positively identified. The results from the analysis can be seen in Figures 10 and 11.

CONCLUSIONS

This study was intended to identify possible alternatives to the use of CFC cleaners of printed wiring boards. The results from this test showed that the Vitronics/EC-7 method compared well with the current method(Prelete/Detrex) for cleaning around components while the Accel/EC-7 and Genesolv 2010 methods compared well to the current method for cleaning under components.

These results should not be used as a final determination of which cleaning method is superior because none of the test boards actually gave superior results. None of the boards were able to pass the standard Westinghouse inspection criteria. This alone gives an alarming result. Some of the vendors used their recommended cleaning procedures, but others such as Baron-Blakeslee tried to match the conditions of the Detrex method done at Westinghouse. Only one cleaning procedure was viewed by Westinghouse personnel, the boards cleaned at Martin Marietta Labs. The other test boards were sent out to be cleaned by mail. This may have been the largest flaw in this test procedure. The lag time between solder reflow and cleaning was not uniform for all the boards and probably was too long to give a fair determination of the cleaner's performance. According to Mil-P-29809 para. 3.5.5.4, boards are required to be cleaned within 1 hour of the reflow process. Flux will transform from a liquid into a gel when in a thin layer, such as would occur on a board. This is why immediate cleaning is necessary. The inability of the Detrex, a proven method, to clean the test boards sufficiently is proof enough that the lag time was too long. This problem alone was probably enough to give such poor results across all the test boards.

<u>OPTIONS</u>

The following are possible options that may be used as a follow-up to this study:

1. Perform a study similar to the one in this test, but with some additions. First, design the test to be as fair as possible. Work with the vendors to design a procedure that they feel will give favorable results while at the same time stay within reasonable time limits. Second, discuss with the vendors the need to shorten the lag time between solder reflow and cleaning. Ask the vendors to explain the results from the first study. Finally, have a quality engineer work with the lead engineer to develop a better defined rating method for the inspection tests and to identify other tests which will be useful in evaluating the boards.

2. Attempt to identify in-house tests that will give better indications of the cleaning abilities of each cleaner. One possibility is to perform a test to evaluate each cleaner's ability to penetrate small spacings and remove any flux trapped in the space. It should be remembered that most vendors caution against using their material in equipment not specifically designed for them.

3. Allow the current IPC tests to certify material for use before performing Westinghouse tests on them. The IPC test is a very complete test and would be a good way of filtering out materials that do not perform well. After IPC certification, a Westinghouse test similar to Option 1 should be performed.

4. Identify one material to investigate further, Accel/EC-7 method or Vitronics/EC-7 method, and attempt to rent or lease the equipment for a period of time to allow work on the cleaning process at Westinghouse.

ADDITIONAL INFORMATION

The following papers were used as additional reference sources and background information for this paper:

1. "EC-7 Cleaning Evaluation for Detrex Corporation", Detrex Lab Test No.: LBE-0028-89, Prepared by John L. Mobley, Manager, Electronic Test & Evaluation Lab

2. "Equipment Considerations when Cleaning with Terpene Hydrocarbons" by Gary Attalla, GRAM Corp.-Vitronics Co.

3. "High Performance Cleaning with Terpene/Surfactant Mixtures", Michael E. Hayes PhD, Director of Research & Development, Petroferm, Inc.

4. "A Practical Guide to the Selection of SMT Soldering and Cleaning Materials", K. S. Borek, Litton Systems, Amecom Division

5. "Complete Cleaning of Surface Mounted Assemblies", J. E. Hale and W. R. Steinacker

6. Mil-P-28809, Circuit Card Assemblies, Rigid, Flexible, and Rigid-Flex

TABLE 1

Test Board Components and Assigned Find Numbers

Find Nos.	Component Type
U1-U10	16 I/O Flat Pack
U11-U20	16 I/O Leadless Chip Carrier (LCC)
U21-U29	20 I/O Leadless Chip Carrier
U30-U33	124 I/O Leaded Chip Carrier (LCC)
U34-U37	68 I/O Leadless Chip Carrier
C1-C10	Caps
CR1-CR10	SOT 23

TABLE 2

Cleaning Process using Detrex/Prelete

Test Boards: S/N 12, S/N 8, S/N 7

Spray Nozzle	Spray Pressure (PSI)	Flow Rate (GPM)
Pre-Clean Top	18	10
Pre-Clean Bottom	13	10
Immersion Left	29	23
Immersion Right	29	23
Distillate Top	23	10
Distillate Bottom	16	10

Belt Speed = 3.0 feet per minute

TABLE 3

Cleaning Process using Microcel/EC-7

Test Boards: S/N 44, S/N 48, S/N 46

Stage	Material	Temp.	Speed	Time(min)
Wash	EC-7	82^{o}F	600 RPM	15
Rinse	Tap Water	130^{o}F	750 RPM	2
Drying	Fil. Air	160^{o}F	900 RPM	2

TABLE 4
Cleaning Process using GRAM EC-1850/EC-7

Test Boards: S/N 13, S/N 33, S/N 31

Parameters:

Conveyer Speed = 3 feet/minute
Solvent Temperature = 65°F
Rinse Solution: Tap Water @ 4000 ohms, 120°F
Dryer Temperature = 275°F

TABLE 5
Cleaning Process using CBL-24Le/Genesolv 2010

Test Boards: S/N 14, S/N 42, S/N 45

Stage	Upper Spray	Lower Spray
Preclean	19 psi	13 psi
Immersion *	25 psi	20 psi
Distillate **	2.2 psi	1.9 psi

* Because of the design specifications of the CBL-Le there is no immersion during the spray stages, so the pressures were lowered to simulate conditions seen by the surface of the assembly if such conditions were present.

** In the CBL-Le the final distillate sprays are used as a final rinse across both surfaces of the board. The pressures are not meant to exceed the ones listed. Due to the fact that final rinse is applied after immersion in a liquid seal for 40 seconds this washing action should adequately duplicate the present conditions Westinghouse requested.

TABLE 6
Cleaning Process using Hydro-Kleen 5/Marclean

Test Boards: S/N 29, S/N 32*, S/N 34*

Procedure:

1. 15 minute wash cycle
2. Flip Board
3. 15 minute wash cycle
4. 5 minute cool water hand rinse
5. 2 minute Deionized water rinse
6. 5 minute cool air dry
7. 3 minute warm air dry

* These boards were soaked a total of 60 minutes before procedure above was begun.

TABLE 7
Cleaning Process using XL-1200/KNI Solvent

Test Boards:	S/N 3, S/N 22, S/N 2	
Procedure:	Wash Stage-	3 minute Immersion Circulation in Re-Entry KNI Solvent at 36^{O}C.
	Rinse Stage	3 minute Immersion in Static DI water at 98-99^{O}C.
	Dry Stage	10 seconds in steam column ambient air dry.

TABLE 8
Visual Inspection Rating Criteria

Rating	Criteria
4	No flux residue on component, leads, or around component
3	Isolated areas of residue on or around the components
2	Isolated areas of flux on component or leads and/or heavier residue present
1	Heavy residue on or around majority of component
0	Flux "puddles" on or around majority of component

TABLE 9
Percentage Area Inspected per Component Type

Component Type	Percentage
124 LCC	30.6%
16 I/O Flat Pack	25.2%
20 I/O LCC	16.1%
68 I/O LCC	11.5%
16 I/O LCC	8.3%
Caps	5.5%
SOT 23	2.8%

TABLE 10

Average Rating/Component Type

Component-> Cleaner	U1-U10	U11-U20	U21-U29	U30-U33	U34-U37	C1-C10
Marclean	0.6	1.0	0.6	1.4	0.6	0.7
Accel/EC-7	2.9	0.9	1.7	3.0	1.0	2.0
Vitr/EC-7	2.2	1.0	2.7	3.7	1.0	3.0
Genesolv	3.5	0.0	0.0	4.0	0.5	0.6
Prelete	2.8	1.8	1.7	4.0	0.0	1.7
KNI Solvent	0.5	0.0	0.0	1.0	0.0	0.0

TABLE 11

Ionic Contamination Test Results

Pass Limit $\leq$ 0.0140 mg/in^2

Board #	Resistivity(Mohm-cm)	Total Contamination ($mg\ NaCl/in^2$)
Marclean #34	36.16	0.0001
Multicore #35	14.51	0.0019
Victronics #33	39.47	0.0000
Accel #48	39.70	0.0000
Genesolv #45	26.43	0.0006
Prelete #12	17.22	0.0011
KNI Solvent #3	36.87	0.0000

TABLE 12

Percentage Area Inspected Under Components/Component Type

Component Type	Percentage
16 I/O Flat Packs	17.0%
20 I/O LCC	13.2%
124 I/O LCC	25.1%
68 I/O LCC	44.7%

TABLE 13
Under Component Rating/Component Type

Component--> Cleaner	U6-U10	U21-U29	U30-U32	U34-U36
Prelete	4.0	2.6	4.0	0.5
Marclean	4.0	0.0	4.0	0.0
Accel/EC-7	4.0	1.2	3.0	1.0
Vitronics	4.0	0.0	4.0	0.0
Genesolv 2010	4.0	0.0	4.0	0.5
KNI Solvent	4.0	3.0	---	2.0

TABLE 14
Weighted Average Ratings for Each Cleaner

Cleaner	Around Components	Under Components
Detrex/Prelete	2.5	2.2
Vitronics/EC-7	2.5	1.7
Accel/EC-7	2.3	2.0
Genesolv 2010	2.3	1.9
MML/Marclean	0.9	1.7
XL-1200/KNI	0.4	2.6*

* Calculated using adjusted percentages to compensate for the lack of 124 I/O LCC which were not placed on these boards.

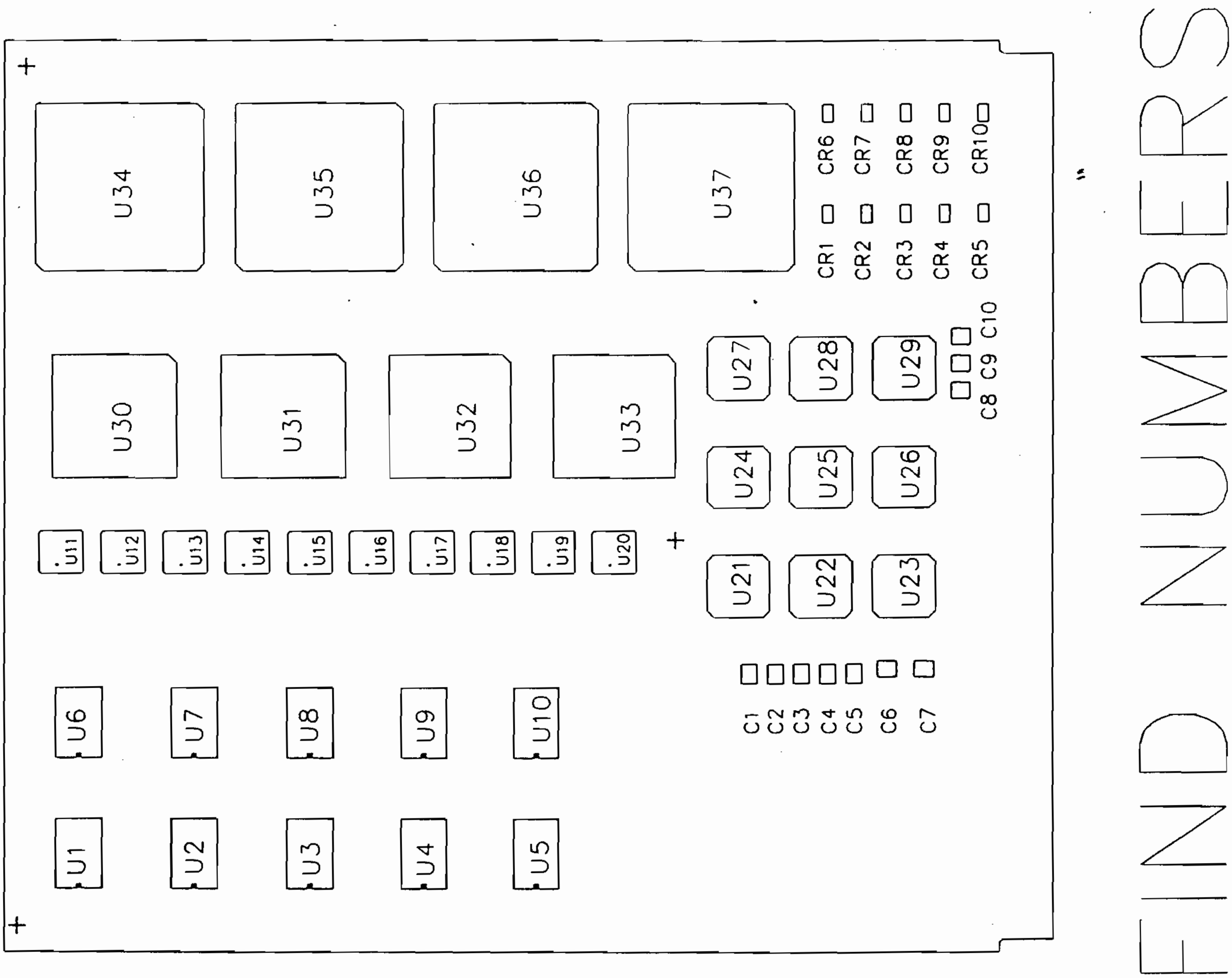


Figure 1
Component Position on Test Boards

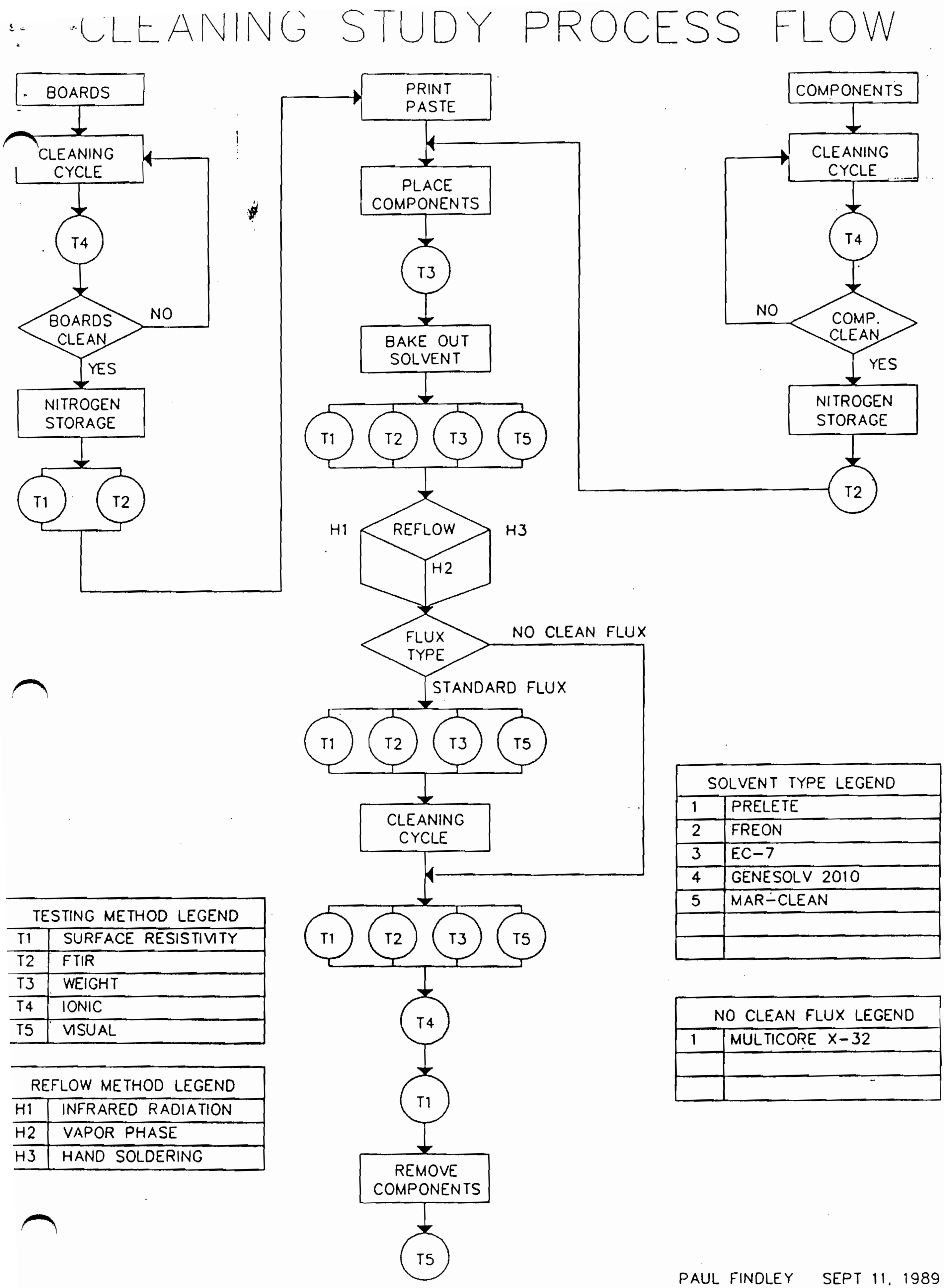


Figure 2
Original Cleaning Study Process

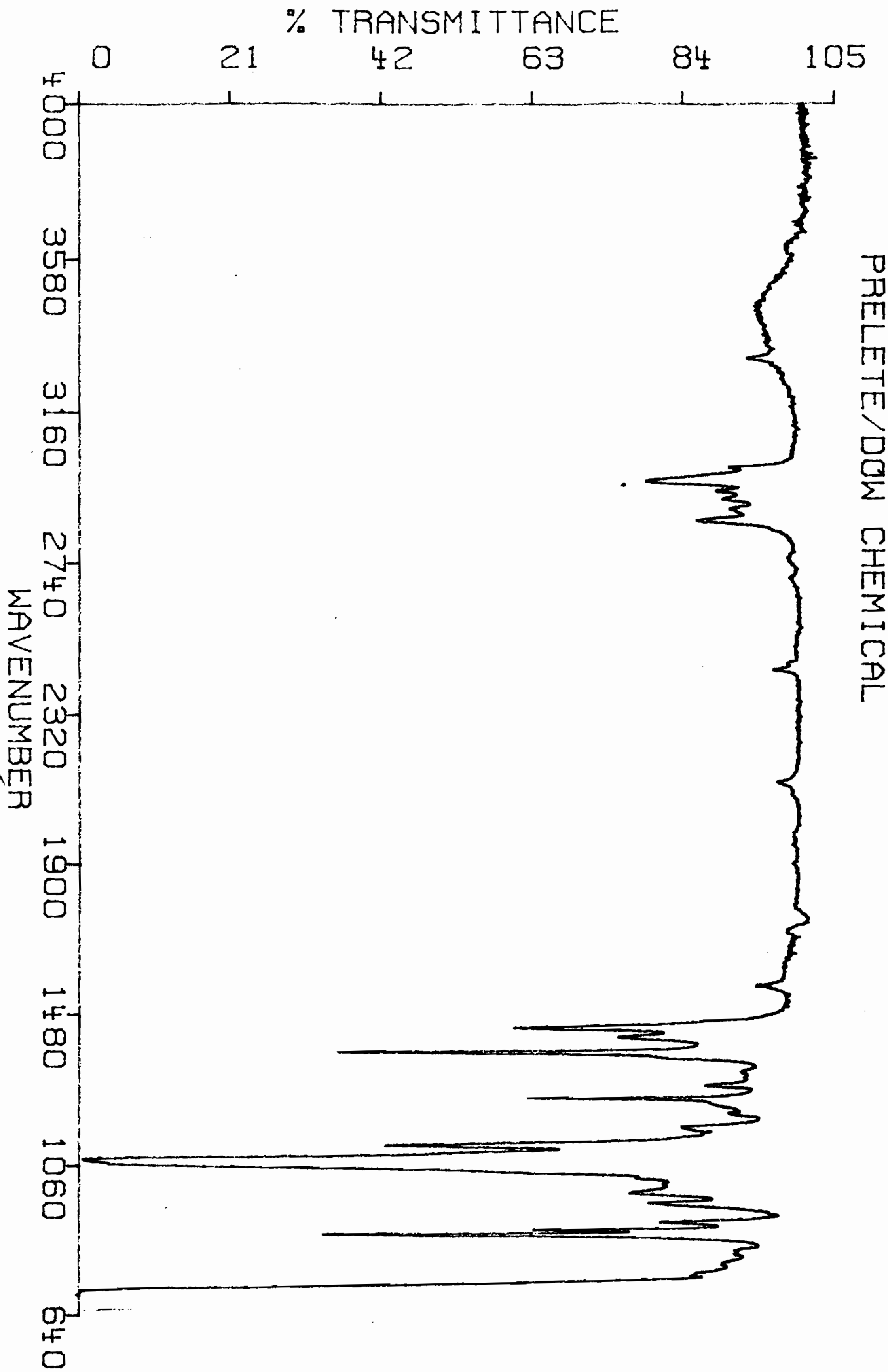


Figure 3
FTIR Spectrum for Prelete

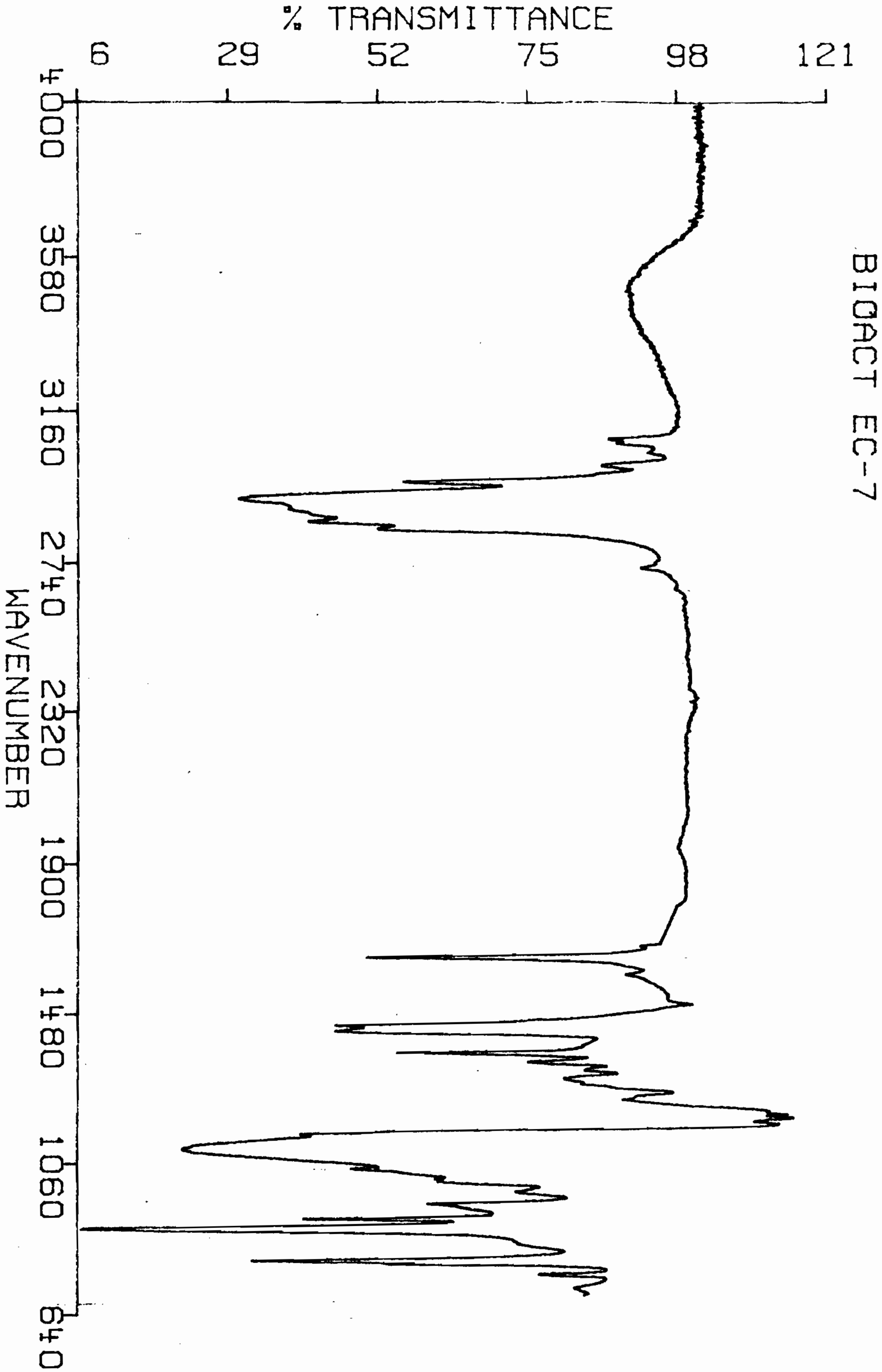


Figure 4
FTIR Spectrum for BioAct EC-7

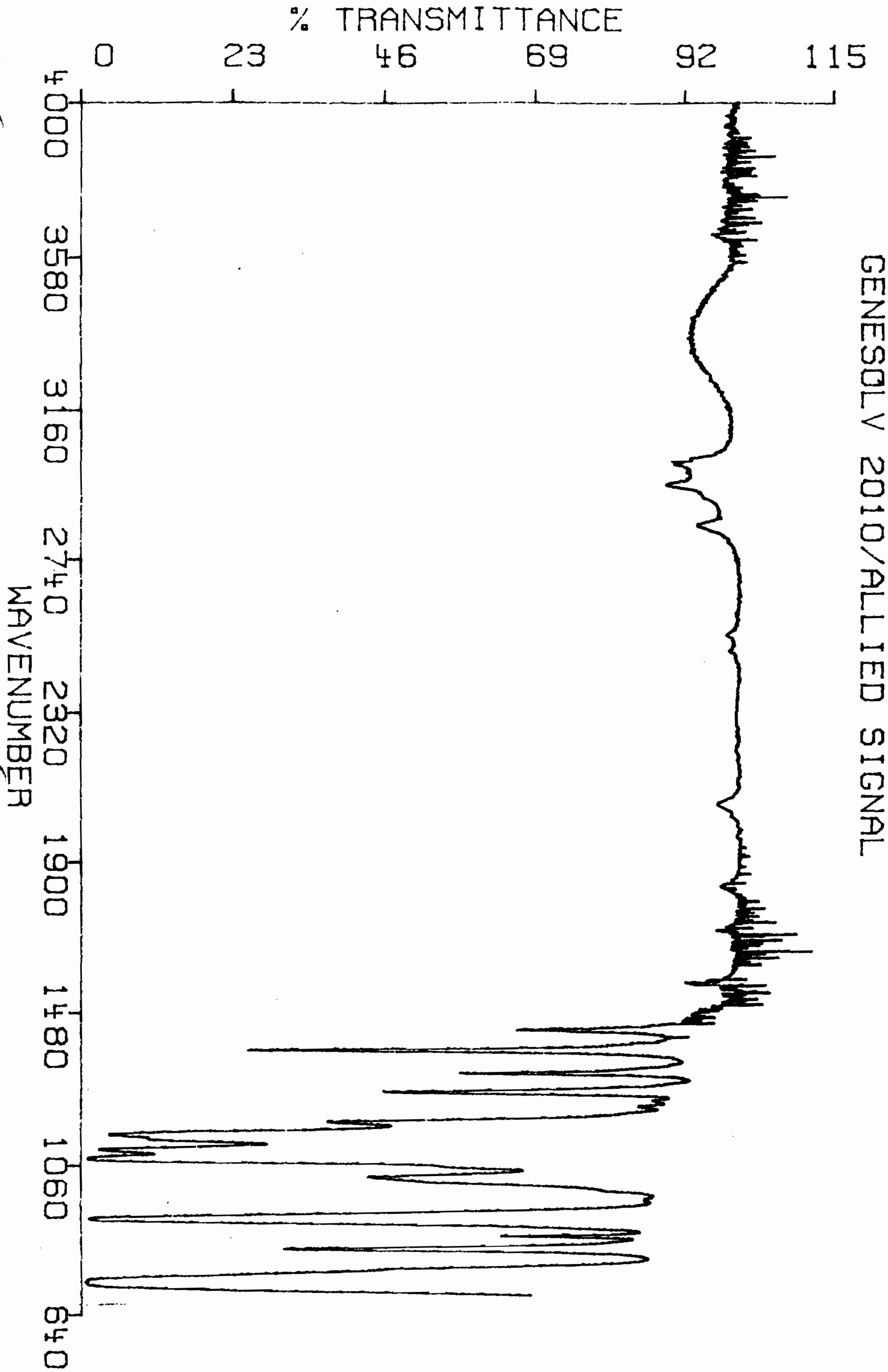


Figure 5
FTIR Spectrum for Genesolv 2010

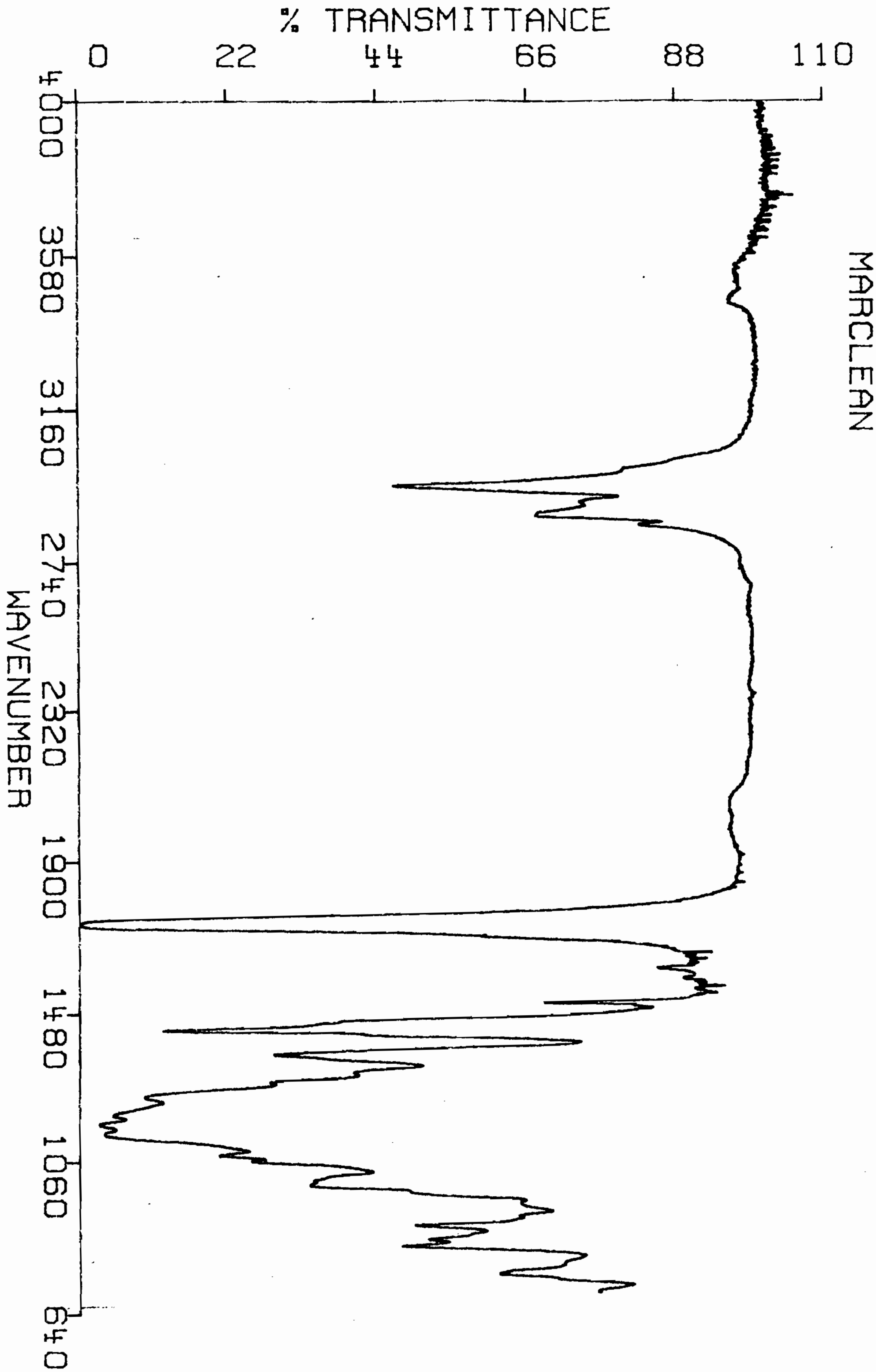


Figure 6
FTIR Spectrum for Marclean

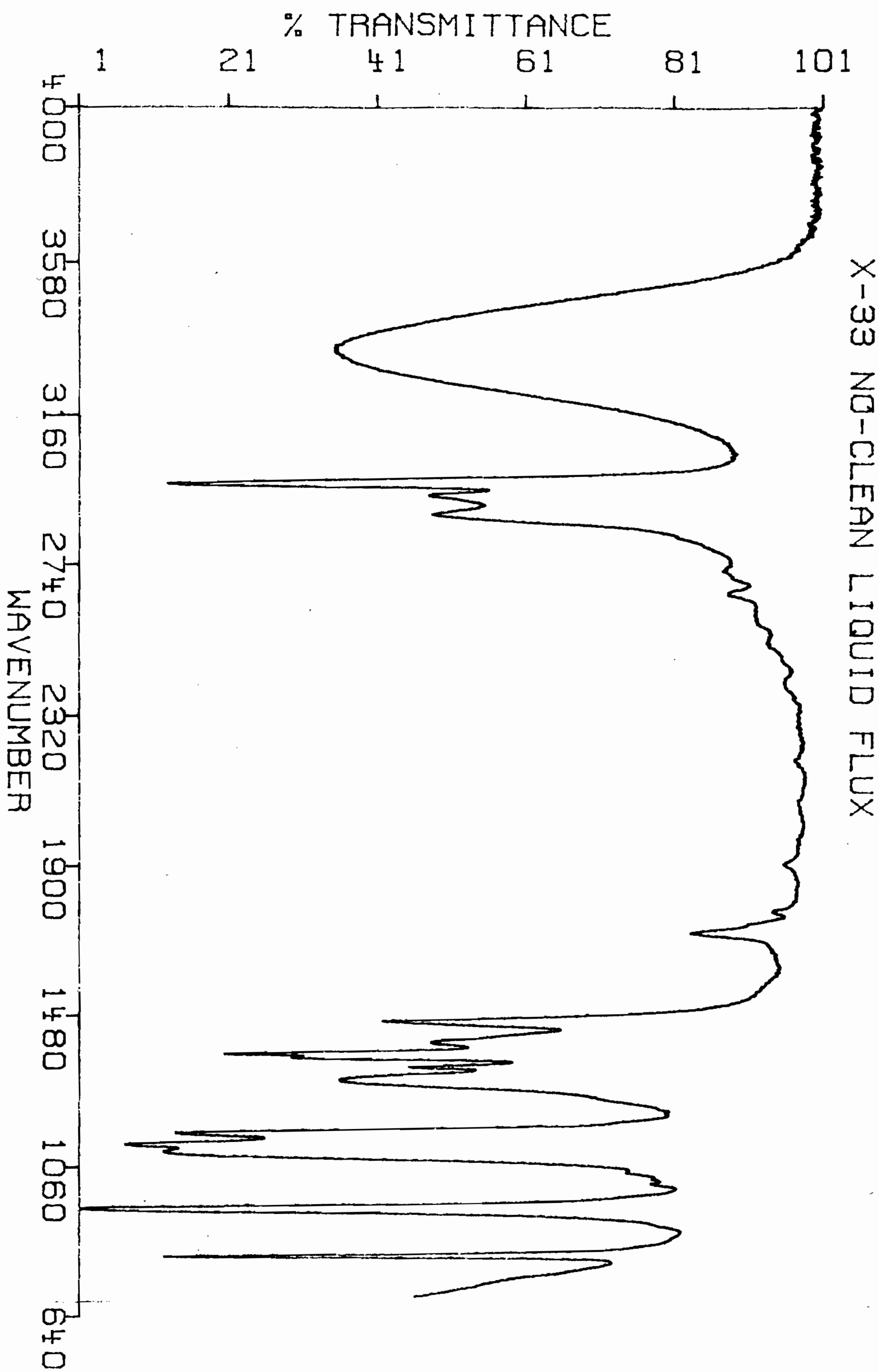


Figure 7
FTIR Spectrum for X-33 No-Clean Flux

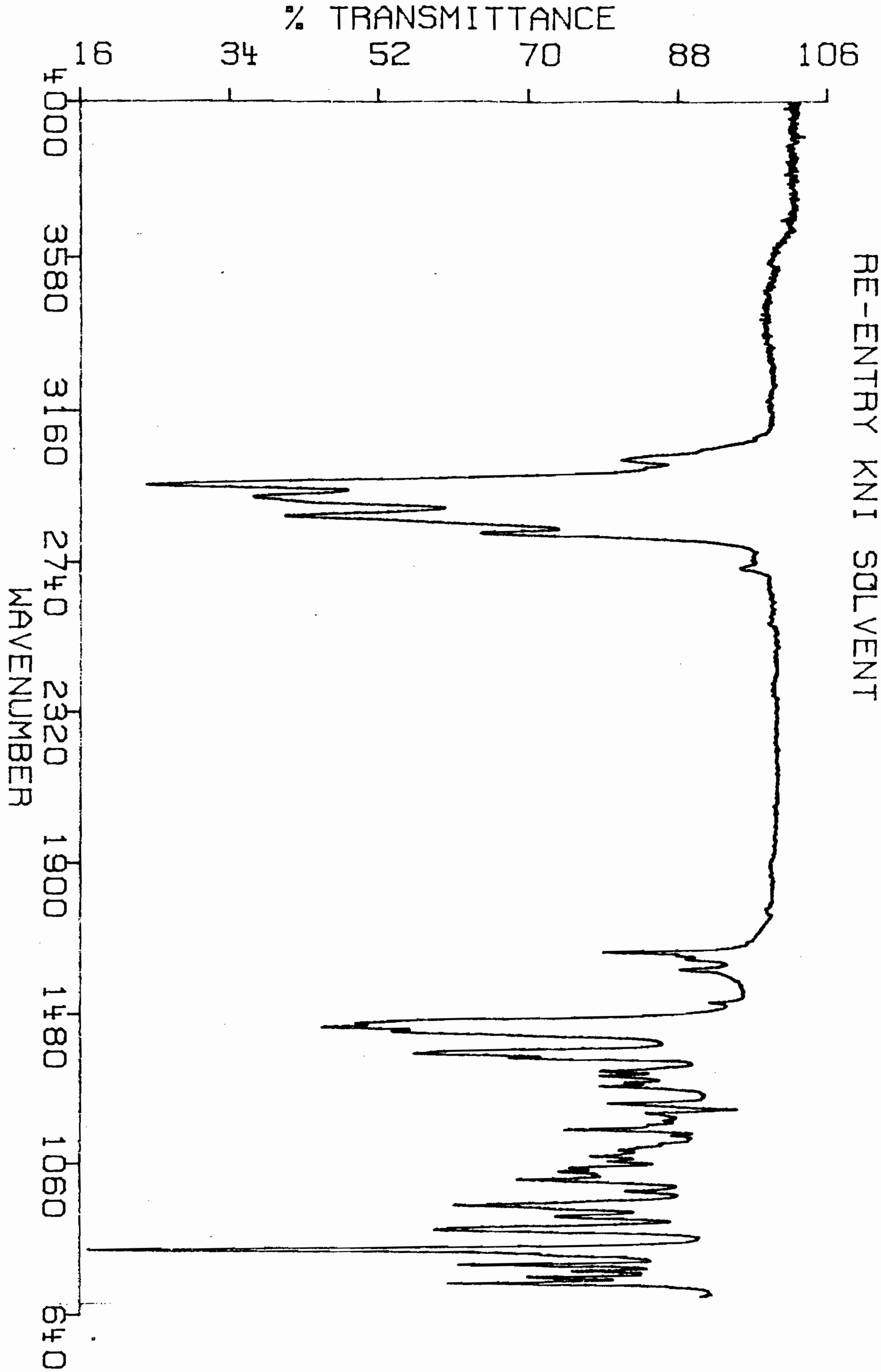


Figure 8
FTIR Spectrum for Re-Entry KNI Solvent

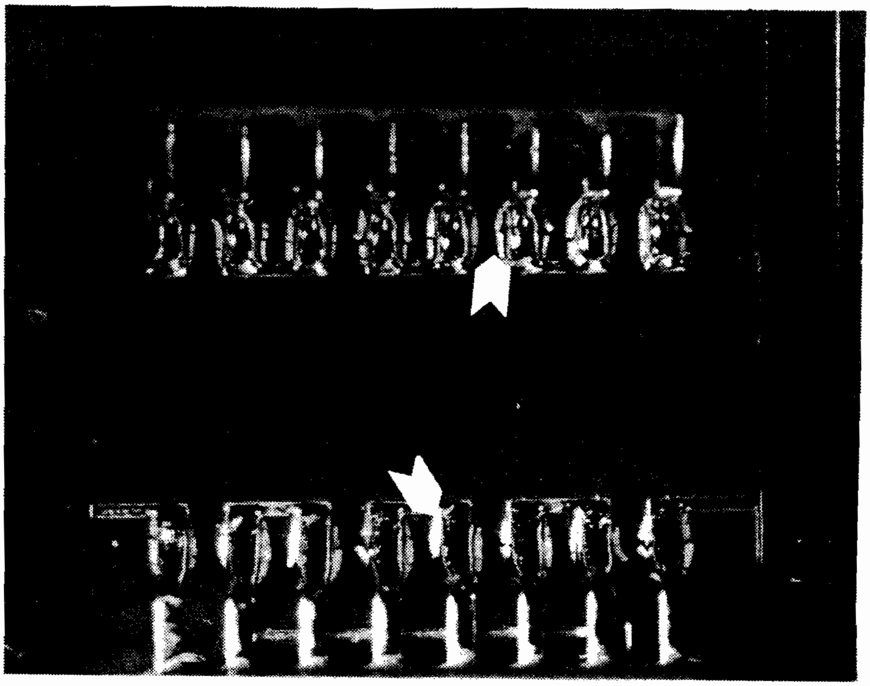


Figure 9
Test Board S/N 29
Cleaner: Marclean
Contamination Around a 16 I/O Flat Pack

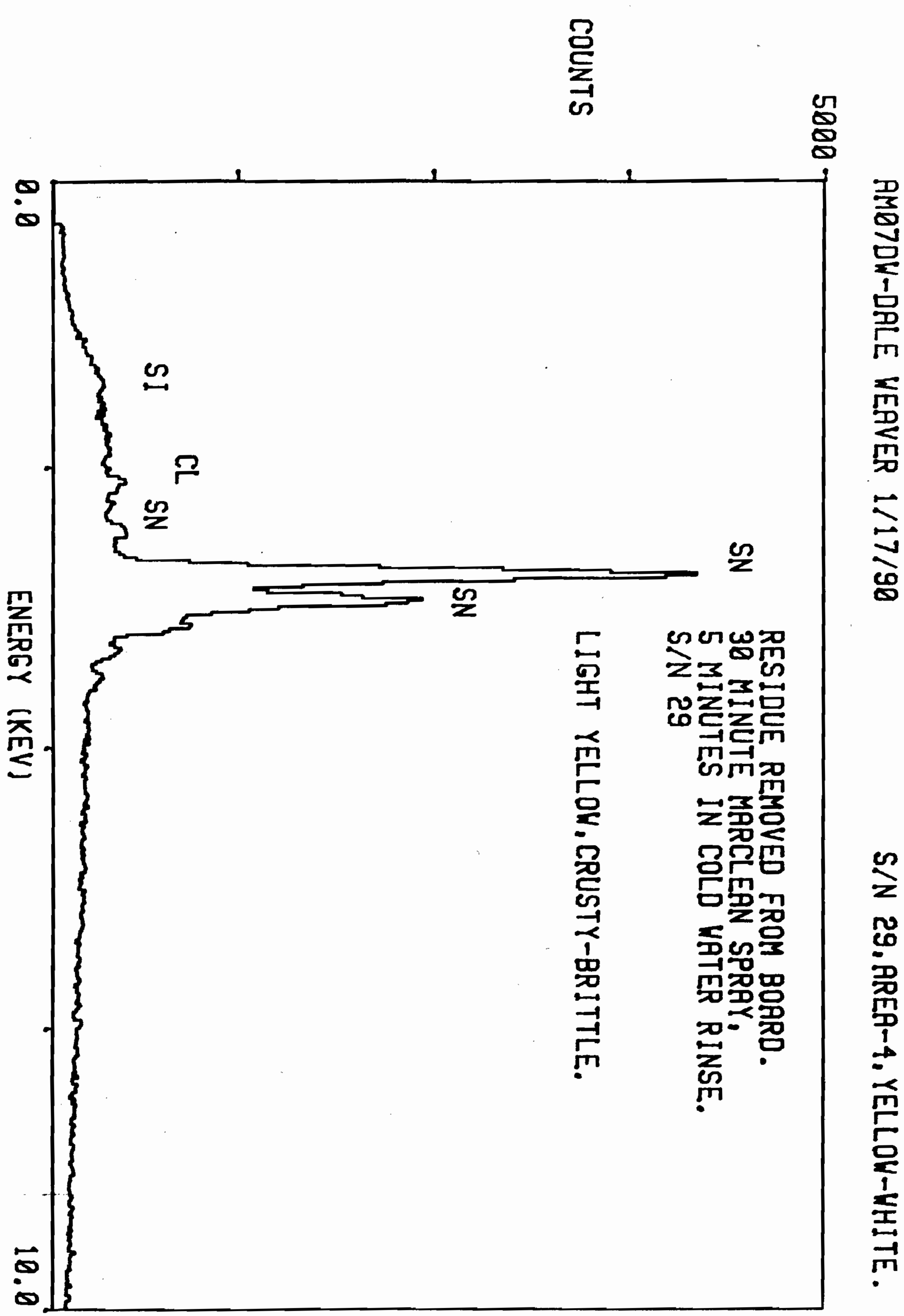


Figure 10
SEM Analysis for Marclean Residue

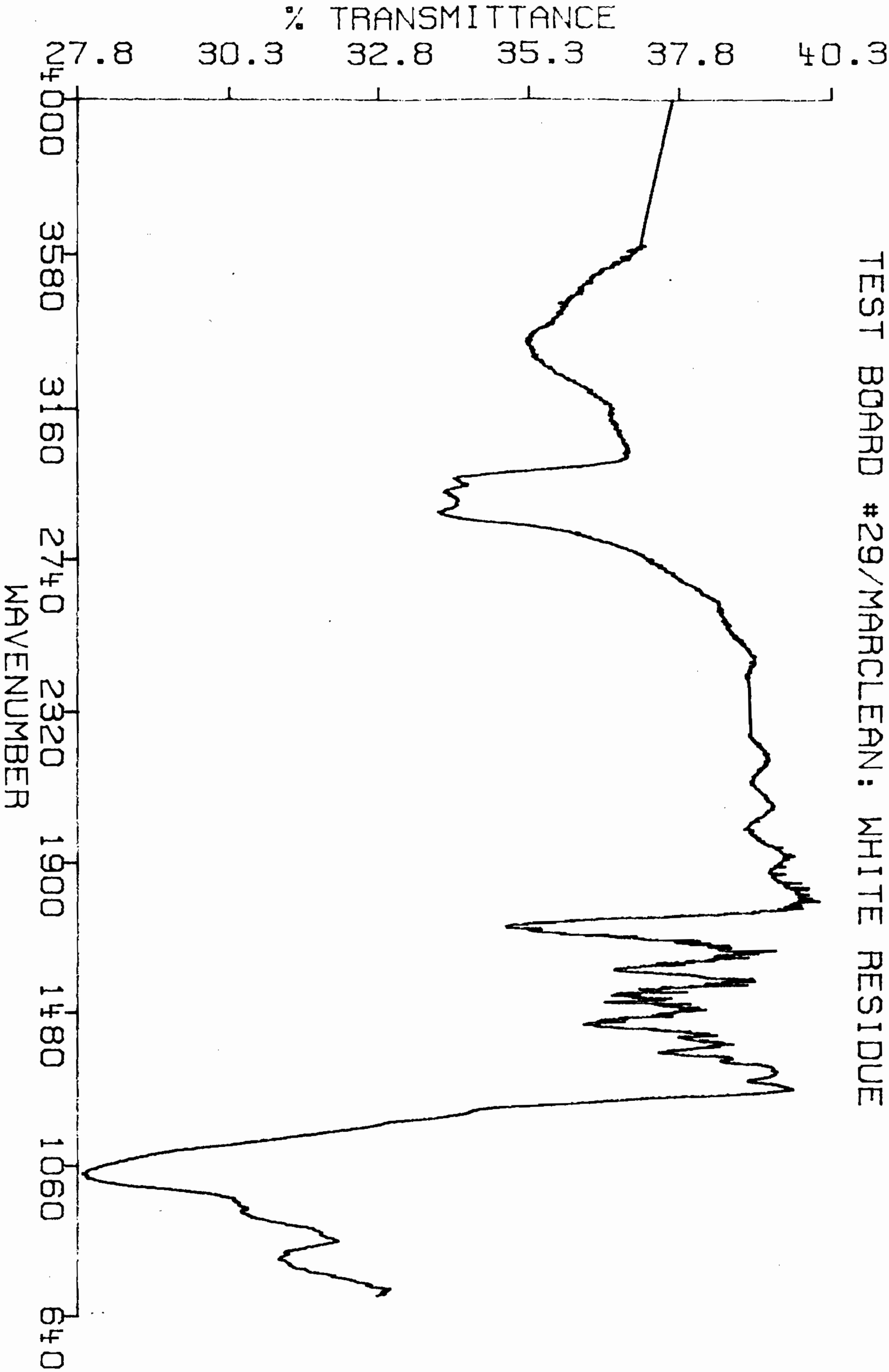


Figure 11
FTIR Spectrum for Marclean Residue

APPENDIX I

The following photographs were taken to give a visual example of the type of contaminations found on the test boards.

Photo Number	Description
A1	Photo showing an actual test board.
A2	Area underneath component U36 (68 I/O LCC) after cleaning with Detrex/Prelete system.
A3	Area underneath component U36 (68 I/O LCC) after cleaning with Genesolv 2010 system.
A4	Area underneath component U36 (68 I/O LCC) after cleaning with Microcel/EC-7 system.
A5	Area underneath component U36 (68 I/O LCC) after cleaning with GRAM EC-1850/EC-7 system.
A6	Area underneath component U36 (68 I/O LCC) after cleaning with Hydro-Kleen 5/Marclean system.
A7	Area underneath component U36 (68 I/O LCC) after cleaning with XL-1200/KNI Solvent system.
A8	Area underneath component U30 (124 I/O LCC) after cleaning with Detrex/Prelete system.
A9	Area underneath component U30 (124 I/O LCC) after cleaning with Genesolv 2010 system.
A10	Area underneath component U30 (124 I/O LCC) after cleaning with Microcel/EC-7 system.
A11	Area underneath component U30 (124 I/O LCC) after cleaning with GRAM/EC-7 system.
A12	Area underneath component U30 (124 I/O LCC) after cleaning with Hydro-Kleen5/Marclean system.
A13	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with Detrex/Prelete system.
A14	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with Genesolv 2010 system.
A15	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with Microcel/EC-7 system.

A16	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with GRAM/EC-7 system.
A17	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with Hydro-Kleen 5/Marclean system.
A18	Area underneath components U21, U23, U25, U27, U29 (20 I/O LCC) after cleaning with XL-1200/KNI Solvent system

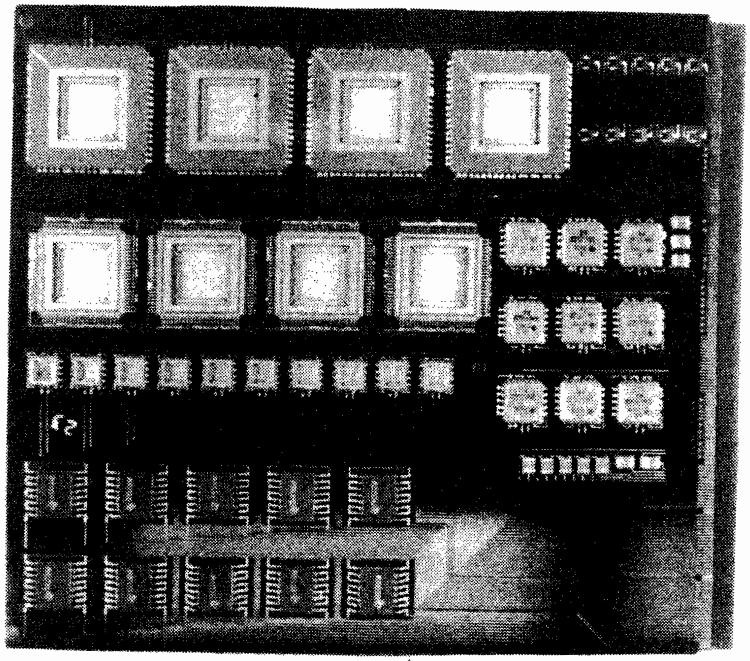
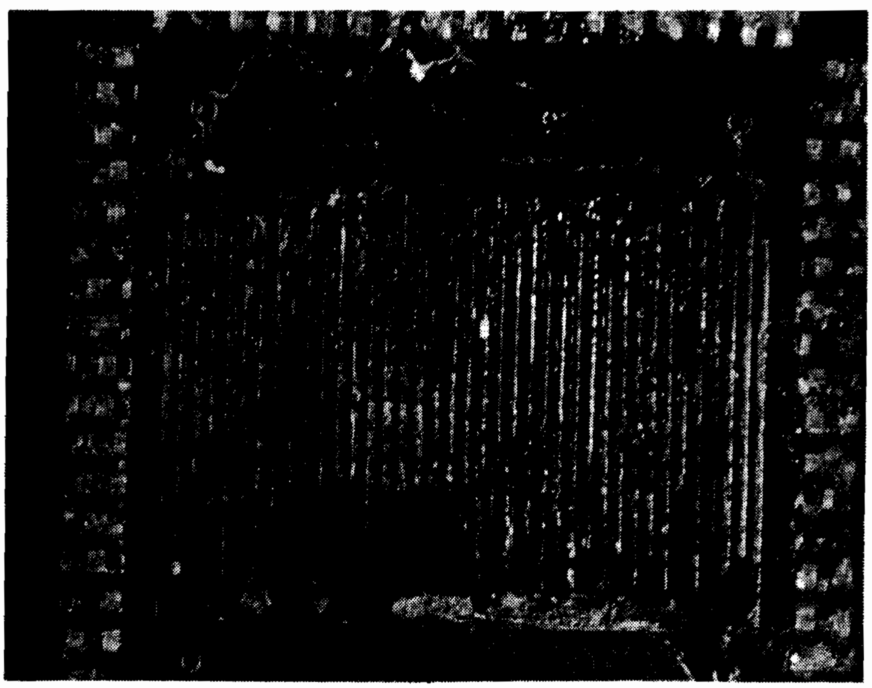


Photo A1



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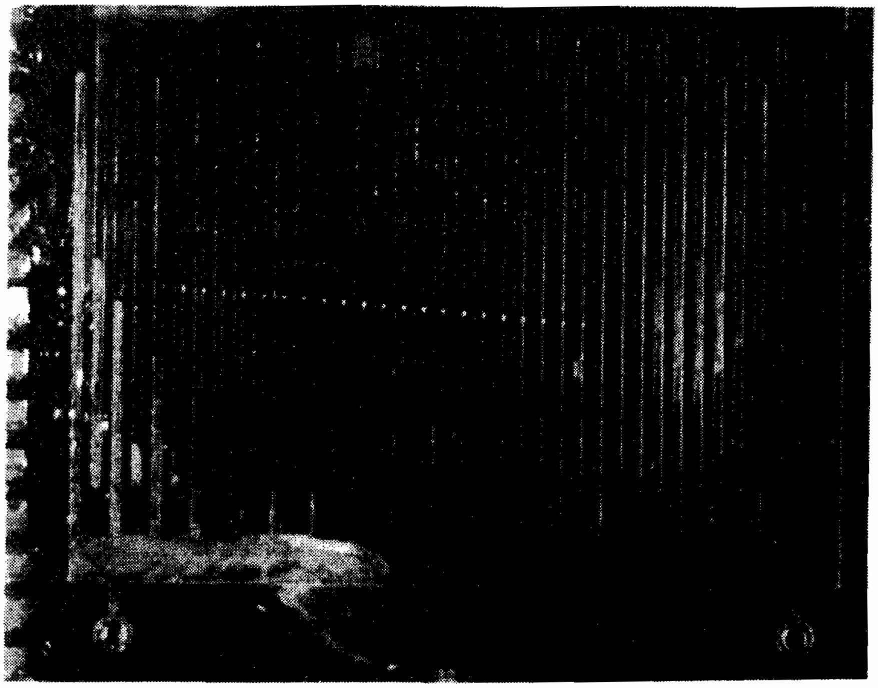

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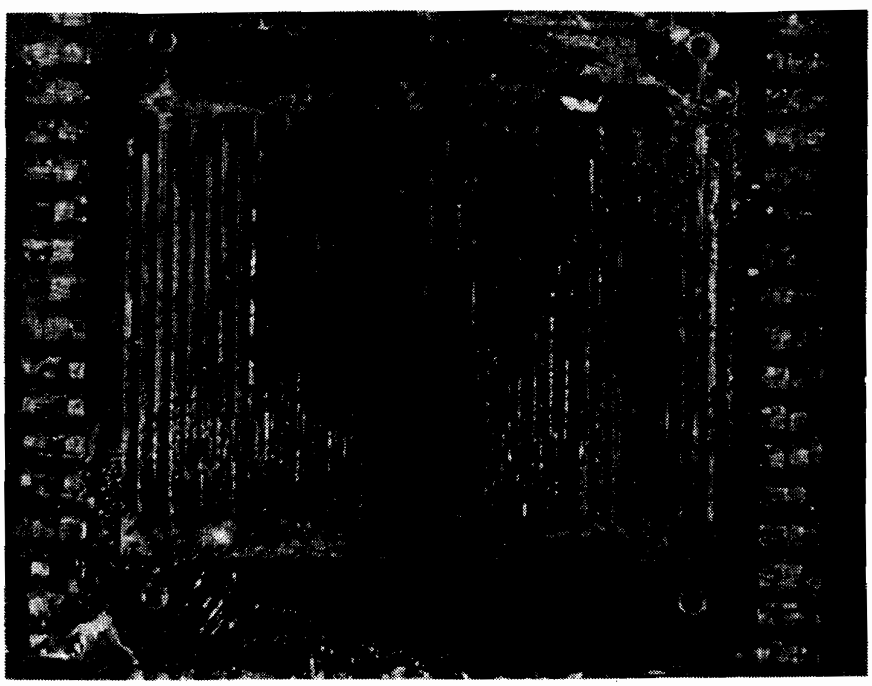

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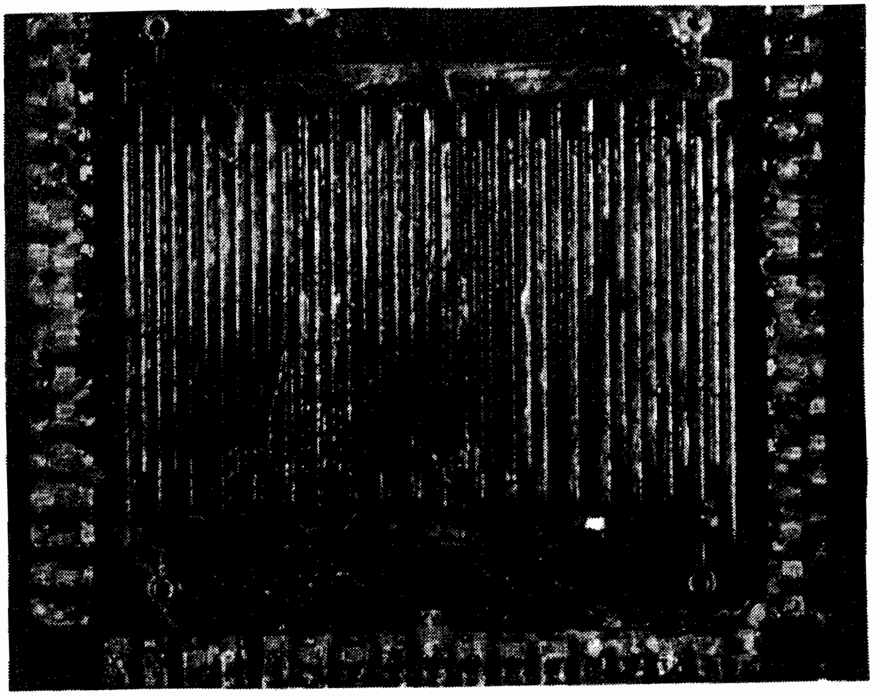

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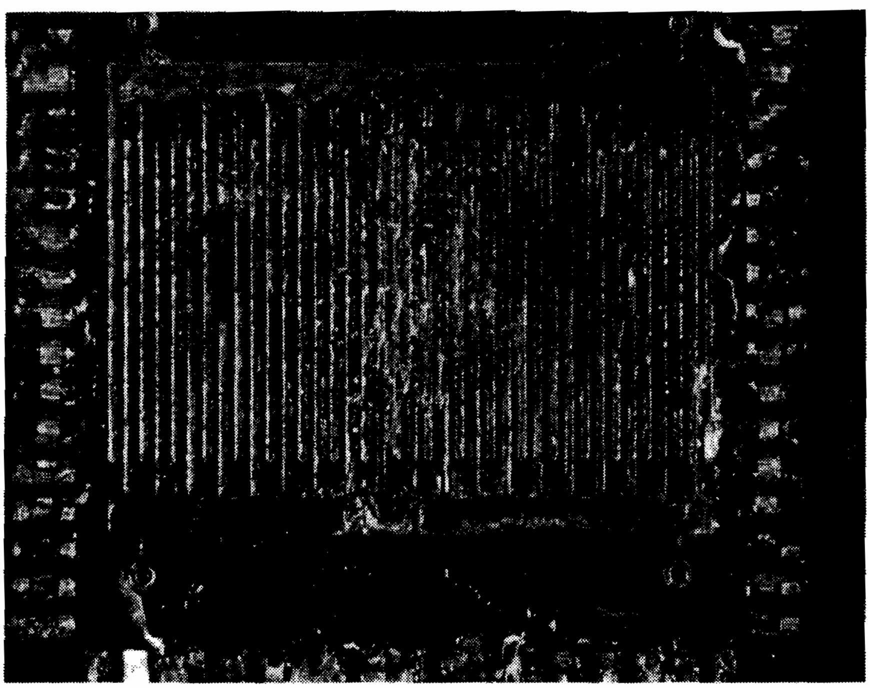

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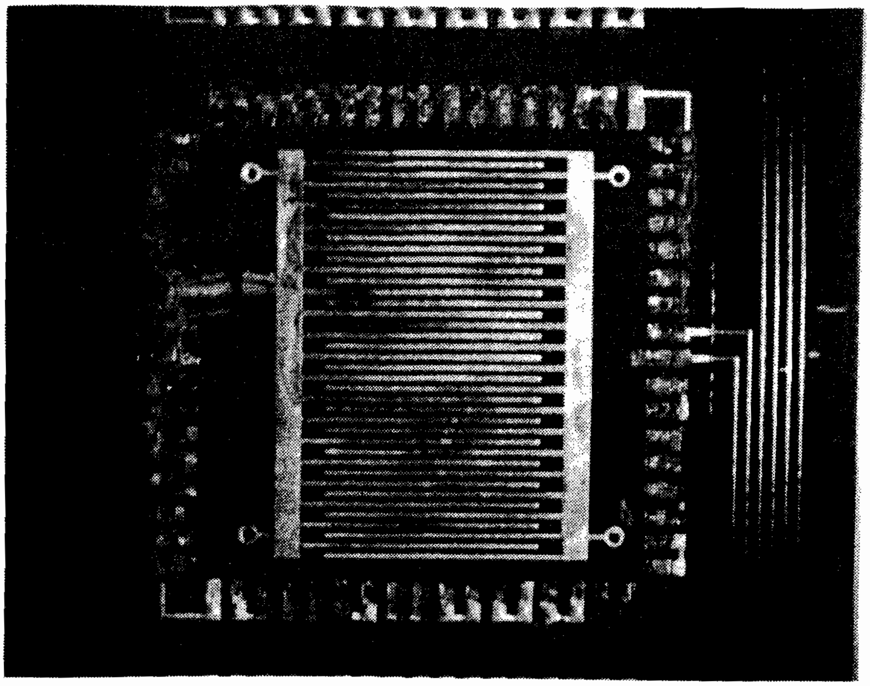

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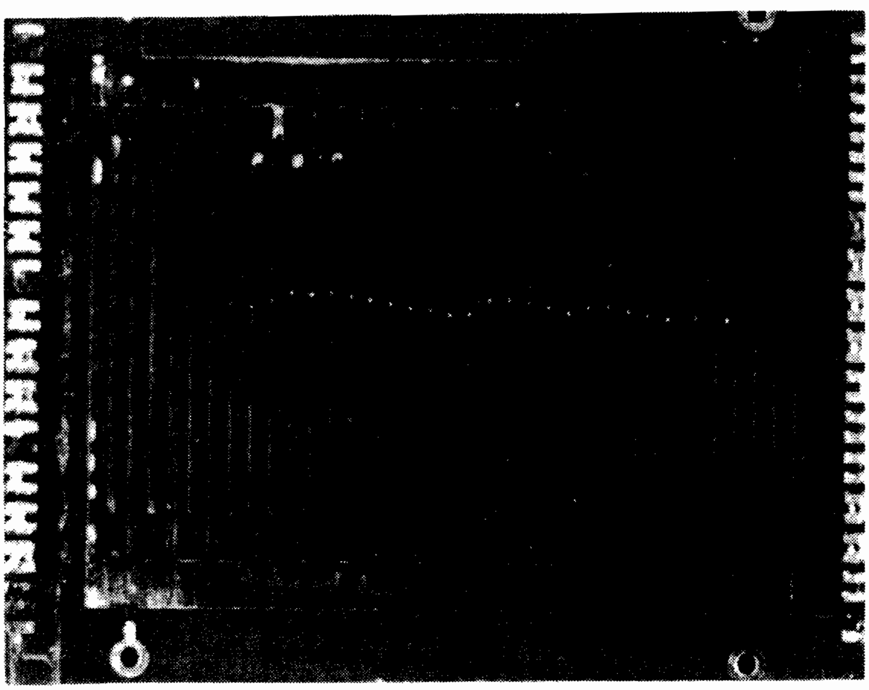

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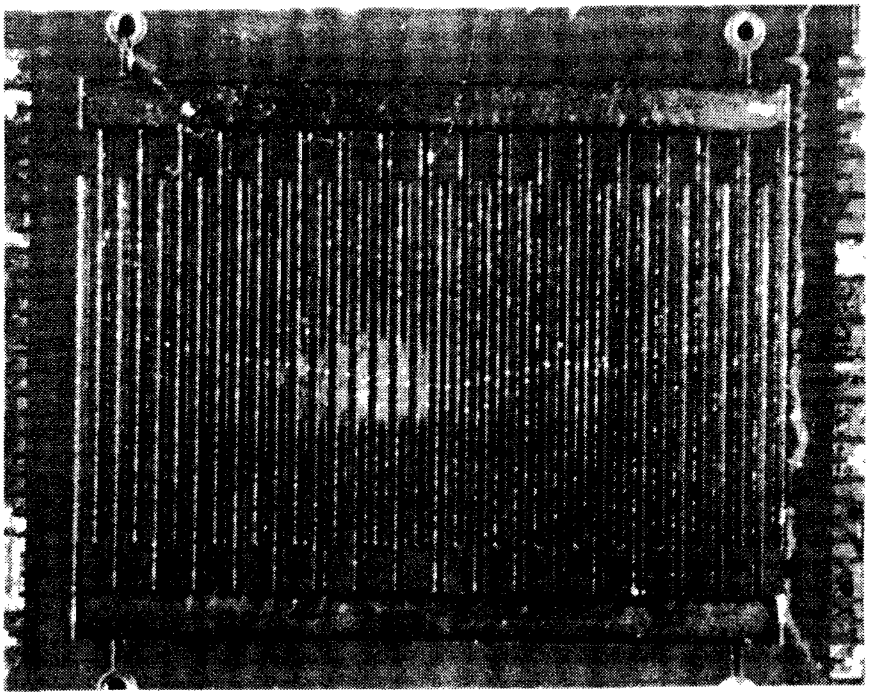

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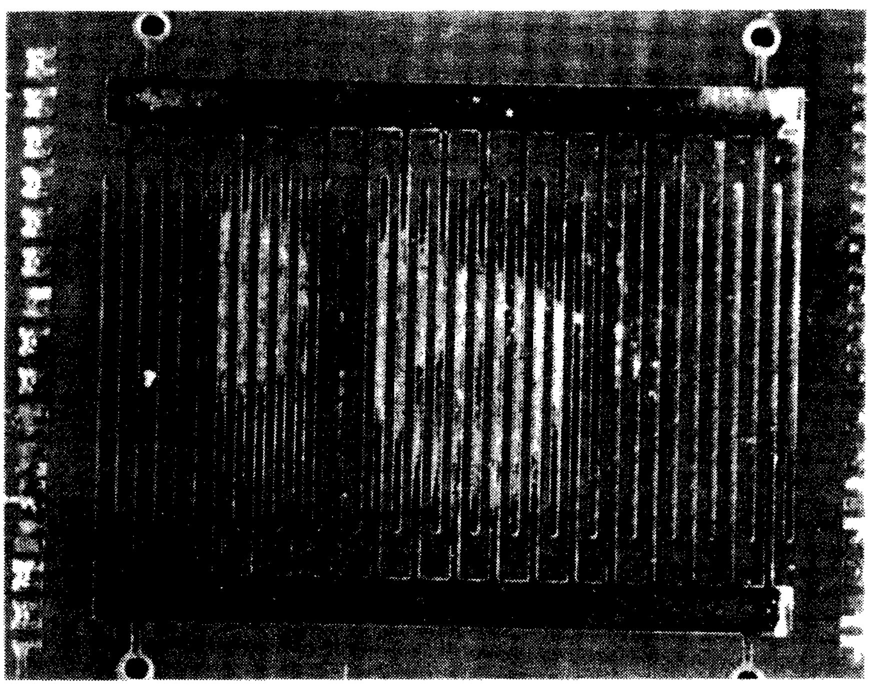

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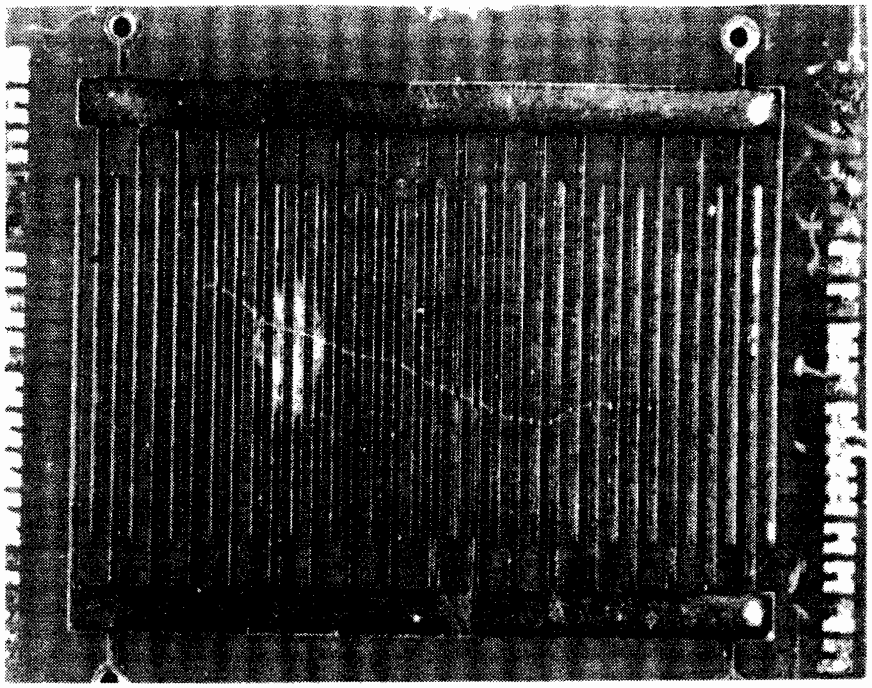

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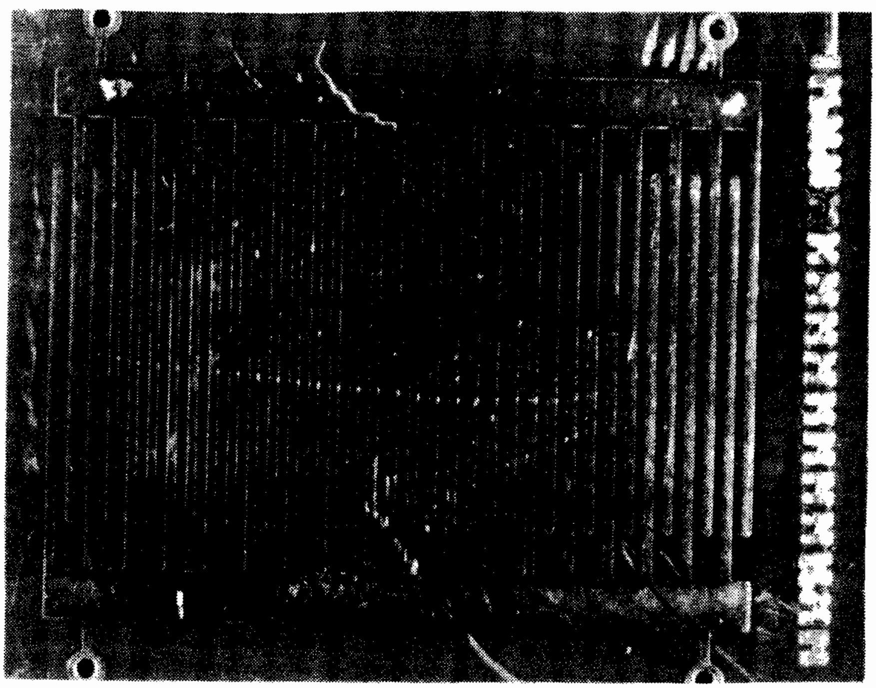

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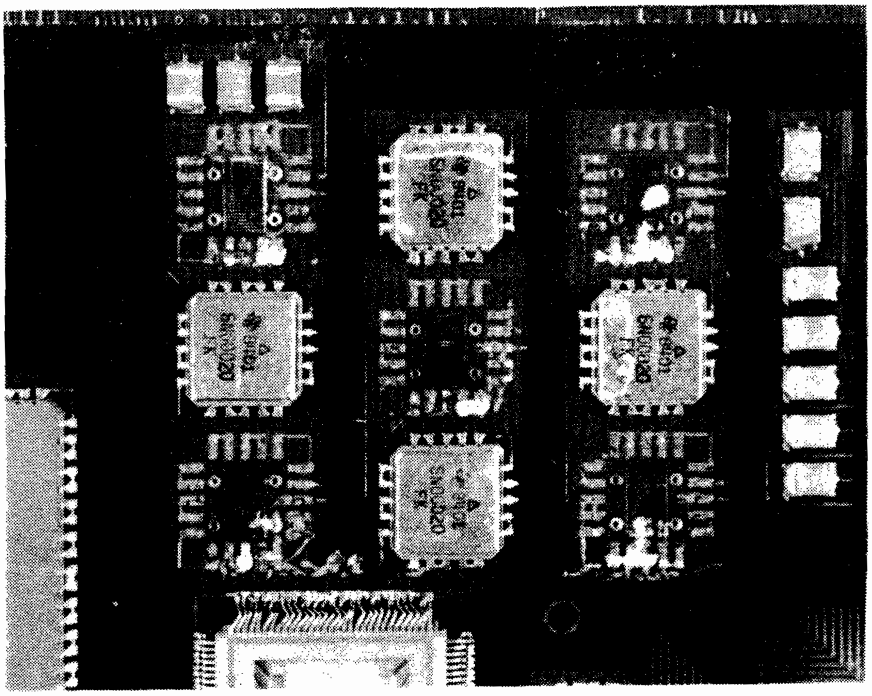
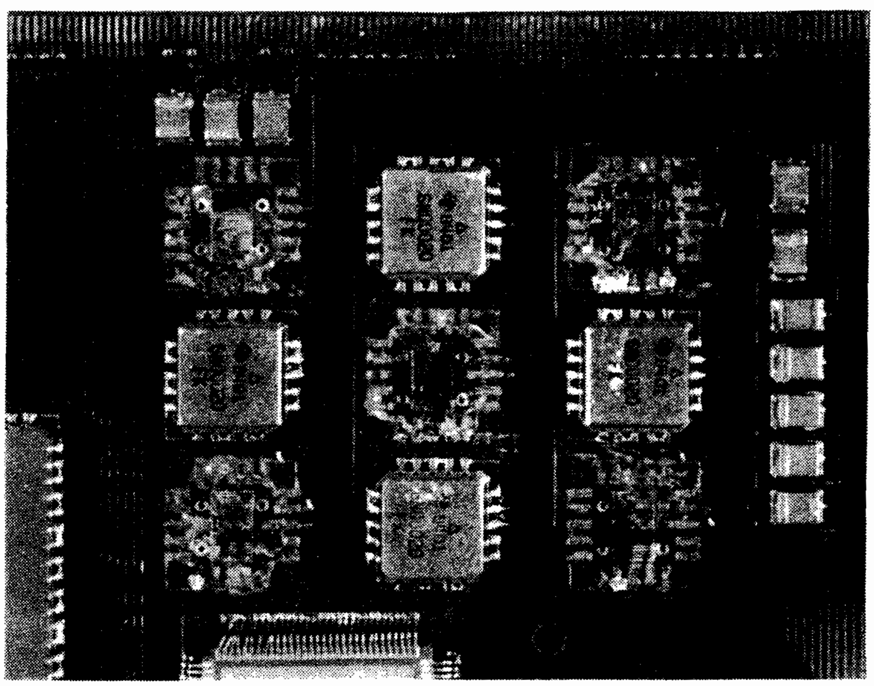


Photo A13



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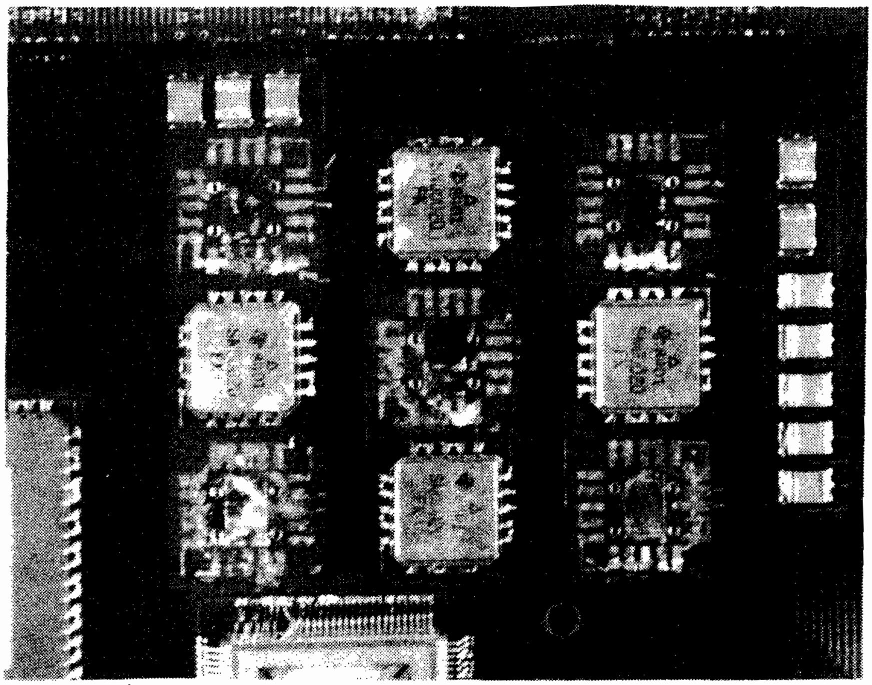
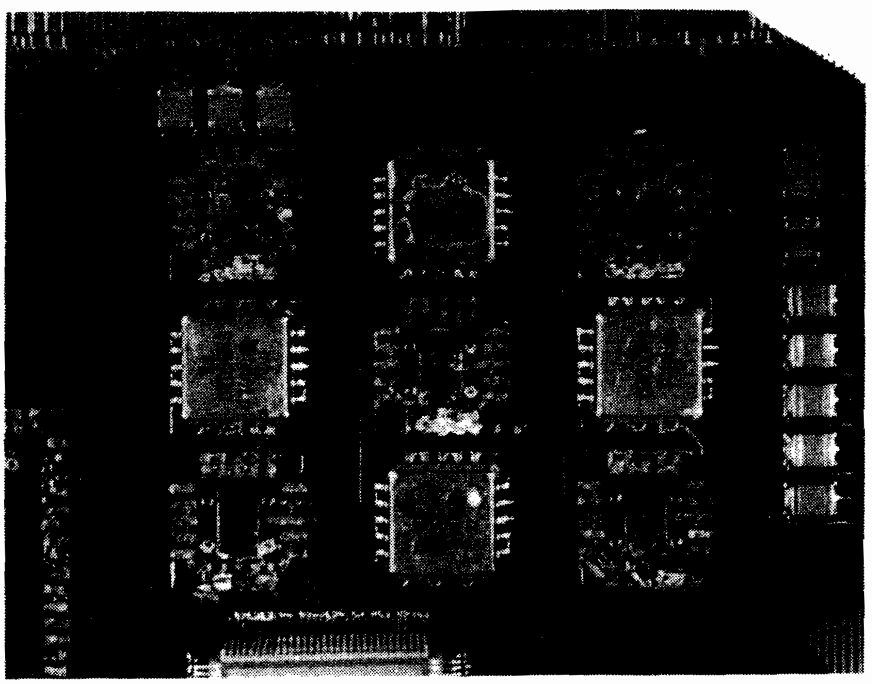


Photo A15



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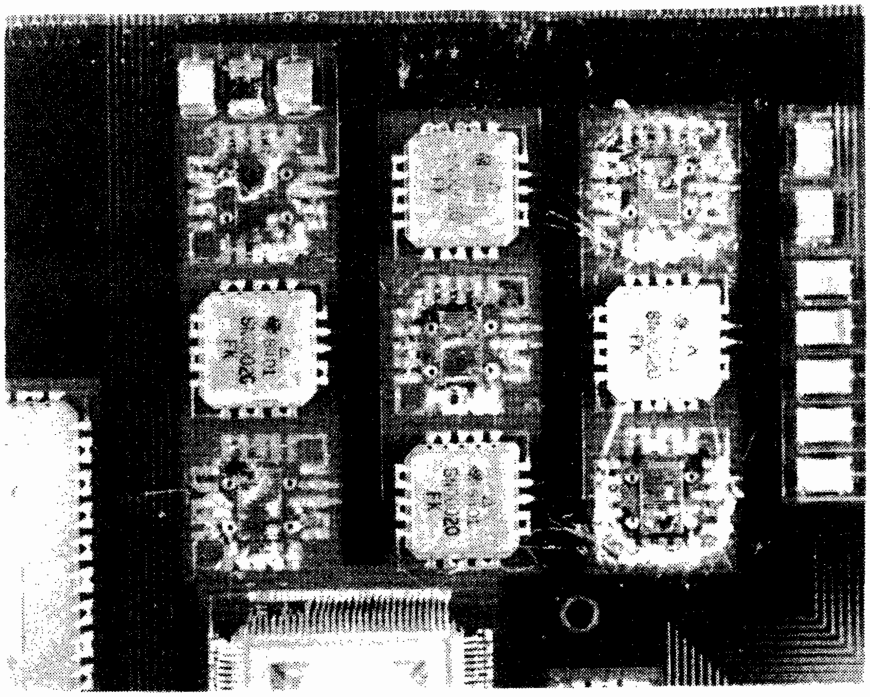

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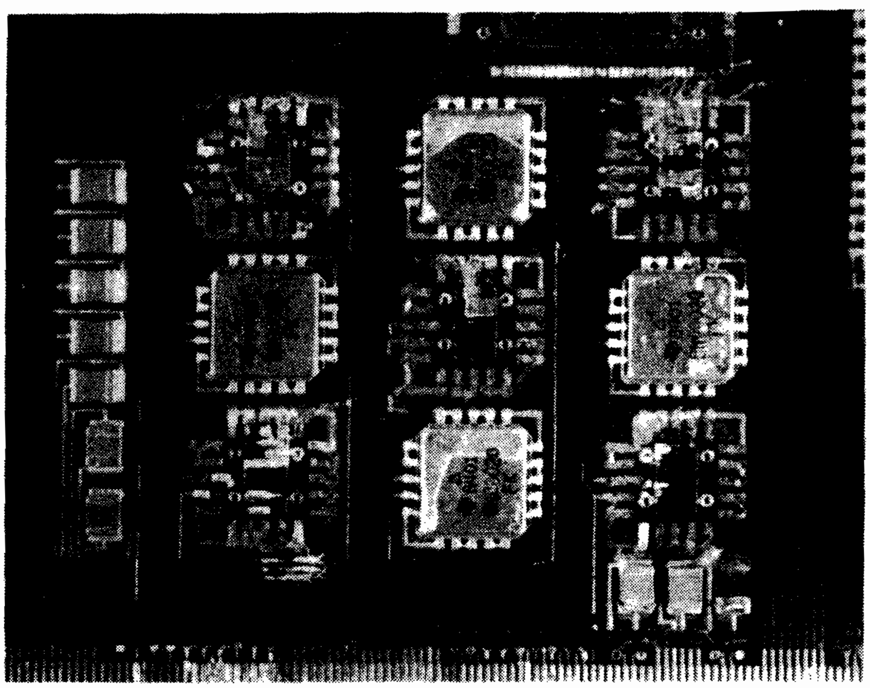

Photo A18