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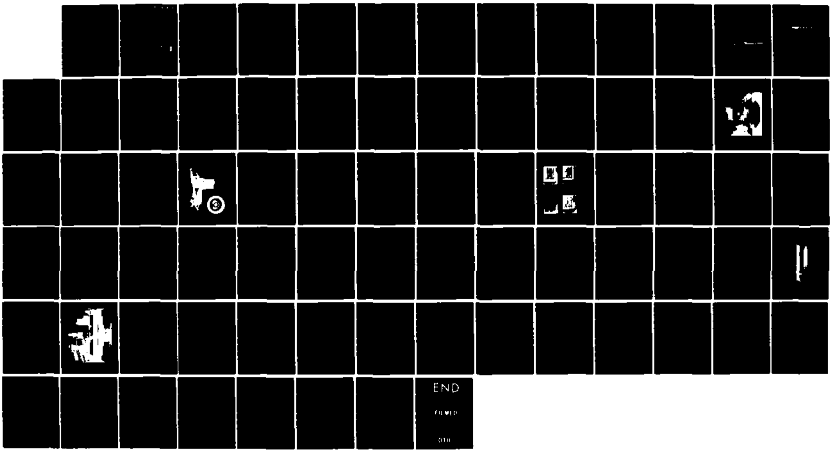

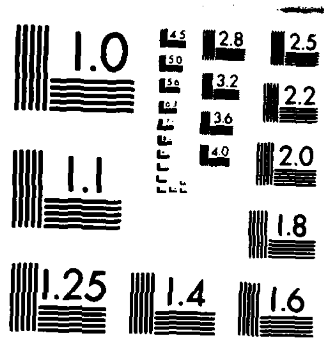

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SYSTEM DEVELOPMENT REPORT FOR AUTOMATED POLYMER DIE ATTACH MACHINE

HUGHES AIRCRAFT COMPANY
TUCSON MANUFACTURING DIVISION

HUGHES
HUGHES AIRCRAFT COMPANY

Prepared for:
U.S. ARMY MISSILE COMMAND
System Engineering Directorate
ATTN: DRSMI - RST
Redstone Arsenal, AL 35898

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The report which follows includes a detailed systems analysis and preliminary video and mechanical designs of an automated polymer die attach machine.

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Report DAAH01-81-D-A002

AUTOMATED POLYMER DIE ATTACH MACHINE

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18 December 1981

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Final Report

Prepared for:

U. S. Army Missile Command
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AUTOMATED POLYMER DIE ATTACH MACHINE

ABSTRACT

The current trend throughout the Military Hybrid Industry is the reduction of operator controlled variables in an effort to reduce cost while maintaining or increasing equipment volume handling capability. An important area in which this can be accomplished is in the chip to substrate assembly operation. Existing equipment is designed for operator recognition and orientation alignment of individual semiconductor chip topographies. The purpose of this manufacturing technology program has been to develop a semi-automatic chip recognition die bonding system. The system developed by this task presents a video image of the die to be placed on a TV Monitor. This image is overlayed with an outline image of the die to show correct orientation. The operator then aligns this overlayed image to the real die. At this point, the machine picks up, orients, and places the die in correct orientation on the substrate without operator control.

The system development activity specified in this task has been accomplished by Kulicke and Soffa Industries, Inc. with technical guidance provided by Hughes Aircraft. This report integrates that activity and is offered in three sections: Section I - Systems Analysis; Section II - Mechanical Design; and, Section III - Video Augmentation Design. Originator supplied keywords include:

The final design activity which is specified in Task 0003 of Army Contract #DAAH01-81-D-A002 is included in a separate volume entitled, "Final Design Report for Automated Polymer Die Attach Machine." This report, also developed by Kulicke and Soffa Industries, Inc., when added to this report completes the analysis and design work performed for the machine under this contract.

-A-

SECTION I

SYSTEMS ANALYSIS

HYBRID DIE BONDER SYSTEM ANALYSIS

Table of Contents

List of Figures

I INTRODUCTION

This systems analysis is the first deliverable item on Hughes purchase order 6-932254-C-W4 for the design of a hybrid die bonder system. Herein we describe our analysis of two basic approaches for the design of a semi automatic hybrid die bonder to be universally applicable in the microelectronics industry for both commercial and defense hybrid circuits. This design approach, and a system specification will then be used in pursuit of the final system design to be delivered under PO 6-932253-C-W4.

II SYSTEM DESCRIPTION - GENERAL

The hybrid die bonder will be an integrated computer based system for the semiautomatic assembly of hybrid circuits. It will be capable of assembling all dies correctly oriented on a single substrate, and then automatically exchange substrates. Semiconductor die will be picked up from standard waffle packs without any prearrangement of the die in the packs. Monoblock capacitors and resistors will be individually fed from the feeding devices. As many as 25 different semiconductor devices must be handled, and ten (10) different passive component feeders must be provided.

With this broad definition in mind, considerable discussions have been held with a variety of potential users, both commercial and military, to ascertain specific requirements that would be placed on a die bonder system so as to maximize its applicability. The most desirable needs are as follows:

(a) Flexibility in assembling a wide variety of circuits in both short and long production runs.

(b) Ability to assemble circuits having from several to in excess of 200 components.

(c) Semiautomatic with operator assistance in die orientation and substrate alignment (later to become fully automatic).

(d) Utilize a minimum of floor space.

(e) Contain friendly computer assisted setup routines for ease of operator programming.

(f) Be capable of interfacing with emerging CAD/CAM circuit development programs so as to interact and transfer information to/from a host computer data bank.

In analyzing a die bonding system to meet these needs, the following elements will be required:

(a) Substrate feeder system.

(b) Component placement system.

(c) Component feeders.

(d) Video system.

(e) Operator controls.

The Substrate Feeder System must be designed to accommodate a variety of substrate sizes and be easily adjustable. In order to provide automatic operation, provisions must be made for storing a sufficient number of substrates, both at the input and output, so as to permit unattended operation for at least one hour. To assure accurate location of the substrate at the bond site, the transfer system must provide smooth repeatable positioning in conjunction with a positive hold down technique.

The Component Placement System must be able to accurately place die and inactive components on the correct substrate pads after being picked up from feeders or waffle packs. A repeatable placement accuracy of $\pm$ .002 inch XY and $\pm 2^{o}$ rotational is required in placing components on the substrate. The work volume for the placement system will depend upon the number of feeders and waffle packs, and will greatly influence operating speed and placement accuracy.

The Component Feeders are required for feeding passive components to a fixed repeatable position for the Component Placement System.

The Video System is extremely important in the success of the system since it will be used to provide operator prompting and assistance for determining component alignment and orientation, and substrate alignment. Correct orientation of die in waffle packs is a serious problem because of the extreme variation in waffle pack compartment size vs die size. This can vary by as much as 30-50%. Additionally, the operator must be able to verify that the correct die corner is present, and that it is not upside down.

The Operator Controls must be simple and easy for the operator to use. Inherently, the system will be quite complex with several subsystems operating simultaneously. However, the operator must be able to interface with "friendly" controls that prompt as they go through setup and operational modes.

Operationally, the system should function as follows:

A substrate is automatically fed by the workholder from a magazine to the bond site and clamped into position. The operator establishes the position of the substrate by aligning it to the crosshairs on a CCTV monitor. Then, following pretaught instructions, the computer directs the component placement system to the location of the first component to be placed. If this component is an integrated circuit chip, the operator, by observing the chip on the monitor, determines its misalignment. An overlay of the chip is also shown so the operator can determine the orientation. The chip is then picked up, rotated to its proper orientation and placed on the substrate. Chip capacitors or other components that are fed by feeders are picked and placed without operator attention. This cycle continues until the substrate has been completely bonded. The substrate is then fed into an output magazine and replaced by a new one, and the process continues. The computer records the number of components that have been placed, and will signal the operator via the monitor when a waffle pack needs to be replaced or feeder refilled. The monitor also displays other instructions and data to lead the operator through each job, and to set up the next one.

III SYSTEM SPECIFICATIONS

The following specifications were generated for a hybrid die bond system after discussions with a number of potential users. They are not intended to be absolutely firm at this time, but rather as design objectives to be pursued through initial system design.

1.1 PERFORMANCE

1.1.1 The system will accommodate the bonding of gold-backed and silicon semiconductors and passive devices to substrates in the following sizes:

DIMENSIONS	SEMICONDUCTOR	PASSIVE DEVICE
Length	.010" to .500"	.030" to .250"
Width	.010" to .500"	.030" to .250"
Thickness	.004" to .030"	.010" to .090"

1.1.2 The system will be capable of attaching up to forty different devices in a variable sequence, during a continuous programmable operation. Forty square waffle pack locations and ten feeders or equivalent will be provided.

1.1.3 The system will perform the operations below:

1.1.3.1 The system will pick up the device to be bonded from a waffle pack or feeder with track.

1.1.3.2 Following device search, the system will verify device presence. If there is no device present, the system will continue to the next cavity of feeders, and pick up another device of the same part number.

1.1.3.3 The system will be capable of determining if it did not pick up a device as programmed. The system will automatically recycle to the next cavity or feeder of the same part number to correct the error.

1.1.3.4 The system will align the device and attach either passive or active devices to the substrate by epoxy die bonding. The substrate will have had epoxy placed by a previous operation.

1.1.3.5 Following completion of bonding or positioning, the system will check for absence of the device in the placement tool. The system will stop and alert the operator if the device is still present in the tool. If the system halts because of failure to place a die, it will be capable of being reset to capture the missed operation without additional data input.

If the device is still present in the tool after bond, it will be capable of being reset to capture the missed "bond" operation without additional data input.

1.1.4 Bond quality will meet the requirements of MIL-STD-883.

1.1.5 Positioning of components will be within ± 0.002" of the programmed XY coordinates and within ± 2 degrees of the programmed orientation.

1.1.6 The system will be capable of selecting parts in any possible sequence from the forty waffle packs and ten part feeders.

1.1.7 The system will not damage the devices being attached to the substrates.

1.1.8 The system will not subject the entire substrate to temperatures in excess of 100° F.

1.1.9 The system will be capable of operation in either the semi-automatic mode or manual mode. The manual mode could be a manually triggered stepping sequence.

1.1.10 In the manual mode the machine will be capable of single step operating by an operator with the provisions for monitoring via a CRT display.

1.1.11 The system will provide all feedbacks, discrete event signals and/or other information required to operate or calibrate the machine in either the manual or semi-automatic mode. Periodic calibration will be required in order to assure correct system placement accuracy. This will be performed by the operator responding to a menu-driven procedure through the use of push buttons on the control panel.

1.1.12 The system will have a nominal die bonding rate of 3.5 seconds per component when operated in the semi-automatic mode.

3.7.2.17

1.1.13 The system will permit [redacted] changeover from the bonding of one hybrid type to another, [redacted]. This time assumes that the circuits have been previ[redacted]aught and are resident on floppy disk.

1.1.14 The system will have an emergency stop capability.

1.2 DESIGN AND CONSTRUCTION

1.2.1 The system will have an automatic die pickup tool changer with multiple stations available. This will enable the system to utilize different diameter pickup tools for large and small parts.

1.2.2 Pickup tools will incorporate provisions for controlled by-directional rotation to 180 degrees in conjunction with vision system for proper part location.

1.2.3 The substrate table will have provisions for part hold down.

1.2.4 Substrate magazines will be capable of being interchanged within several minutes.

1.2.5 The control panel will contain the controls and displays required for operation (both semiautomatic and manual modes), test, adjustment, calibration and monitoring of the machine.

1.2.6 Manual override features will be incorporated which will enable manual operation in the event of loss of semi-automatic control.

1.2.7 The system will not lose stored programs upon actuation of emergency stop or loss of power. Programs are stored on floppy disks which protect them against power interruptions.

1.2.8 The equipment will include a "floor standing" cabinet design with locked storage space as space permits. [redacted]. The video screen will be [redacted] level.

1.2.9 The system will be capable of using 2" x 2" flourowave type waffle packs that have different spacings between the cavities.

1.2.10 The system will include an automatic feed and unload system for substrates, having widths of 0.6"; 1.0"; 1.2"; 1.5"; 2.0"; 2.5"; 3.0"; 3.5"; 4.0". The longest substrate will be 4.0 inches, and all are rectangular.

2.0 GENERAL REQUIREMENTS

2.1 Good engineering grounding practices will be followed to avoid ground loop problems.

2.2 Modular construction will be employed to permit ease of maintenance, troubleshooting and repair.

2.3 The system will operate from the following primary electrical source and air as required:

208V a-c, 1 phase 50/60HZ
20 PSI of Air Maximum
Vacuum at 25mm of mercury

2.4 Materials, construction and workmanship will be commensurate with the intended usage of the equipment, and will be in accordance with recognized good commercial practice.

2.5 Suitable finishes, supplying adequate protection for an interior laboratory environment will be utilized. All finishes will conform to recognized good commercial practice. Exterior painted surfaces will be finished with epoxy enamel or equivalent.

3.0 PROGRAMMING CHARACTERISTICS

3.1 The system will be capable of interfacing data to/from an external host computer.

3.2 The system will be capable of being programmed manually as well as remotely from a host computer.

3.3 The system will include a floppy disc system for storage of user programs.

4.0 VIDEO SYSTEM

4.1 The system will permit the operator to view the device and manually correct for orientation and location variances.

4.2 The system will be capable of operating under varying illumination levels.

4.3 The system will be capable of accommodating and functioning with the various heights of components with respect to focus in any one waffle pack. Focus is manual by operator. (Ref: $\pm$ .005)

4.4 The waffle pack or other parts handlers will not be moved by operator or machine after the optical recognition system has recognized the device location and orientation.

4.5 A video screen will be provided to display the magnified image of what the system is actually seeing.

4.6 The system will be capable of a Z axis movement of the camera (programmable) to provide proper focus for different waffle packs.

IV ANALYSIS OF SYSTEMS

A hybrid die bonder is not unlike several other sophisticated assembly systems manufactured by K&S. All employ high speed, high repeatable servo controlled motions, computer based controls, and integrated vision systems. The K&S Model 6300 die bonder, for example, automatically transfers die from a wafer to lead frames, cerdips or chip carriers. All transfer motions are servo controlled, but the pickup and deposit positions are fixed. The significant difference in the hybrid bonder, therefore, is that both pickup and deposit positions are variable, and with 40 waffle packs, pickup positions can vary in excess of 3000.

It is therefore, necessary to evaluate different parts placement techniques and their influence on system cycle times, placement accurracies, floor space and system integration. The other major subsystems: workholder, component feeders, video systems and operator controls were considered to be important certainly, but not requiring significantly different designs from what is conventionally used in the industry.

Two basic systems were evaluated:

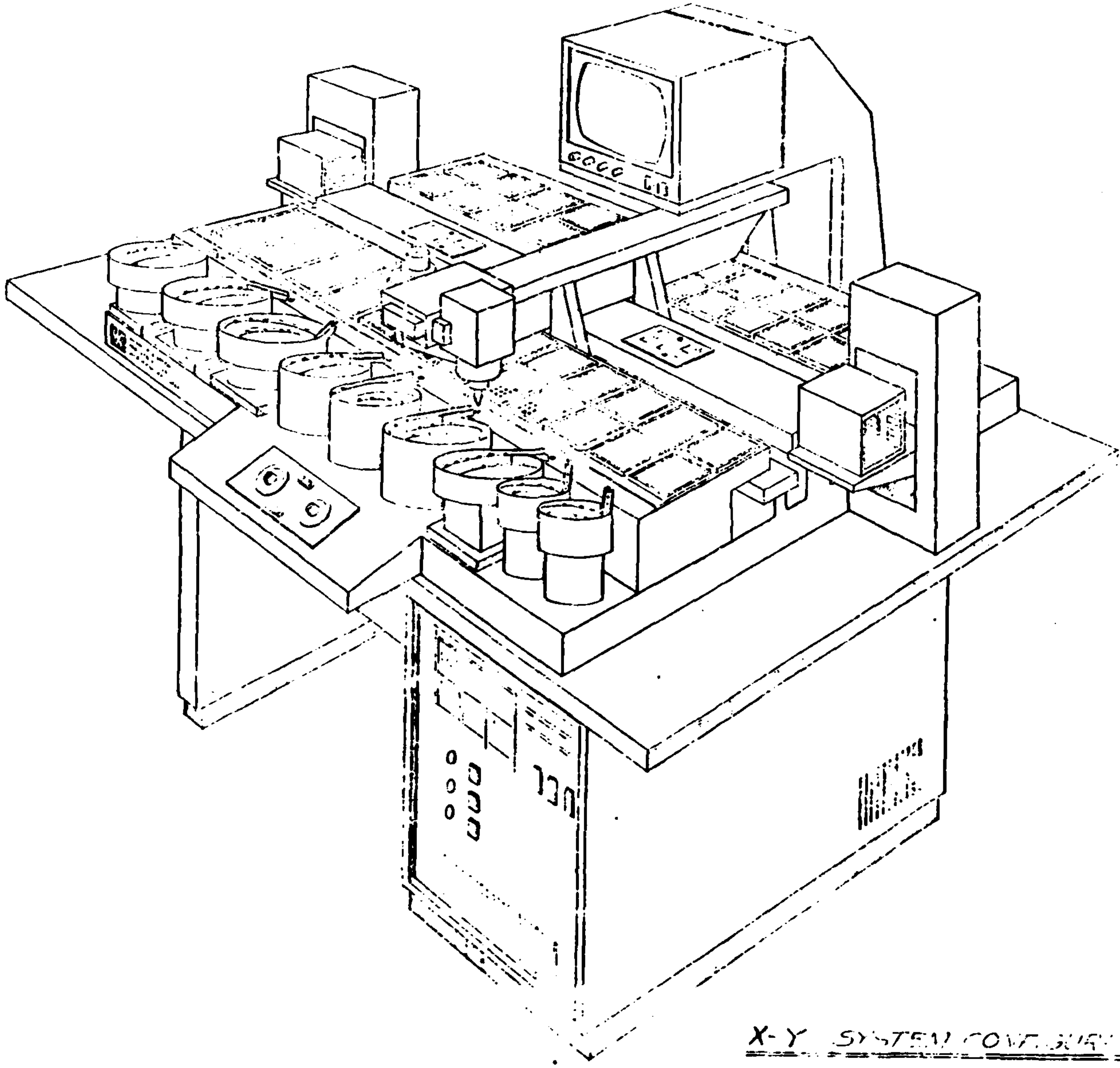
1. X-Y System - Waffle packs and component feeders are placed in a recti-linear array and the transfer mechanism moves in straight lines parallel to the axis of the array (X-Y). See Fig. 1

2. R-Ø System - Waffle packs and feeders are placed in a circular array around a cylindrical coordinate placement system. See Fig. 2.

The initial evaluation was to determine the maximum placement rate for the minimum mechanism speed. Both systems were set up to place die from 40 different waffle packs. Since die alignment time was common for both systems and a small vertical pickup motion would also be common, a standard time of 2.3 seconds was assigned for these actions. Therefore, significant axis of motion became X-Y for the X-Y system and R-Ø for the R-Ø system.

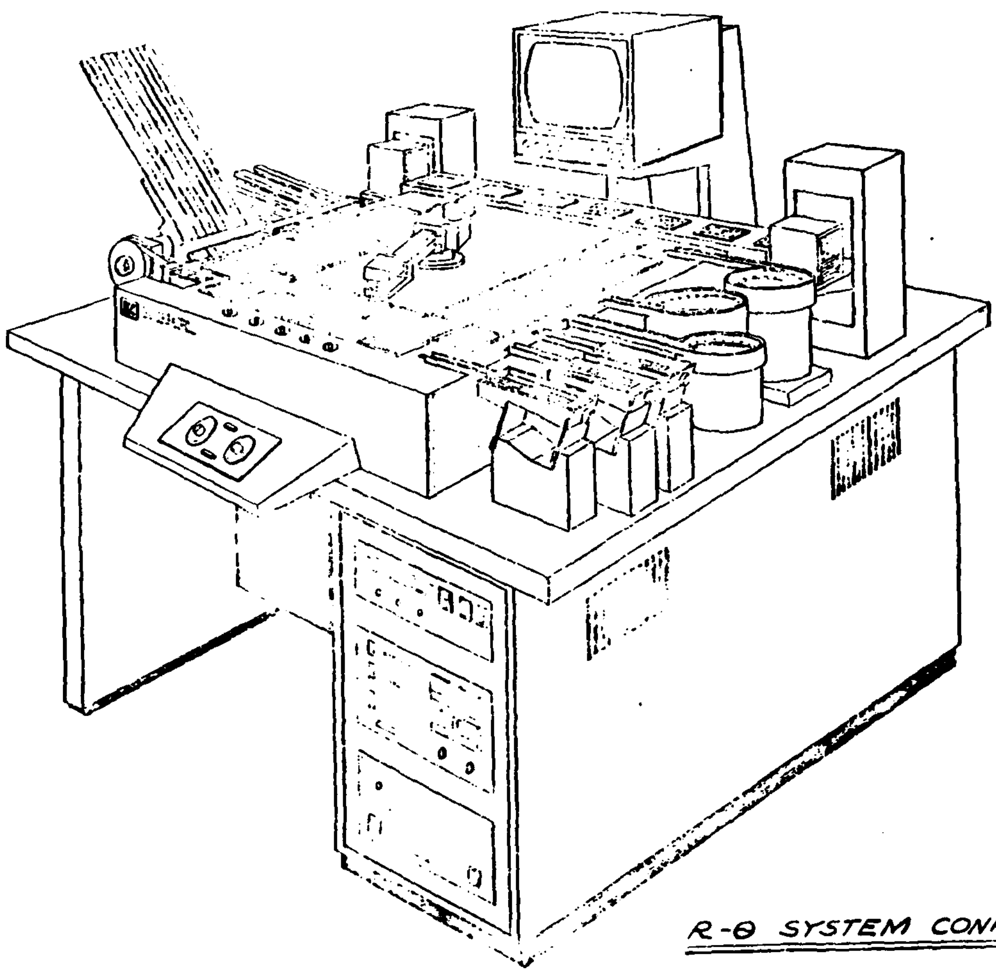
Figures 3, 4, 5 and 6 are graphs of die placement rates vs axis speeds for different configures systems. Figure 3 is for an X-Y system with a fixed bond site. Figure 4 is for an X-Y system with the bond site moving row for row along the waffle pack array so that placement becomes a single Y axis motion. Figure 5 is for an X-Y system with a moving bond site, but waffle pack arrays are split on both sides of the bond site. Figure 6 is for an R-Ø system.

Drive motion for highly precise linear axes having accuracies of $\pm$ 0.0005 inch is best suited to a ball screw technique. This technique is common in K&S and competitive wire bonders and other similar systems. A nominal top speed of 10 in/sec is considered to be optimal from a reliability point of view. Consequently, all placement rates in the figures should be evaluated up to 10 in/sec speed. For the R-Ø system a top rotational speed of 300°/sec is considered readily attainable and still assure high reliability.



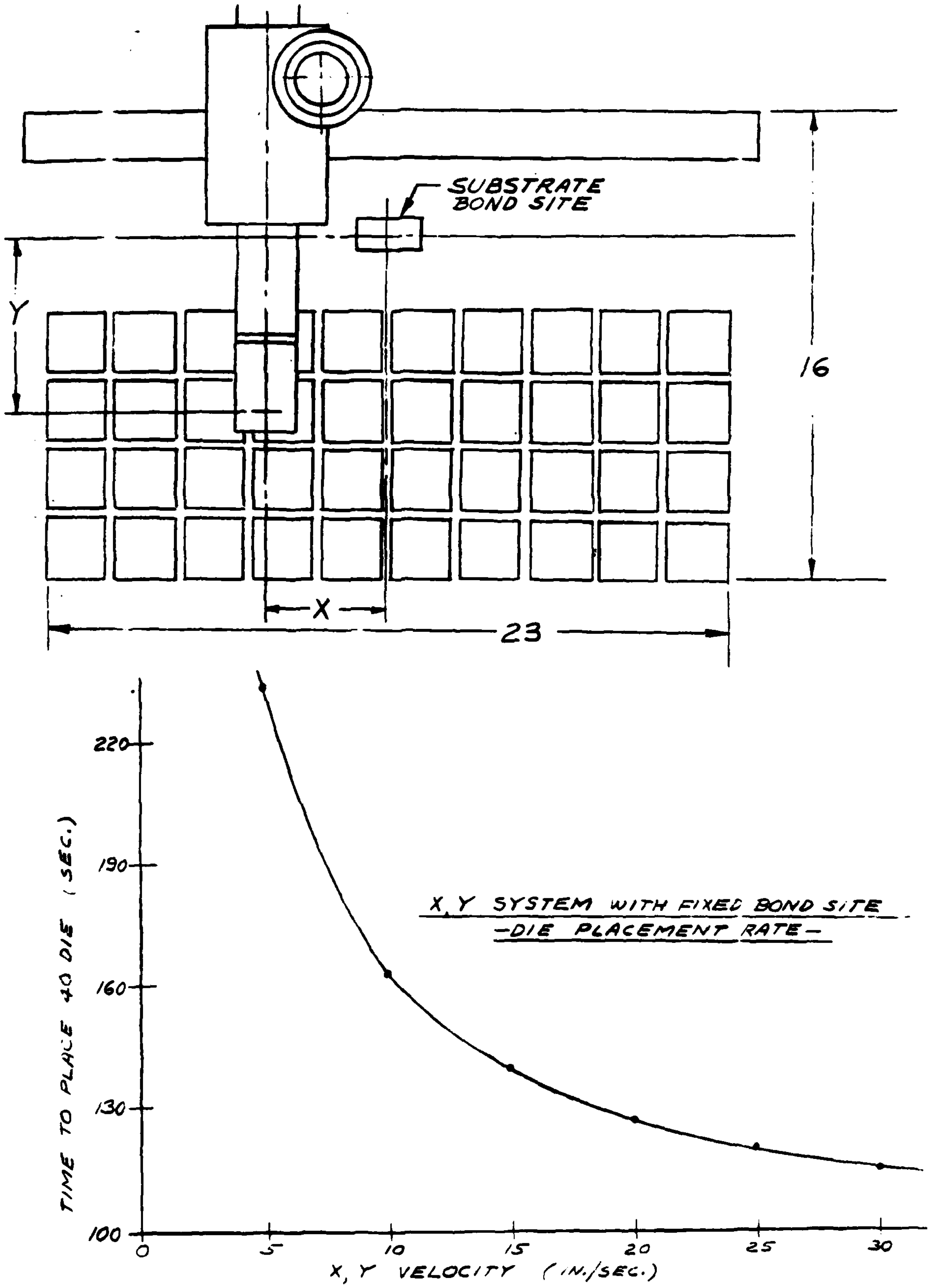
X-Y SYSTEM CONFIGURATION

FIG. 1



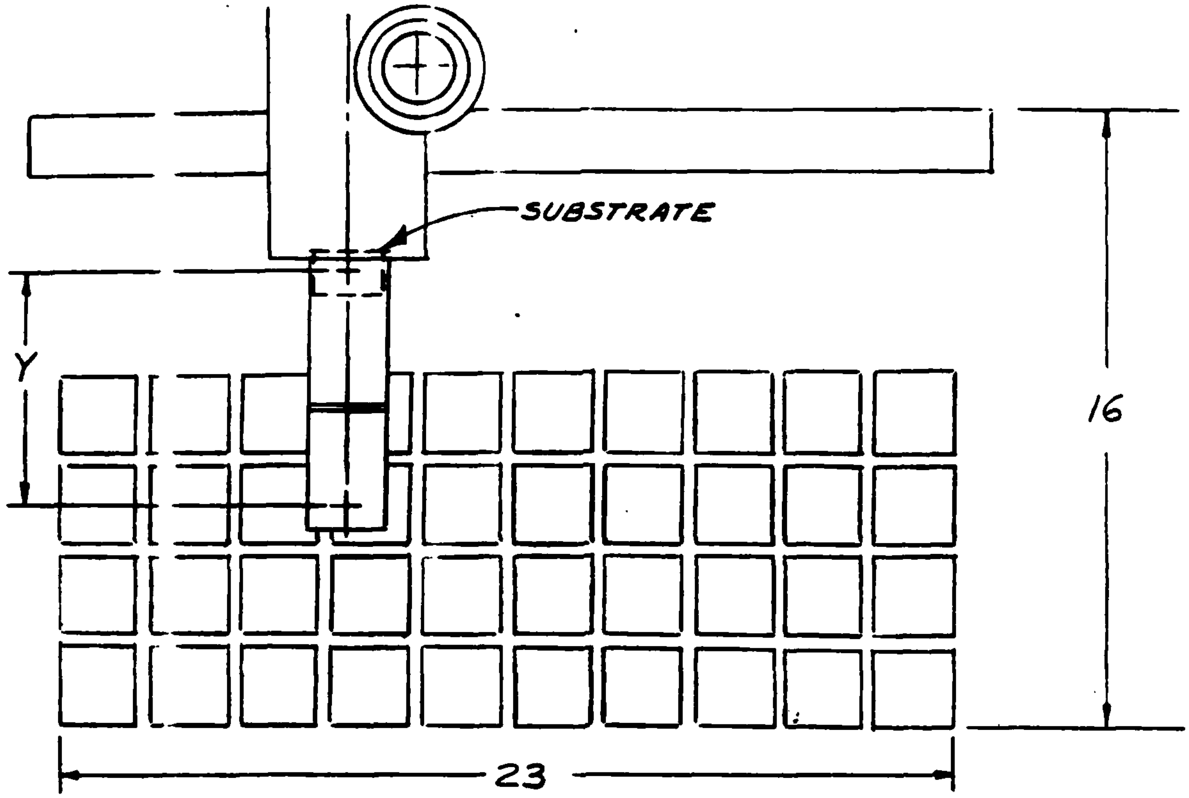
R-θ SYSTEM CONFIGURATION

FIG. 2



SUBSTRATE BOND SITE
Y
16
X
23
220
190
160
130
100
TIME TO PLACE 40 DIE (SEC.)
X, Y SYSTEM WITH FIXED BOND SITE
-DIE PLACEMENT RATE-
0
5
10
15
20
25
30
X, Y VELOCITY (IN./SEC.)

FIG. 3


SUBSTRATE
Y
16
23

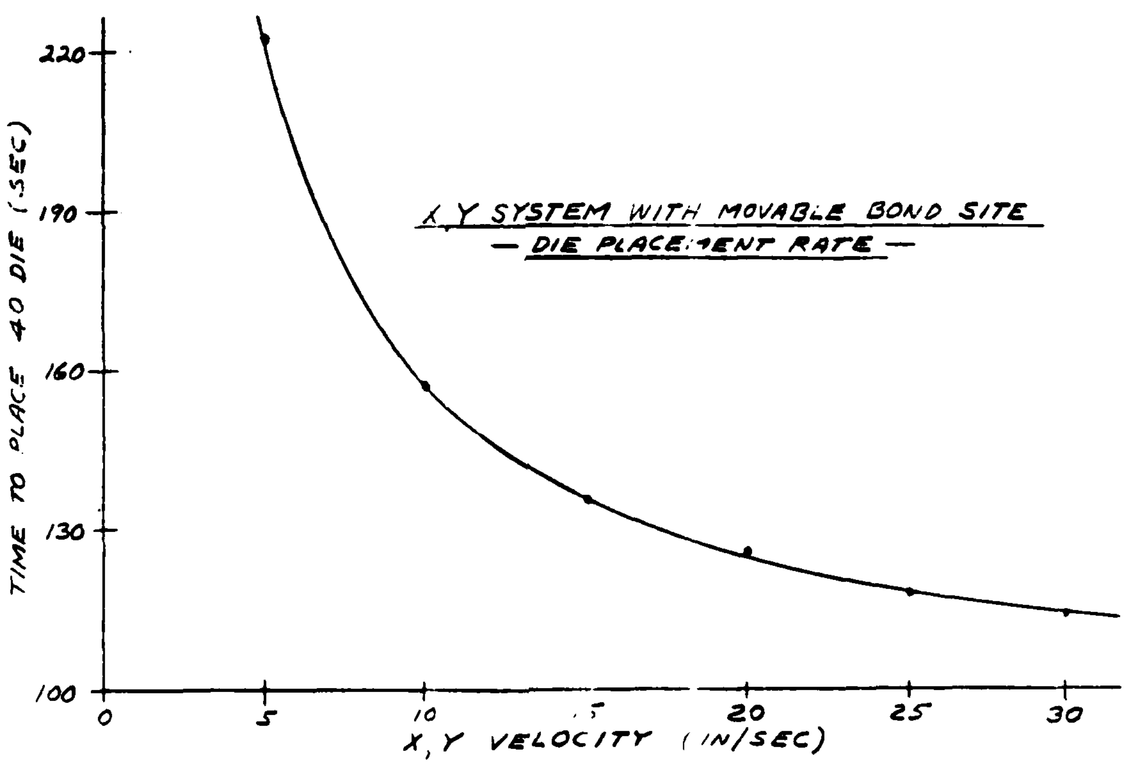

X,Y SYSTEM WITH MOVABLE BOND SITE
— DIE PLACEMENT RATE —
TIME TO PLACE 40 DIE (SEC)
220
190
160
130
100
0
5
10
20
25
30
X,Y VELOCITY (IN/SEC)

FIG. 4

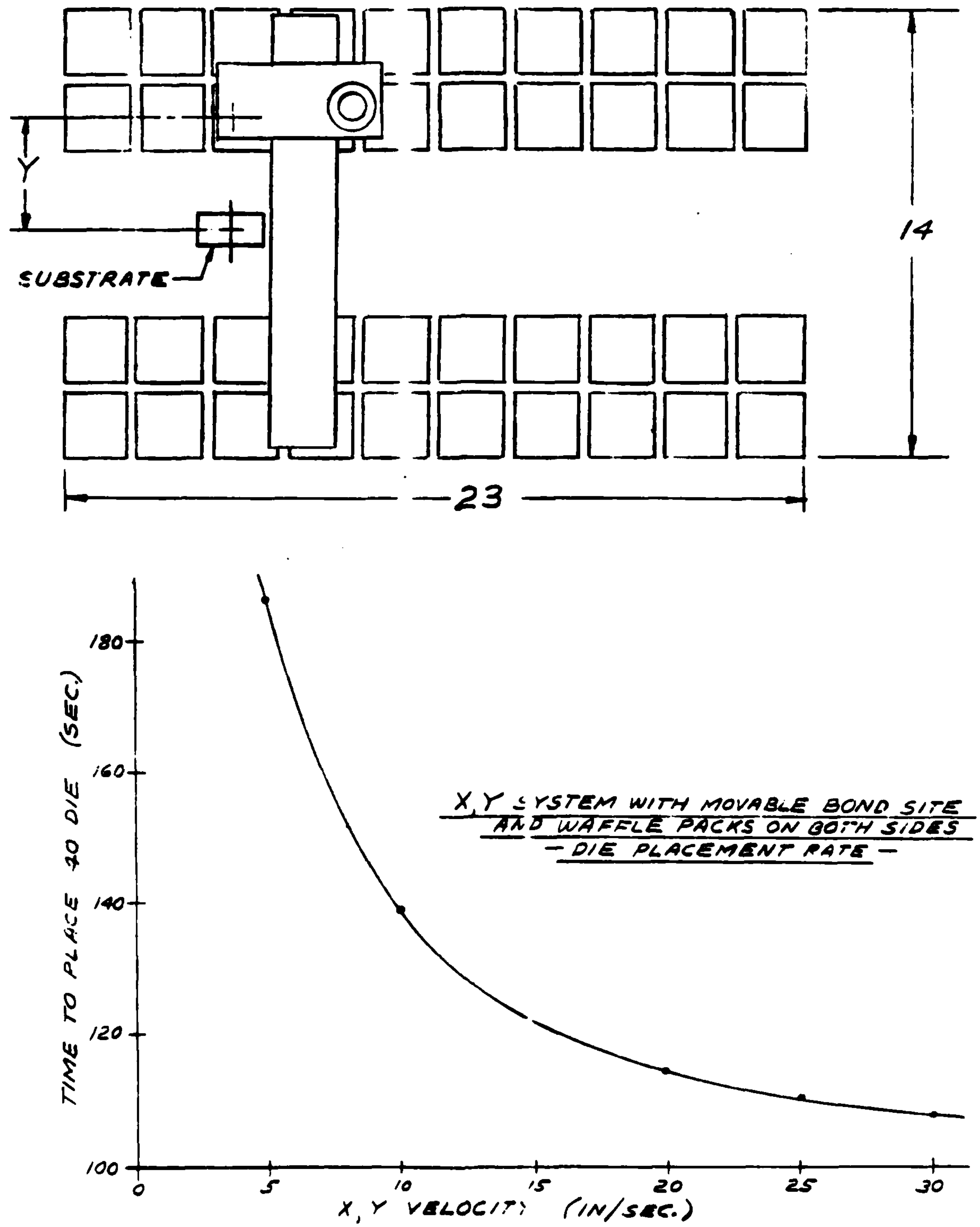

Y
SUBSTRATE
14
23
X,Y SYSTEM WITH MOVABLE BOND SITE
AND WAFFLE PACKS ON BOTH SIDES
— DIE PLACEMENT RATE —
TIME TO PLACE 40 DIE (SEC.)
180
160
140
120
100
0
5
10
15
20
25
30
X, Y VELOCITY (IN/SEC.)

FIG. 5

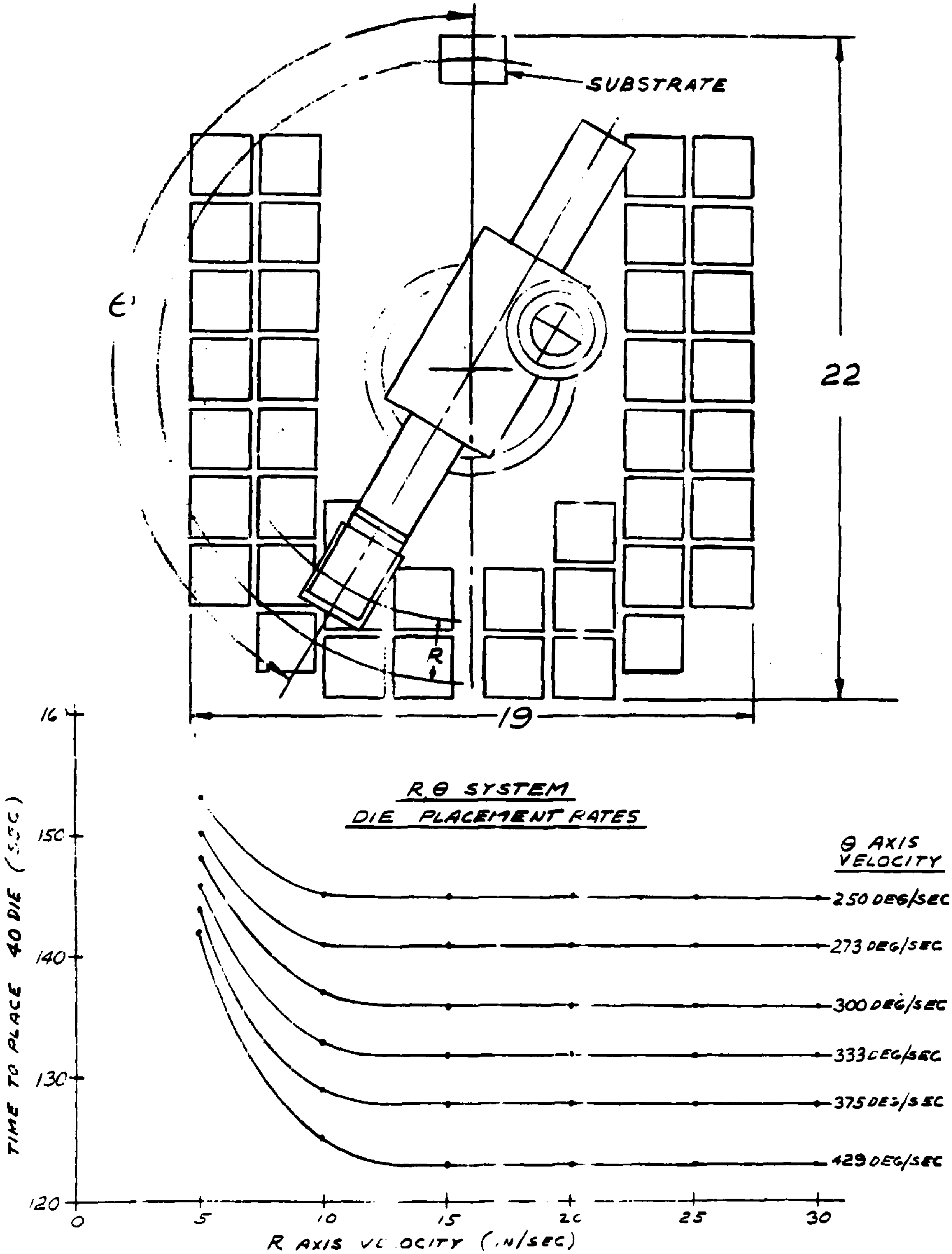

SUBSTRATE
22
19
R
θ
R,θ SYSTEM
DIE PLACEMENT RATES
θ AXIS VELOCITY
250 DEG/SEC
273 DEG/SEC
300 DEG/SEC
333 DEG/SEC
375 DEG/SEC
429 DEG/SEC
TIME TO PLACE 40 DIE (SEC)
R AXIS VELOCITY (IN/SEC)
120
130
140
150
0
5
10
15
25
30

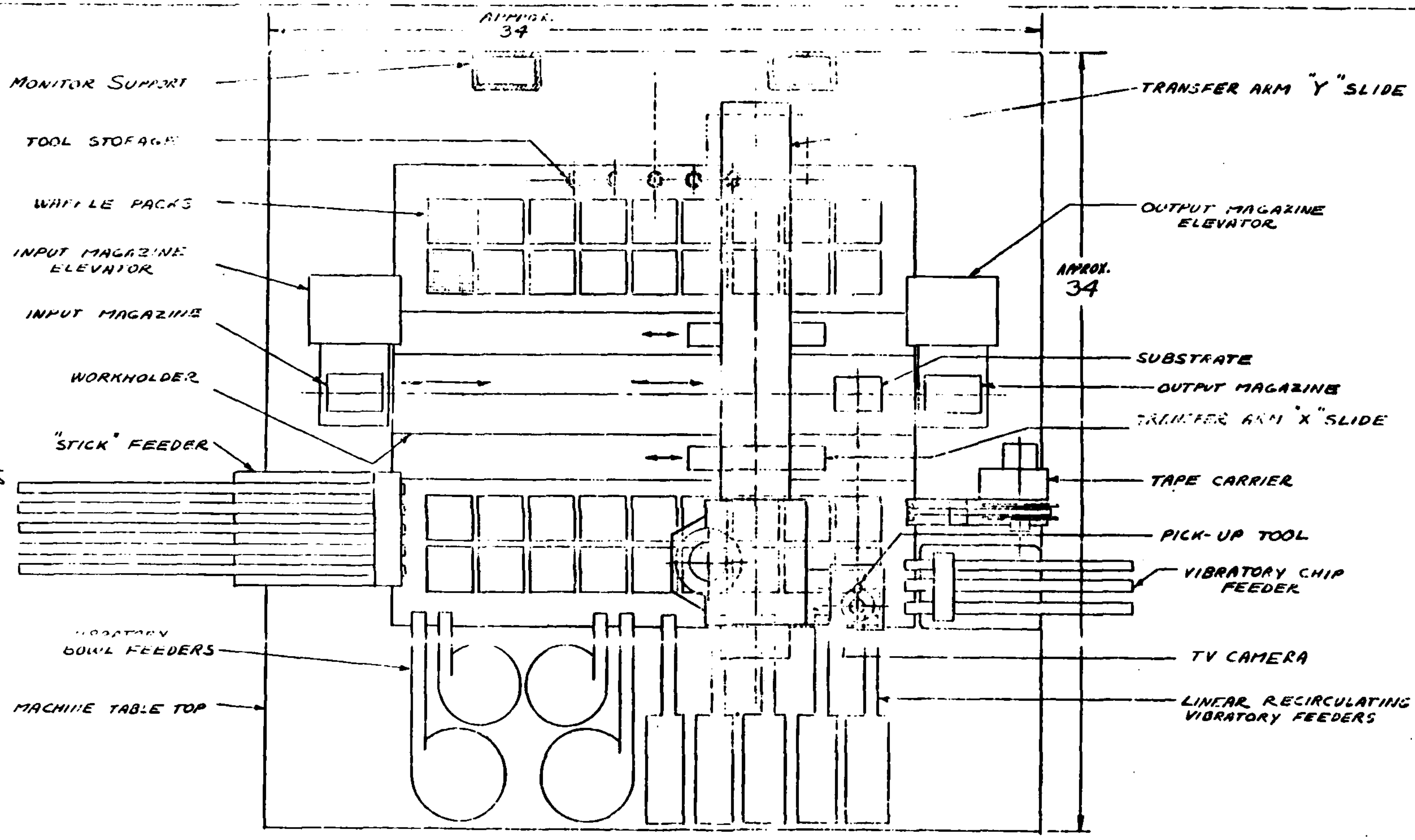
FIG. 6

As can be seen, the R-Ø system shows a faster placement rate.

A further analysis of system size is shown in figures 7 and 8, where the R-Ø concept again shows better utilization of space. It also permits closer interfacing by the operator, and more flexibility in rearranging for changes in the number and sizes of feeders.

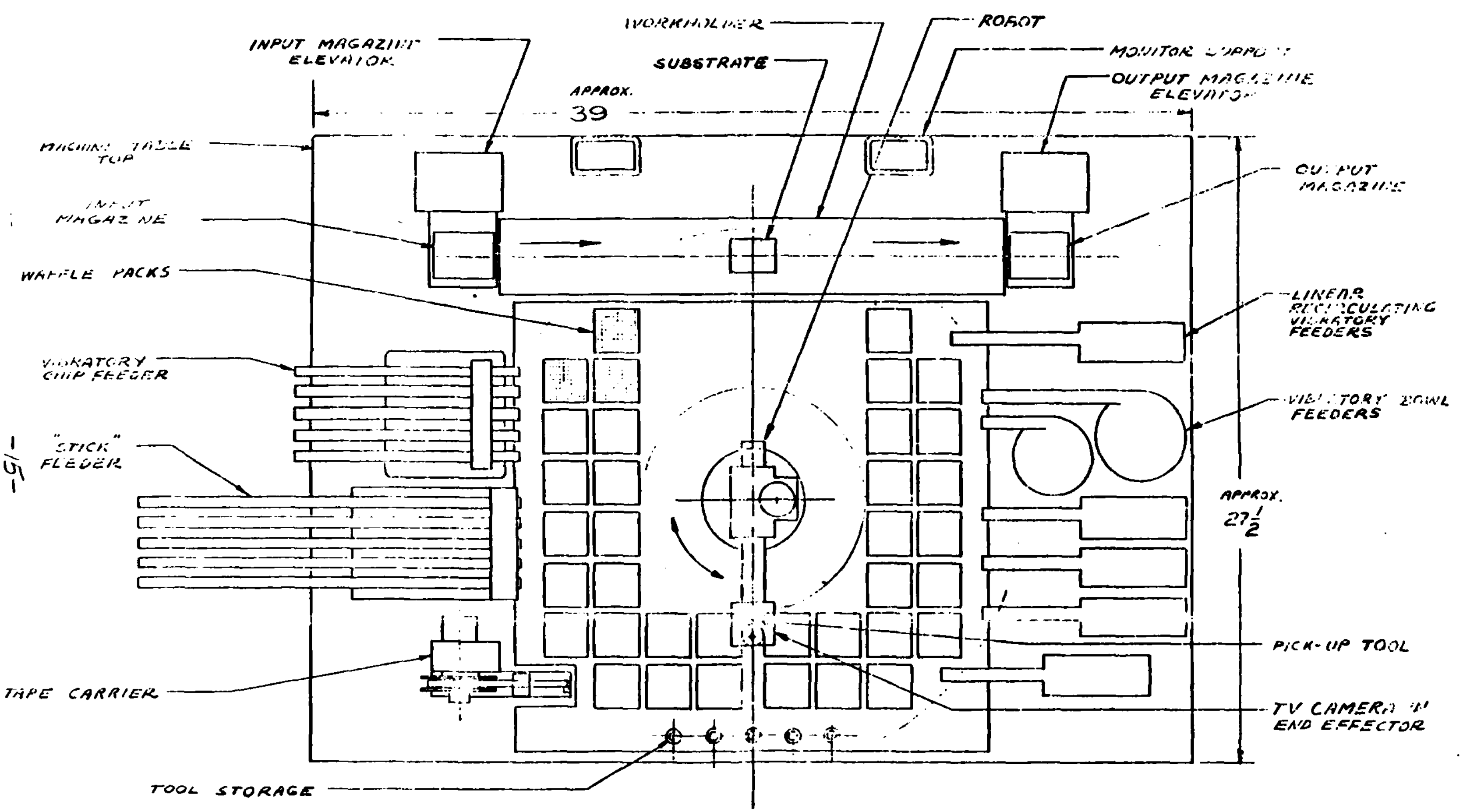
Both types of placement systems are familiar to K&S since the X-Y design is inherent in many K&S products, and the R-Ø is inherent in the K&S proprietary small parts assembly robot (SPAR).

It is, therefore, our conclusion that, for the reasons given, the R-Ø system is best suited to the die bonder application. A further positive factor is cost. The SPAR robot is intended to be a general purpose, but highly flexible piece of automation for which there is an enormous potential market. In such high production, the cost can be kept quite low for the amount of technology derived. Additionally, the SPAR control system is designed with a high level of software to make it readily adaptable to specialized assembly applications such as a hybrid die bonder.



X-Y SYSTEM - PLAN VIEW

FIG. 7



R-Θ SYSTEM - PLAN VIEW

FIG 8

V SYSTEM DEFINITION

The selection of a small parts assembly robot (SPAR) as the parts placement mechanism permits a logical arrangement of parts around the periphery of the SPAR base and the substrates transferring through the SPAR's sphere of operation from left-to-right. This is considered to be a typical batch assembly arrangment whereby the operator can interface closely to monitor, setup or manually control the system.

This SPAR based system is shown in Figure 9. It is a photograph of a model prepared to evaluate parts locations, human engineering interfaces and general equipment layout. Figure 8 is a top view drawing of the system. Specific system features are as follows:

A. Transfer Arm: The central mechanism of the hybrid bonder is the transfer arm. It carries a component pickup tool and CCTV camera, and is able to position them anywhere within its 12-inch maximum, five-inch minimum reach. The principal axis of motion are driven by DC servo motors, coupled to high accuracy position encoders. Location accuracy will be ±.002 inch or better. Component pickup is accomplished by a plastic or rubber vacuum pickup tool. The tool moves vertically under servo motor control, and its actual stopping height and bond force are programmable. It also rotates about its own vertical axis. This rotation is controlled by the computer through a servo motor and permits a component to be rotated after pickup and placed in any orientation on the substrate.

B. CCTV System: A key element in the system is the CCTV camera and monitor. The camera is a very small, solid state matrix array device mounted along side the pickup tool on the end of the robot arm. Like the tool, the camera rotates about its vertical axes and moves vertically to keep components of different thickness in proper focus. The magnification of the camera lens is such that the image on the monitor is large enough to allow the operator to identify die detail and to determine die orientation before pickup. Integral in the camera assembly will be an illumination system.

C. Operator Controls: During normal operation and setup, it will be necessary for the operator to control the position of the pickup tool and TV camera. This is accomplished by a control system that consists of two knobs mounted on a panel which itself rotates about a center that is mounted on a potentiometer. The knobs allow the operator to move the pickup head in R and Ø. Rotating the entire panel moves the potentiometer, which controls the rate of rotation of the pickup tool and TV camera. A pushbutton switch converts one arm-control knob into a control for the vertical height of the tool and camera. Therefore, the operator can place the pickup tool or camera in any position and in any orientation within the reach of the arm. Similar switching allows the same panel to control the position and motion of the workholder.

D. Waffle Packs and Component Feeders: The waffle packs are mounted on trays that slide out from beneath the arm cover so that the operator can easily replace them. Provisions will be made for the storage of covers adjacent to their respective waffle pack so that they do not get mixed. Component Feeders will be investigated to select the best method for each component type. Vibratory bowl and linear feeders as well as stick and tape feeders will be evaluated.

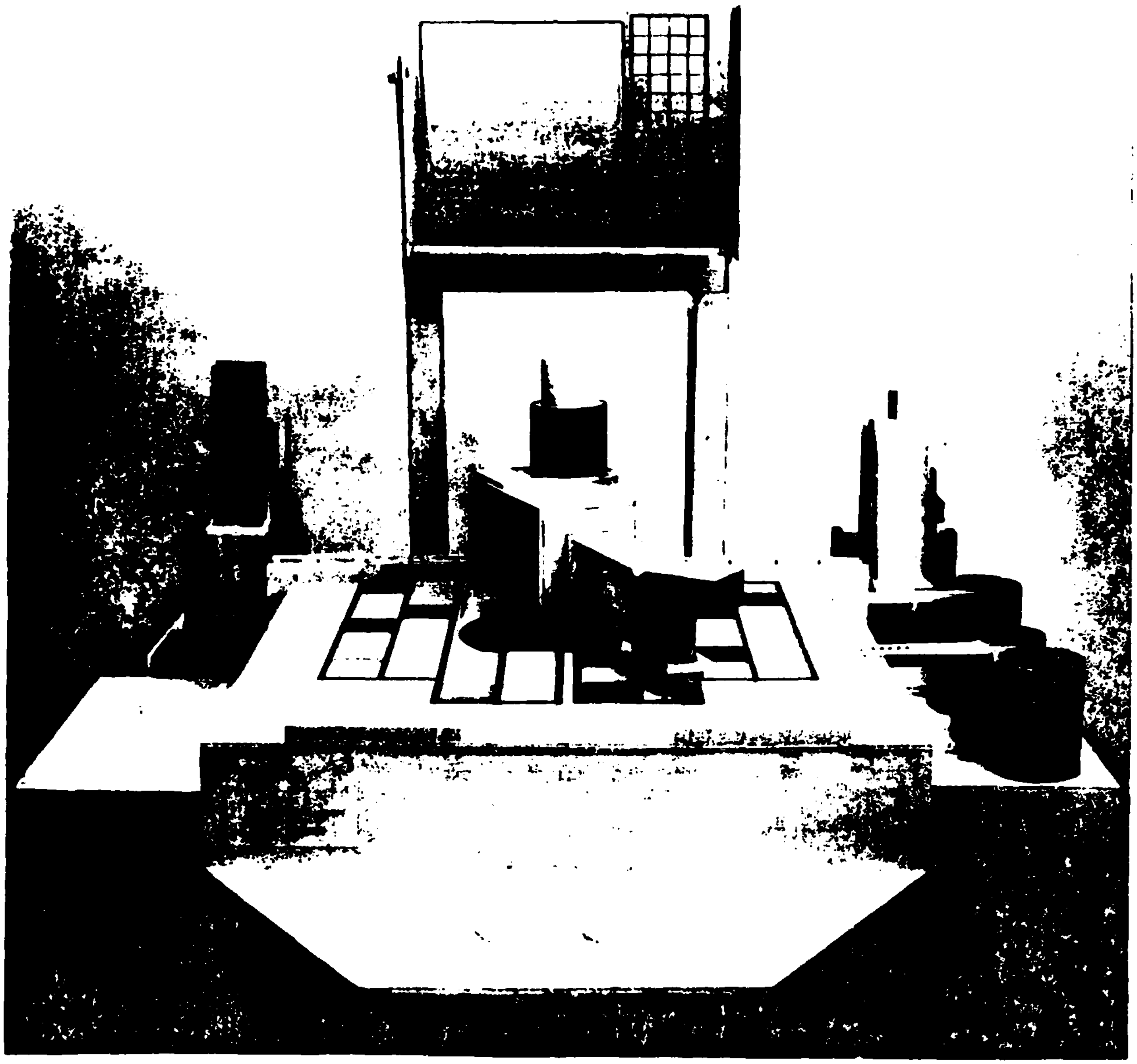


Figure 9. Photogragh of Spar Based System Mockup

E. Substrate Workholders and Magazine Feeder: This unit is similar to the workholder and feeders currently in production at K&S. (Substrates are held in multilevel magazines that permit automatic, reliable feeding and minimize operator handling) from die bond through cure and wire bond. (Substrates are vacuum-clamped at the bond site. The mechanism design allows for a quick changeover from one substrate size to another.)

Operationally, the program that sequences the various subsystems to perform the hybrid assembly operation will be contained in the SPAR control module. A special "User Application" software package will tie the various subsystems together with the SPAR system and provide the specialized operator control interfaces for teach and operational modes.

In the Teach mode, the operator will teach all pickup positions for die and passive components. This is accomplished by positioning the SPAR pickup tool over the center line of each component feeder by activating various SPAR axes. (Rotate, horizontal, vertical, tool rotate, etc.) Once each position is reached, the operator presses a RECORD switch which dumps the position data into the system memory. For waffle packs, a special palletizing routine will be used to minimize the amount of operator teaching. The operator actuates the palletize teach mode which positions the TV camera for verification of waffle pack location. In addition, the operator inputs the number of cavities in the X and Y direction and the system automatically calculates the centerline and location of each cavity. This is done for each waffle pack. Note: A CAD/CAM interface will permit waffle pack cavity numbers to be down loaded (as well as up loaded) from a remote host computer via an ASCII coded serial line interface. Code format and protocol to be mutually determined.

Likewise, the pad locations are taught for the substrate. Note: A CAD/CAM interface will permit substrate pad location data to be downline loaded from a remote host computer via an ASCII coded serial line interface. Code format and protocol to be mutually determined.

The operator then ties the final operational program together by determining which order of component placement is desired. Once this data is stored in the computer, it is permanently stored on a floppy disc. Any future setup using a previously stored program will simply require verification of pad and pickup points by single stepping through the program. If the operator notes any offsets, they can be readily corrected at that time.

Once a program has been taught and verified, production can start on a semi-automatic basis. The operator interfaces only to align each substrate prior to bond, and to perform orientation for each die removed from waffle pack. A typical operational scenario is as follows:

(Assume that the last die on a substrate has just been bonded and the tool has just risen above the bond site.)

A. SUBSTRATE INDEX AND ALIGNMENT SEQUENCE

Host computer sends signal to workholder subsystem to advance a new substrate to bond site. If elevators are empty, operator is requested to replace input and output magazines. Workholder then indexes appropriately.

Tool on arm moves to a ready position near the substrate site.

Workholder subsystem sends signals to host that a new substrate is in place. As soon as new substrate is in place, the arm moves to the location or reference point #1 on the substrate.

Control panel is activated and operator enters correction to the reference point, if necessary. The arm then moves to reference point #2 and the operator may enter a correction if necessary.

B. BONDING SEQUENCE

1. Arm moves to cavity containing the next die to be bonded (die type previously taught. Waffle pack location and cavity location updated by robot computer.) Note: During arm movement, TV screen is blank to prevent watching a moving rotating image.

2. Host sends die type information to video subsystem.

3. Control panel is activated for alignment and die identification.

   (1) Operator positions TV camera until die appears parallel to crosshairs and in proper location.

   (2) Operator depresses "Begin Identification" sequence button.

   (3) Video subsystem overlays graphics for die requested on display.

   (4) If overlay matches die pattern, operator depresses "Overlay Match" switch -- go to step #7.

   (5) If overlay does not match, operator depresses one of four buttons to bring up different overlays -- go to step #3.

   (6) If no match could be found, operator presses "Abort Overlay" switch. Video sequence ceases; host is notified. Go to next die cavity and begin step #1.

   (7) Video subsystem sends quadrant information to host computer.

4. Tool moves down to pick up die; vacuum turns on; after sufficient delay, tool rises up.

5. Missing die detection checked. If die is not on tool, go to same die cavity using same coordinates of cavity for second attempted pickup and repeat.

6. Arm swings to deposit site.

7. If the missing die detector senses that the die has been dropped during transfer, but before the area near the substrate, go to waffle pack using same die type but a new cavity location.

8. If the missing die detector senses that the die has been dropped very close to or over the substrate, the following sequence occurs:

9. - arm moves away from substrate.

10. - operator is signaled that die may have been dropped on substrate and to remove the die.

11. - when operator's corrective action is accomplished, he signals robot computer.

12. - Computer goes to same waffle pack without updating die type (new cavity).

13. - die is bonded to substrate.

14. - if this was not last die on substrate, go to step #1.

15. - If this was last die on substrate, computer tabulates number of remaining chips in waffle packs to see if another substrate can be bonded. If enough, plus a safety remain, then repeat sequence.

Note: The same procedure is followed for placement of inactive components except that they will not require operator assistance for alignment.

C. <u>RELOADING OF WAFFLE PACKS AND FEEDERS</u>

Reload Sequence:

1. Control panel is activated and video display prompts operator actions.
2. Operator instructed to remove empty waffle packs.
3. When empty waffle packs have been removed, operator signals computer.
4. Computer displays location of waffle pack types so operator can correctly place new packs of like type on machine.
5. Operator signals computer when reloading is accomplished.
6. Operator then fills all feeders as required.
7. When finished, computer requests a Continue from operator.
8. When signal is received, go to step A.

VI MECHANICAL DESIGN

The hybrid die bonder system is designed to be run by an operator seated at the control panel on the front of the machine. Additional controls may be located alongside the TV monitor, but within easy reach of the operator.

Robot System

The robot mechanism consists of a flanged base that contains a servo motor, precision zero backlash gear box and position encoder to control the Ø or rotational axes of the robot arm. Mounted to the top of this base is the horizontal arm. The arm is supported by linear motion bearings and is driven by a servo motor through a zero backlash rack and pinion gear system. This drive also contains a precision rotary position encoder.

At the end of the horizontal arm is the vacuum pickup tool and TV camera assembly. The pickup tool consists of a removable tip that is held in place by an electro magnet. Turning off the electro magnet releases the tool and allows a new one to be picked up. The tool tip is a flexible rubber or urethane material which will conform to slightly irregular surfaces and not more delicate surfaces on ICs. The entire tool assembly rotates about its vertical axis to place components in any orientation on the substrate. In addition to vacuum to pick up components a short burst of positive pressure is applied to the tool to assure that tiny components have been released by the tool on placement. This "puff off" air as well as the vacuum are controlled by solenoid valves mounted at the end of the arm.

The TV camera consists of a fixed lens tube and a rotating camera assembly. See figure 10. The end of the lens tube is surrounded by an array of small, high intensity lights that can be switched on and off in any combination to create the best possible lighting conditions for the camera. The camera rotates about its vertical axis and is driven by the same motor as the pickup tool. A drive shaft through the arm will transfer the power from the motor to the driven components. In similar fashion, a motor will drive the TV camera pickup tool assembly in the vertical direction. This vertical motion will keep the TV camera in focus on different height components and raise and lower the pickup tool to pick and place components. In general, these assemblies will be made from light weight aluminum with hardened steel ball bearing ways for sliding components.

The robot is mounted on its flanged base to the system table top. The robot base is covered by the structure that supports the waffle pack trays. These trays are mounted on precision slides so that the waffle packs easily slide out from under the robot arm safety cover. The trays detent-lock into their normal home position to assure repeatable location. The table top also supports the various component feeders and the substrate workholder and magazine elevators.

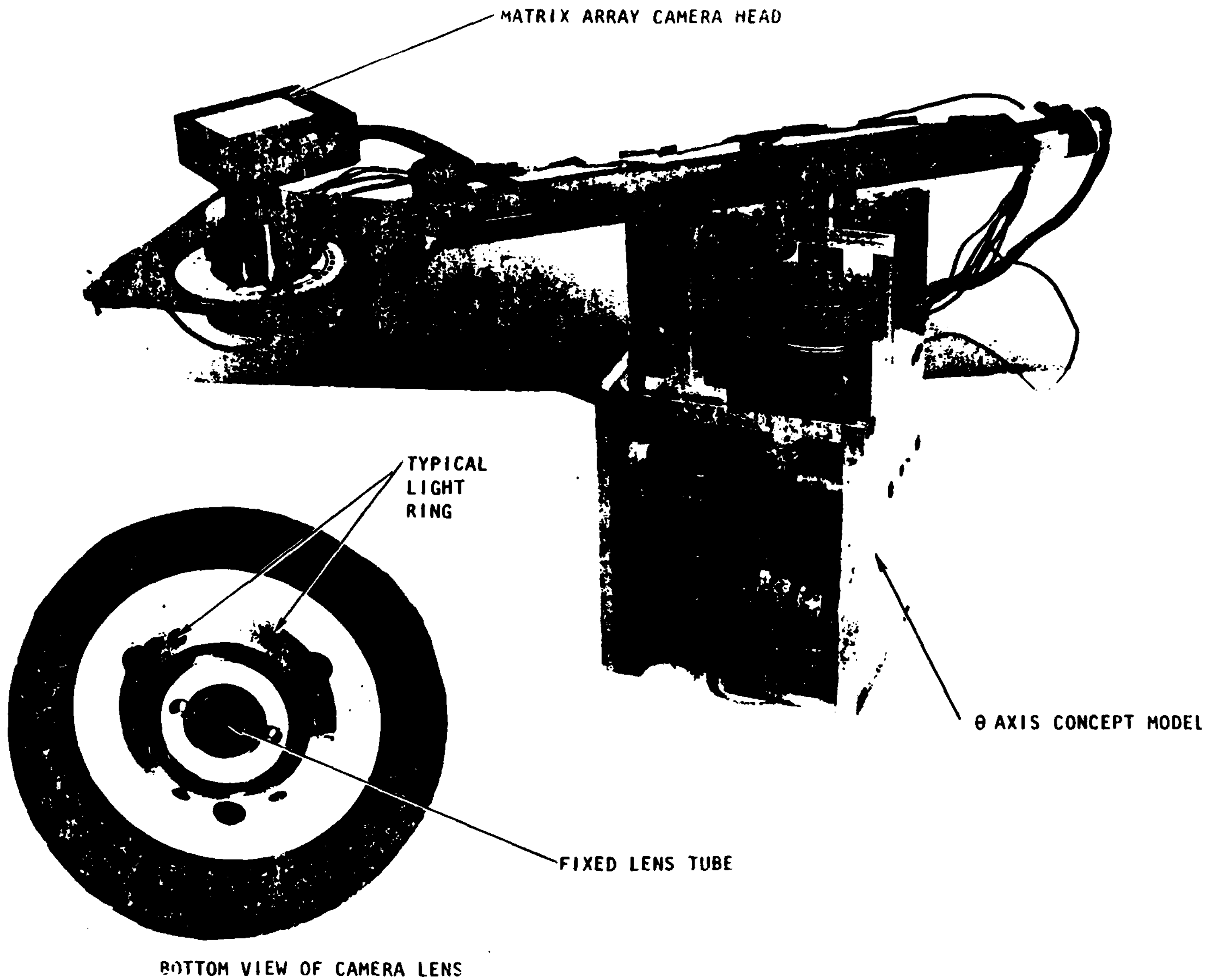


Figure 10. Concept Model- T.V. Camera Assembly

TV Monitor and Safety Cover

The TV monitor is mounted in front of the operator on a structure that also mounts to the table top. The monitor enclosure will pivot so that its viewing angle can be adjusted to suit each operator.

The tip up robot safety cover mounts to the monitor support structure. It is counterbalanced for easy up and down movement by the operator. Lifting the cover automatically prevents operation of the robot until an interlock switch is reset.

Substrate Feed System

The lack of standard sizes and shapes in hybrid circuits makes it difficult to design a universal substrate feed system. However, the system is general enough so that the concepts described here can be applied to most applications.

Magazines

Substrates will be stored in multi-level magazines with one substrate per level. The magazine width will be dictated by the substrate width and the magazine length will be able to accept the longest substrate of that width. Short substrates will be allowed to move around within the magazine. A spring loaded gate on each end keeps the substrates from sliding out during handling. The gates automatically open when mounted on the magazine elevators. Provisions will be made for an optional machine-readable serial number to be enscribed on each magazine elevator. The magazines will be designed to be easily stacked for storage during times in the process when they are not used. The magazine material will be aluminum and steel coated to resist wear from ceramic substrates. They can also be immersed in substrate cleaning solvents.

Elevators

The function of the elevator is to lower/raise the magazine one level at a time to present a new substrate to the feeder or to accept a new substrate from the feeder. At the input end of the feeder the elevator contains a pusher mechanism to slide the next substrate out of the magazine onto the feeder. The pusher travel will be sufficient to feed the shortest substrate regardless of its position in the magazine. The elevator will accept magazines of different substrate widths without adjustment, but the pusher blade may have to be changed to correspond to significant changes in substrate width.

Substrate Feeder

The purpose of the feeder is to move the substrate from the input magazine to the bond site and onto the output magazine. In general, this feeding technique will be a walking beam to index the substrates along one step each cycle. The substrate will be guided along a fixed back edge of the feeder with the front edge adjustable for different substrate widths.

At bond site a pusher will register the substrate against the back edge guide and clamp it there during bond. A second pusher will align the substrate again just before it enters into the output magazine. An optional pusher/clamp can be added at the input end of the feeder to align and hold the substrate during a substrate serial number read operation.

In summary, the feed concept is to have the magazine, elevator and feeder align to provide a common back edge for the substrates regardless of their width.

Changeover by operator from one size to another is a simple adjustment of the front edge guide and alignment of pusher blades. While the system illustration shows the feeder at the back of the bonder, it could also be placed at the front. This would make it easier to set up the feeder, but would make it necessary to change the waffle packs from the back side of the machine. The decision as to where to place the substrate feeder will depend on the frequency of setup changes anticipated by the user.

Another option is substrate sorting. If the user desired to sort out rejected substrates a second output elevator/magazine can be added. Good substrates would be fed into one magazine, and rejects into another.

This feed system as described is universal enough to be adapted for use on wire bonders, pull testers and other inspection devices.

System Base

The system table top is mounted to the system base. This tubular frame structure contains the system electronics and power supply. Access doors and removable panels cover the frame base and provide entrance to all areas of the electronic area. Forced air circulation cools the electronic components. A filter is provided for this air and it is located on the side of the system base, well off the floor to avoid picking up dust or objects from the floor.

VII. VIDEO AUGMENTATION DESIGN

The video system provides the important functions of prompting the operator in machine operations as well as determing die location and orientation and substrate alignment. To accomplish these tasks will require a microprocessor based system with mass storage unit.

The substrate alignment will be performed by the operator aligning two known reference points on the substrate (from which all bond site locations are referenced) to crosshairs on the monitor. This is accomplished by positioning the SPAR arm with camera over the reference points and rotating the camera so as to coincide the crosshairs with the reference points. Thus, X-Y and rotational offset data from a pretaught standard can be inputted to the computer for any particular substrate.

The major responsibility of the video system is to determine die orientation in the waffle pack cavity. Since die can lie in a cavity with X-Y and Ø (rotational) offsets, the operator must first correct for these so the pickup tool can pickup the die at its geometric center and place it with correct orientation on the substrate. Additionally, the die may be located in the waffle pack cavity 0°, 90°, 180° or 360° from correct pickup and, of course, upside down.

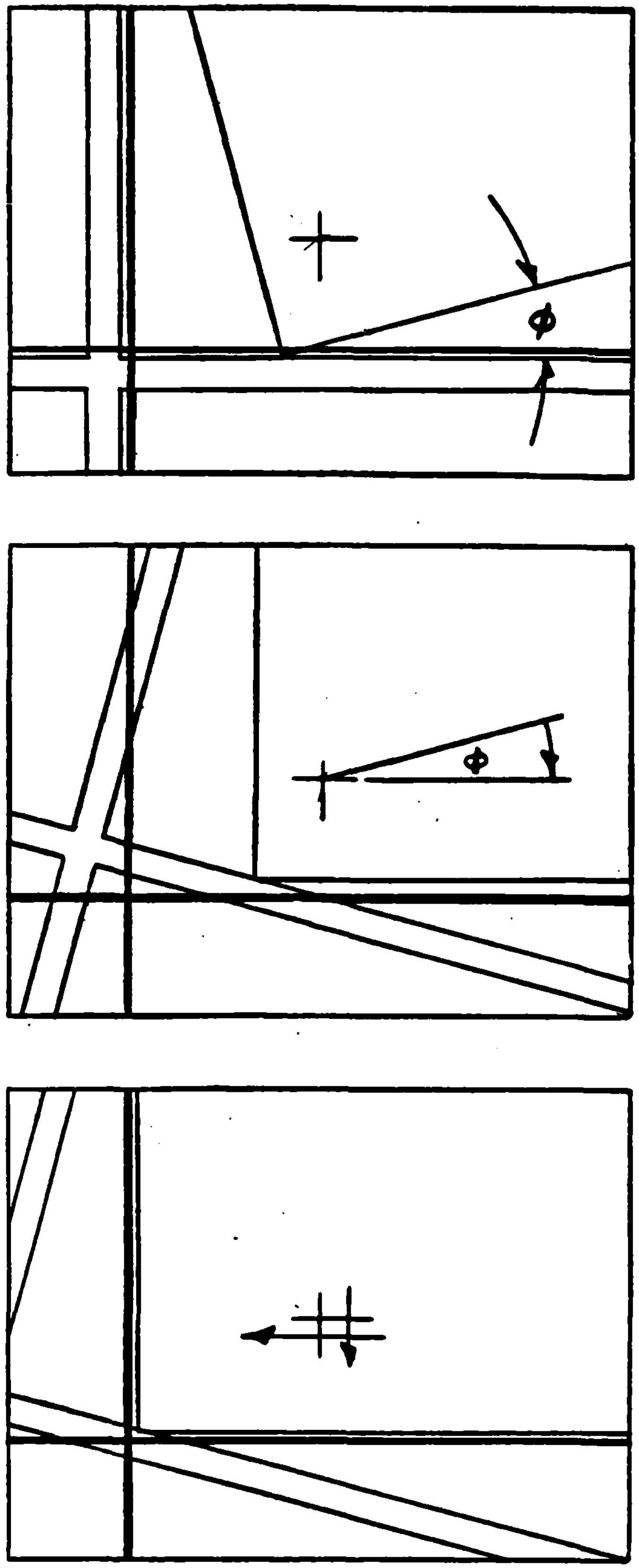
The X-Y and Ø offsets are first corrected by the operator moving the SPAR arm over the die cavity's left bottom corner. Using the crosshairs, the operator rotates the camera to correct for Ø offset and moves the arm to correct for X and Y offsets. (See Figure 11). Once these are corrected, the operator then calls up a graphic overlay feature that is used to determine die corner orientation.

For each type of die being used, there are four possible overlays. Each overlay corresponds to one-quarter of the die surface oriented so that the particular corner of the die is in the lower left of the field of view. (See figure 12) The operator depresses one of four switches to bring up a previously stored overlay of that die. The operator then compares the overlay to the actual video picture of the die to ascertain if a match exists. If no match exists, the remaining switches are pressed in sequence. Once a match is found, the operator presses the OVERLAY-MATCH switch and correction data is then fed to the host computer which instructs the SPAR arm as to the exact location of the die for pickup. If no match is found (wrong die or upside down), the operator presses the ABORT OVERLAY switch and the SPAR arm will automatically move to the next die cavity for the same die type. (See figure 13)

The data base for the overlays is built by constructing a series of rectangles around die pads using a joystick interconnected to the video display via a software routine. This is done for each die quadrant and will uniquely identify that section of the die. Once formulated on the display screen, the operator presses the STORE QUADRANT # ______ switch and the data is stored on a floppy disk.

The overlay technique will be capable of storing data on hundreds of different die through the use of a floppy disk storage system. Hence, once the data is taught, it will be maintained for the duration. Additionally, provisions will be made to access this information from an external host computer using CAD/CAM based information.

It should be noted that the overlay technique is intended only to provide die orientation data for the operator to use, and is not capable of reliably verifying die type by part number. This is because with hundreds of different die, the geometry of die pads and conductor lines can, in many cases, be nearly identical for the field of view being used.



VIDEO IMAGE
AT START OF
CYCLE

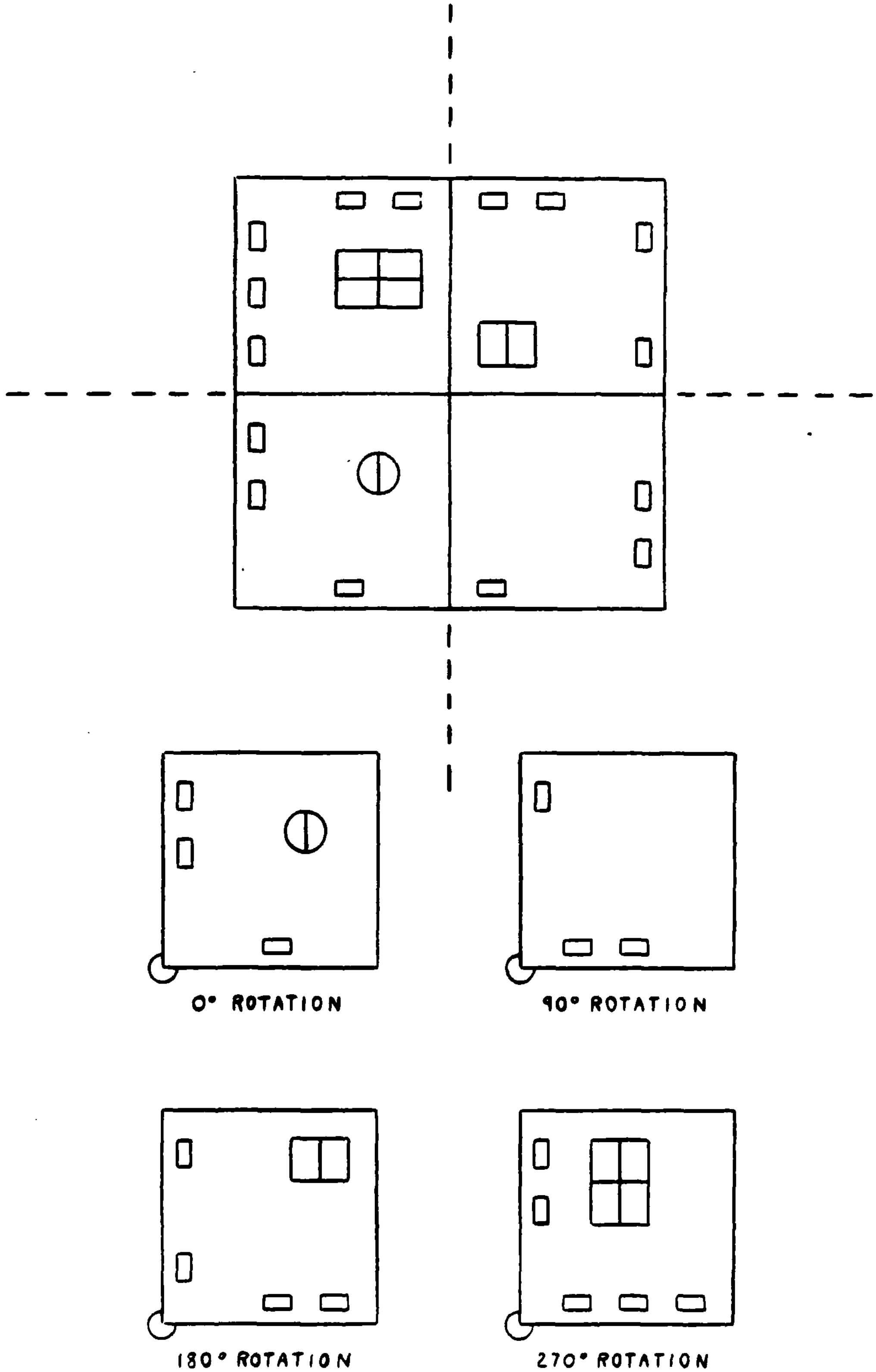
OPERATOR
ROTATES
CAMERA O DEG.

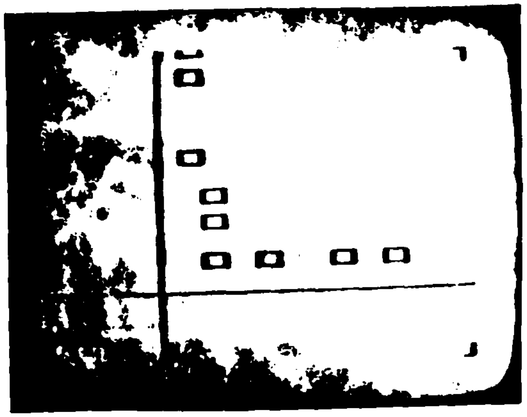
OPERATOR
MOVES ARM IN
X,Y

DIE/WAFFLE PACK ALIGNMENT

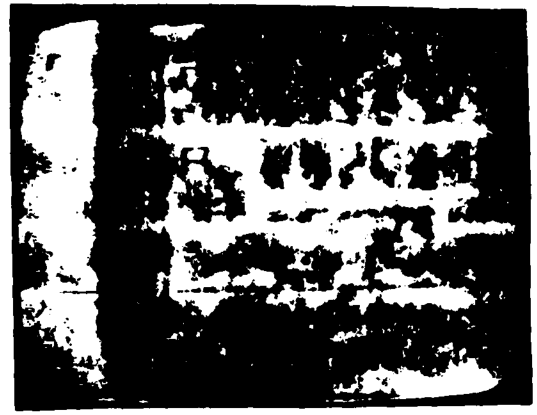
FIG. 11

FIG. 12 DIE OVERLAY INFORMATION

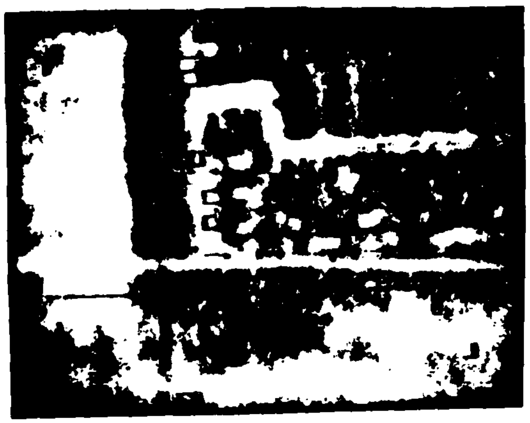




TYPICAL OVERLAY FROM DATA BASE



VERTICAL AND HORIZONTAL OVERLAY MISMATCH



VERTICAL AND HORIZONTAL OVERLAY MISMATCH

OVERLAY MATCH

FIGURE 13 - PHOTOGRAPHS OF SOFTWARE GENERATED DIE OVERLAYS

VIII ELECTRICAL DESIGN

The block diagram for the hybrid die bonder is shown in Figure 14. The SPAR robot and its control will be coupled to the various peripheral substystems through RS232 serial lines or binary I/O lines. Total system control integration will be via the special user application software package.

The SPAR system consists of an LSI 11/23 control computer, four DC servo Axis, each with microprocessor control, RS232 serial communication ports, binary I/O ports, floppy disk mass storage and control panel.

All system electronics will be located in the base of the system enclosure with the power supply separated from computer and control circuits which will be card-rack mounted.

The power supply will be a variation of a standard K&S configured supply. Power for the video, workholder and robot will be separated for reliability and maintenance reasons.

The workholder subsystem will have its own microprocessor to control movement of the substrates in and out of magazines and through the workholder, communicate with the SPAR control and provide real time diagnostics in its own process. In addition, operator accessable controls for manual elevator jog, manual workholder jog and elevator reset are provided.

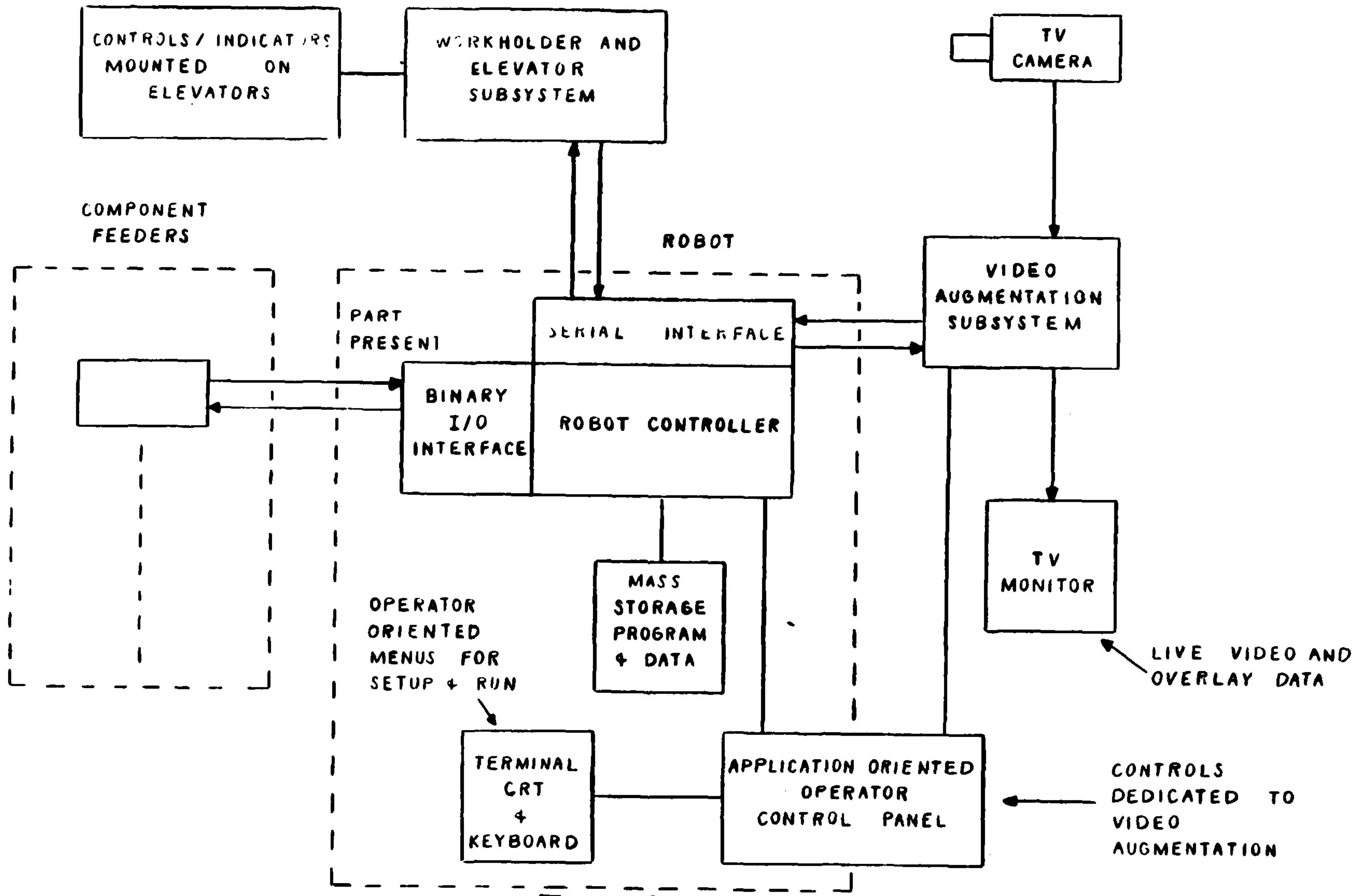


FIGURE 14

ROBOTIC BASED HYBRID ASSEMBLY STATION

IX SOFTWARE DESIGN

Since the hybrid die bonder will be developed as a special assembly application of the K&S SPAR robot, the software will be developed using a mixture of two programming disciplines. The assembly applications will be programmed using an advanced robotic control language (RCL) developed by K&S. This language is a heirarchical high-level language with control and datum constructs specifically designed for the assembly environment. The die bonder operator has no access to the RCL, but answers questions and selects choices which are presented by the RCL program. In this manner the RCL allows the SPAR to be taught and controlled by a person familiar with the assembly process but possessing no previous programming skills. Applications not requiring robotics skills, such as CAD/CAM acquisition and video augmentation overlay construction, will be developed using the PASCAL language.

The philosophy in developing the hybrid die bonder software is to present to the user at all times the image of a highly interactive "friendly" machine. Primary operator actions will be prompted by the presentation of video display action menus. In addition, detailed action prompts and requests for information will be presented to the operator as needed.

The following scenario for teaching waffle packs illustrates the advantages of this kind of software:

Operator wishes to add a waffle pack for chip pickup. The operator selects Edit Mode. The following menu is presented:

EDIT MODE

CHOICE	PRESS KEY
etc.	1
etc.	2
ADD WAFFLE PACK	3
etc.	4

The operator presses key "3" and the following requests are presented:

	Display	Action
0.	Enter Chip ID and Waffle Pack location number (1-40)	Operator enters the chip ID and location number for this pack. Arm automatically moves to top left corner of designated location.
1.	Confirm Top-Left Corner	The operator moves the arm until the Top-Left corner of the waffle pack is under video crosshair. Presses "Enter" key. Arm automatically moves to bottom right corner.
2.	Confirm Bottom-Right Corner	The operator moves the arm until the Bottom-Right corner of the waffle pack is under the video crosshair. Presses "Enter" key.

Because the system contains a complete data base of all existing flouroware waffle pack configurations no further operator actions are required.

Substrate Reference Spaces

To allow die placement on a substrate to be taught through CAD/CAM acquisition or by operator "show-and-tell" methods, a generalized concept of space must be created. That is, it would be convenient to create a small multi-dimensional space in which all die point references within the working area of the substrate can be located and then cast that "frame-of-reference" into the multi-dimensional real-world space of the SPAR. Furthermore, this must be done in such a manner as to allow an unsophisticated die bonder operator to teach these constructs.

However, the die attach points cannot be referenced rigidly in the real-world frame because it is impractical to fixture the substrate within the tolerance accuracy desired for die placement. Therefore, a proper solution would bind die attach points rigidly to the spatial frame of the substrate and then bind the substrate frame non-rigidly to the real-world frame of the robot. In so doing, it is now possible for an operator, or automatic vision system, to align each substrate and, consequently, each bond point into the real-world space by identifying no more than two points on the surface of the substrate.

The K&S SPAR control language allows easy creation and manipulation of such point and frame constructs. To teach a substrate and all die attach points an operator need only enter two substrate alignment points and each die attach point in response to video display prompting messages. In a CAD/CAM system a point can be designated as the Cartesian origin and another is identifed which lies along the positive X-axis. These points form the basis for the spatial frame. All die attach points can now be expressed as Cartesian coordinates of some specified dimensionality, i.e. millimeters or inches. Having now transferred this information to the SPAR, all an operator must do is identify the two alignment points.

SECTION II
MECHANICAL DESIGN

SECTION II

MECHANICAL DESIGN

NOTICE

The Kulicke and Soffa Model 8101 Small Parts Assembly Robot (SPAR), its Related Control and System Control Language (RCL) are proprietary developments of Kulicke and Soffa Industries, Inc. and are exempt from rights provisions under this referenced contract.

Table of Contents

I. INTRODUCTION

This is the third deliverable item under Hughes Purchase Order 6-932254-C-W4 for the Preliminary Mechanical Design of the Hybrid Die Bonder. The Die Bonder System employs a Kulicke and Soffa developed Small Parts Assembly Robot (SPAR) system to perform the die pick up and placement function.

The mechanical design of the Hybrid Die Bonder System consists of the following subsystems:

a. SPAR System - A precise, high speed, d.c. servo driven, programmable, four axis mechanical handling unit with a computer based control.

b. Waffle Pack and Component Feeder - Provision for mounting standard integrated circuit waffle packs and feeders for passive components.

c. Substrate Handling System - Holding and transfer system for circuit substrates to provide infeed to and out feed from the assembly station.

d. Operator Controls - Necessary pushbuttons and displays for operator interface to set up, run programs, and perform troubleshooting on the system.

e. System Cabinetry - The equipment housing for the entire system.

Details for each of these subsystems is presented in the following sections.

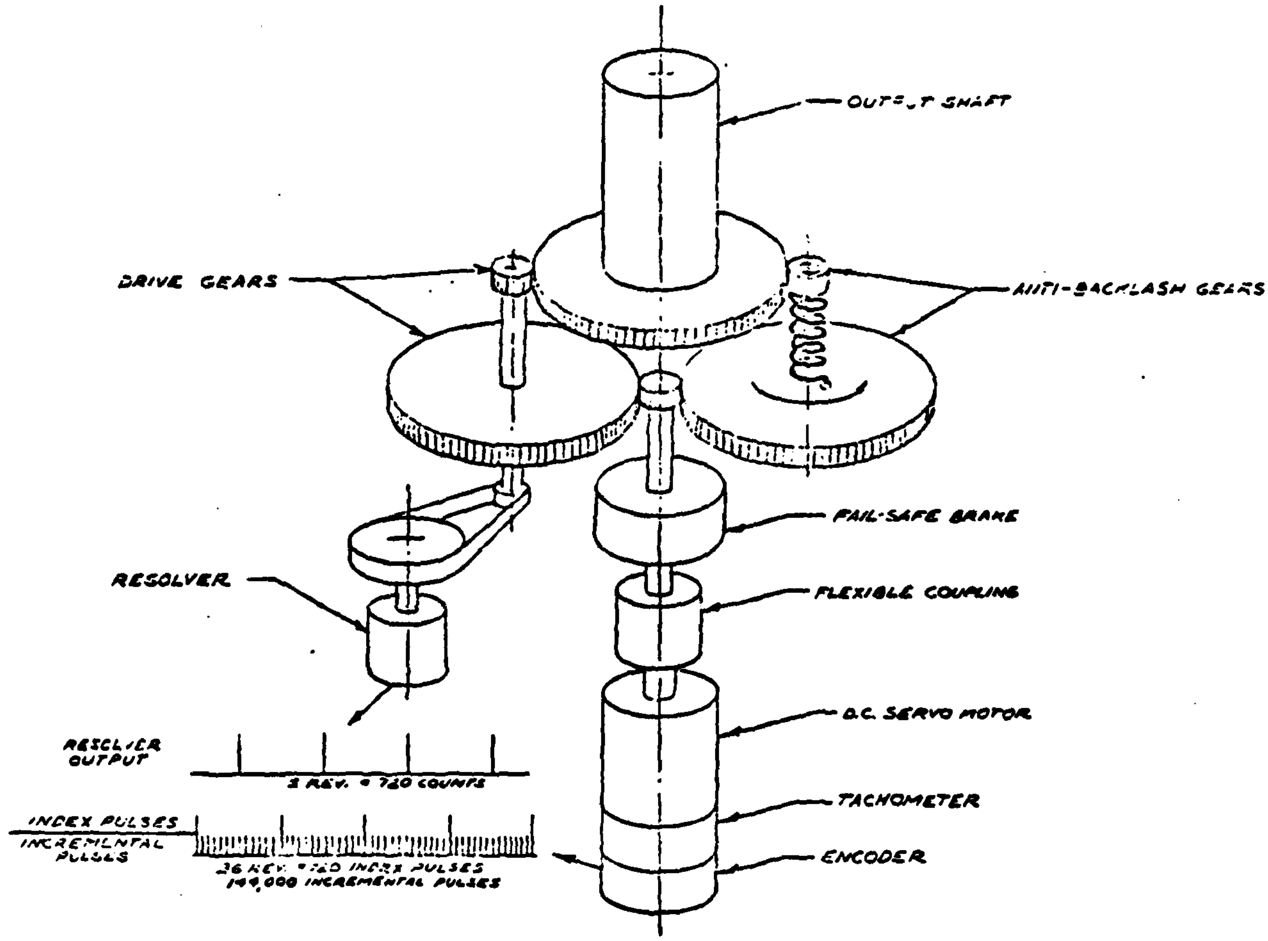
II. SPAR SYSTEM

The SPAR mechanism consists of three elements: a rotary base, a horizontal arm, and a vacuum pickup tool/TV camera assembly.

The basic components of the rotating base are shown in Figure 1. The high speed D.C. servo motor drives a twin path, antibacklash gear train to produce precise high torque rotation of the output shaft. The antibacklash elements of the gear train are preset at assembly, are selfcompensating for gear wear, and require no adjustment. They are housed in the robot base and are factory lubricated and sealed.

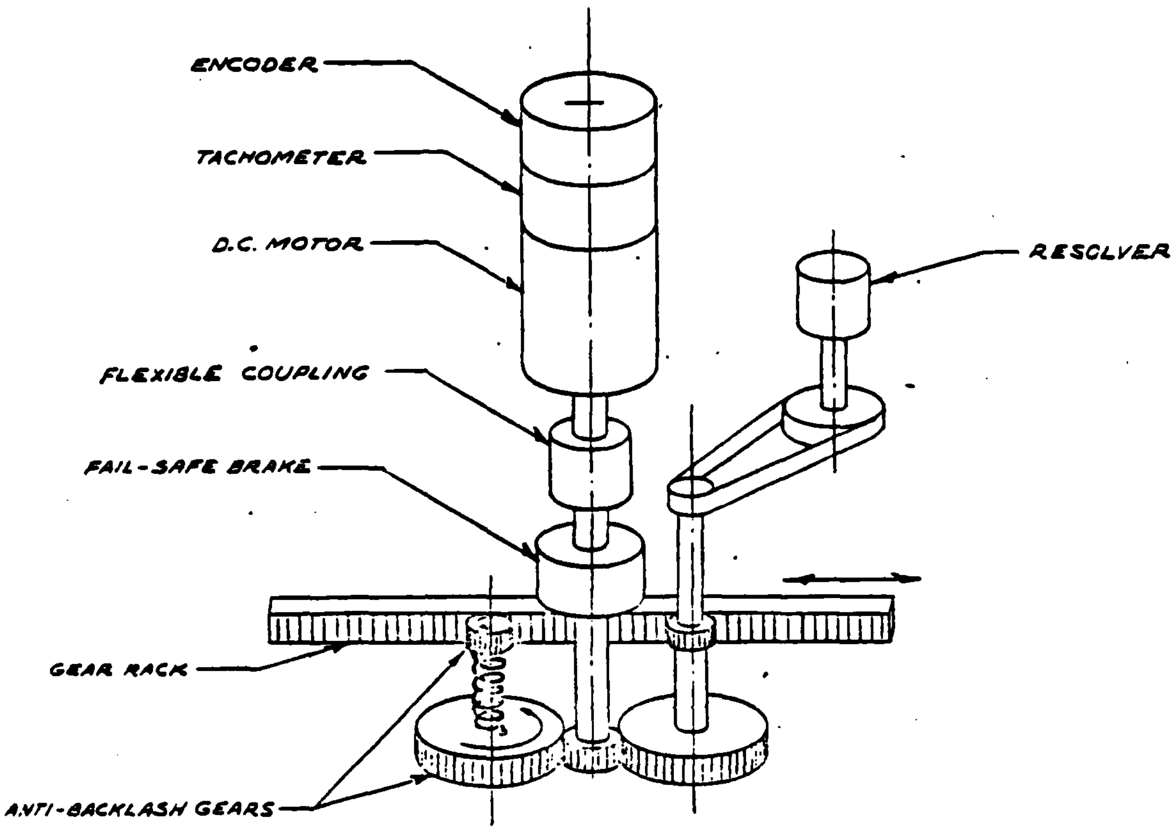
Output shaft speed is monitored by a D.C. tachometer coupled to the motor. Shaft rotation is determined by the position of both the encoder and the resolver. Working together these two devices produce an absolute position signal every nine seconds of shaft rotation. This is equal to 0.0005 inches of travel at the maximum operating radius of the arm.

The horizontal arm is mounted to the output shaft. Its drive components are shown in Figure 2. A helical tooth rack and pinion driven by a similar antibacklash gear train and d.c. servo motor move the arm in the horizontal direction. Maximum reach is 12 inches and minimum is 5 inches. The same type of speed and position control as used on the rotation axis is used, and produces an absolute position signal every 0.0002 inches of travel.



ROTATE AXIS DRIVE SYSTEM

FIG. 1



HORIZONTAL AXIS DRIVE SYSTEM

FIG. 2

The arm is guided by precision linear ball bushings and the entire mechanism is protected by a combination of flexible and rigid covers.

The third element of the robot mechanism is the pickup tool/TV camera assembly. A line drawing of the basic components is shown in Figure 3.

Both the camera and the tool are mounted into the same housing. This housing moves vertically in precision ball bearing ways, and is driven by a d.c. servo motor thru a small rack and pinion. An encoder and tachometer provide motion and position control to enable the system to focus the TV image, and place components with a programmable, repeatable force.

The pickup tool is mounted at the end of a slender rod. The rod is guided by linear and rotary bearings so that it can rotate and move vertically within the housing. A spring system holds the rod down against a stop and over travel of the housing extends the spring and applies a predictable bond force.

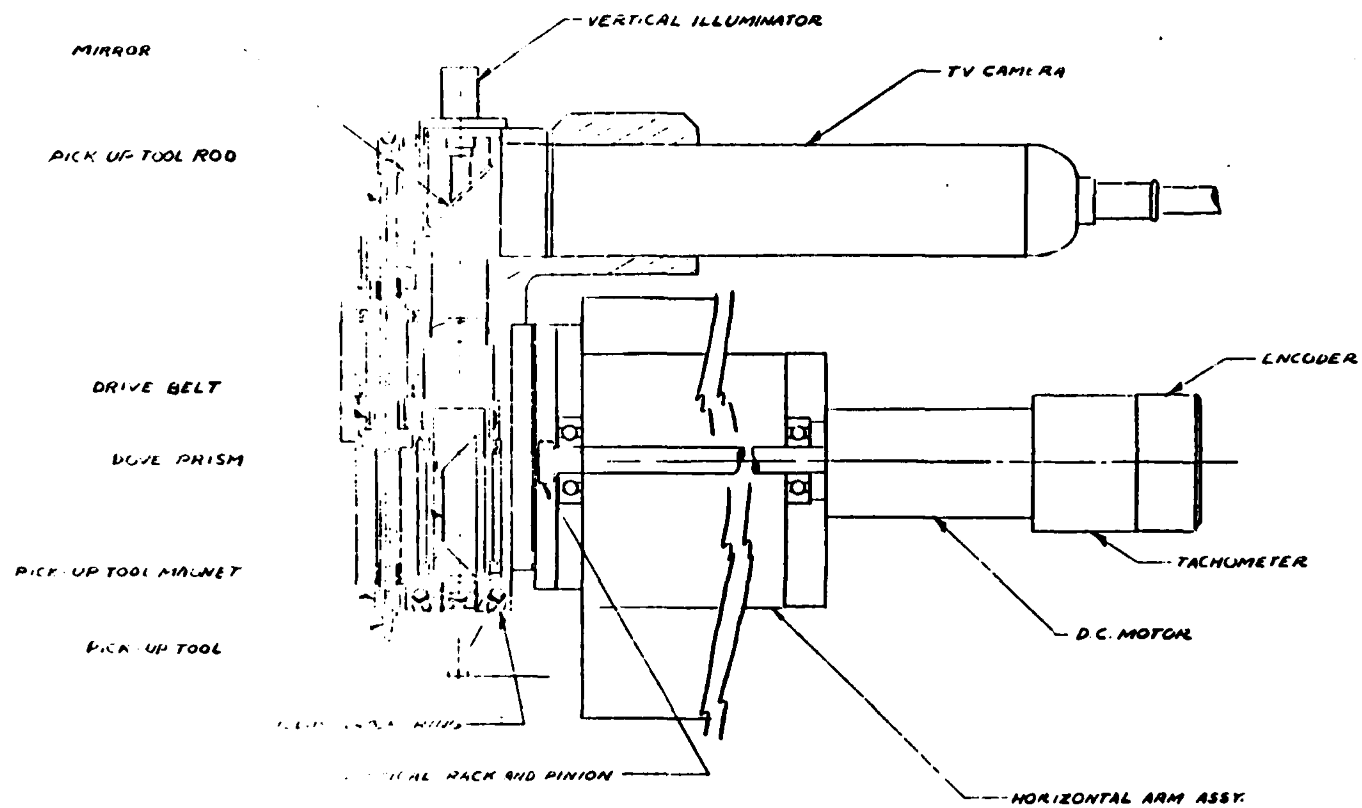
The cone shaped pickup tool in held into the end of the arm by a permanent magnet. Tool changeover is accomplished by inserting the tool tip into a tool holder in the table of the bonder. A solenoid actuated clamp locks onto the tool tip and when the arm is withdrawn the tool is pulled out of its magnetic chuck. A new tool is picked up by moving the rod over a new tool and releasing its solenoid clamp. The permanent magnet chuck assures that the tool tip will not be lost any time power is removed from the robot.

A hard, long wearing carbide material tool tip will be used to pick up capacitors, and a softer urethane material will be used on fragile integrated circuits. Pick up of components is accomplished by vacuum and to assure that tiny components have been released by the tool on placement, a burst of positive pressure is applied when vacuum is turned off. This "puff off" air as well as the vacuum are controlled by solenoid valves mounted on the pick up housing. A vacuum sensing switch monitors the pickup vacuum and signals the system if a component has not been picked up or if it drops off during the placement motion.

The tool rod is coupled by a timing belt to a small d.c. servo motor with tachometer and encoder. This motor rotates the tool rod and also drives the TV image rotation system.

The image system consists of two fixed lenses, a mirror and a rotating dove prism. The dove prism is the heart of the optical design. As the prism rotates about its optical axis the image viewed through the prism is seen to rotate at two times the rate of rotation of the prism itself. The lenses and mirror provide proper optical correction of the image, and direct it to the face of the TV camera.

The objective end of the lense tube is surrounded by an array of small high intensity lamps that can be switched on and off in any combination to create the best possible shadow conditions for die edge identification. A thru-the-lense light is also included to illuminate the die surface for die topography identification.



PICK-UP TOOL — TV CAMERA ASSEMBLY

FIG. 3

KULICKE & SOFFA INDUSTRIES INC

III. WAFFLE PACKS AND COMPONENT FEEDERS

All integrated circuits will be picked up from waffle packs. Waffle packs will be labeled with a user identification number. When they are brought to the system to set up a new job, the operator will have instructions as to where to locate each waffle pack. Fixturing on the system will accurately locate the waffle packs and all locations will be identified with a position number. Provision will also be made for storing the waffle pack cover adjacent to its waffle pack. Covers will therefore not get mixed up when packs are removed from the system.

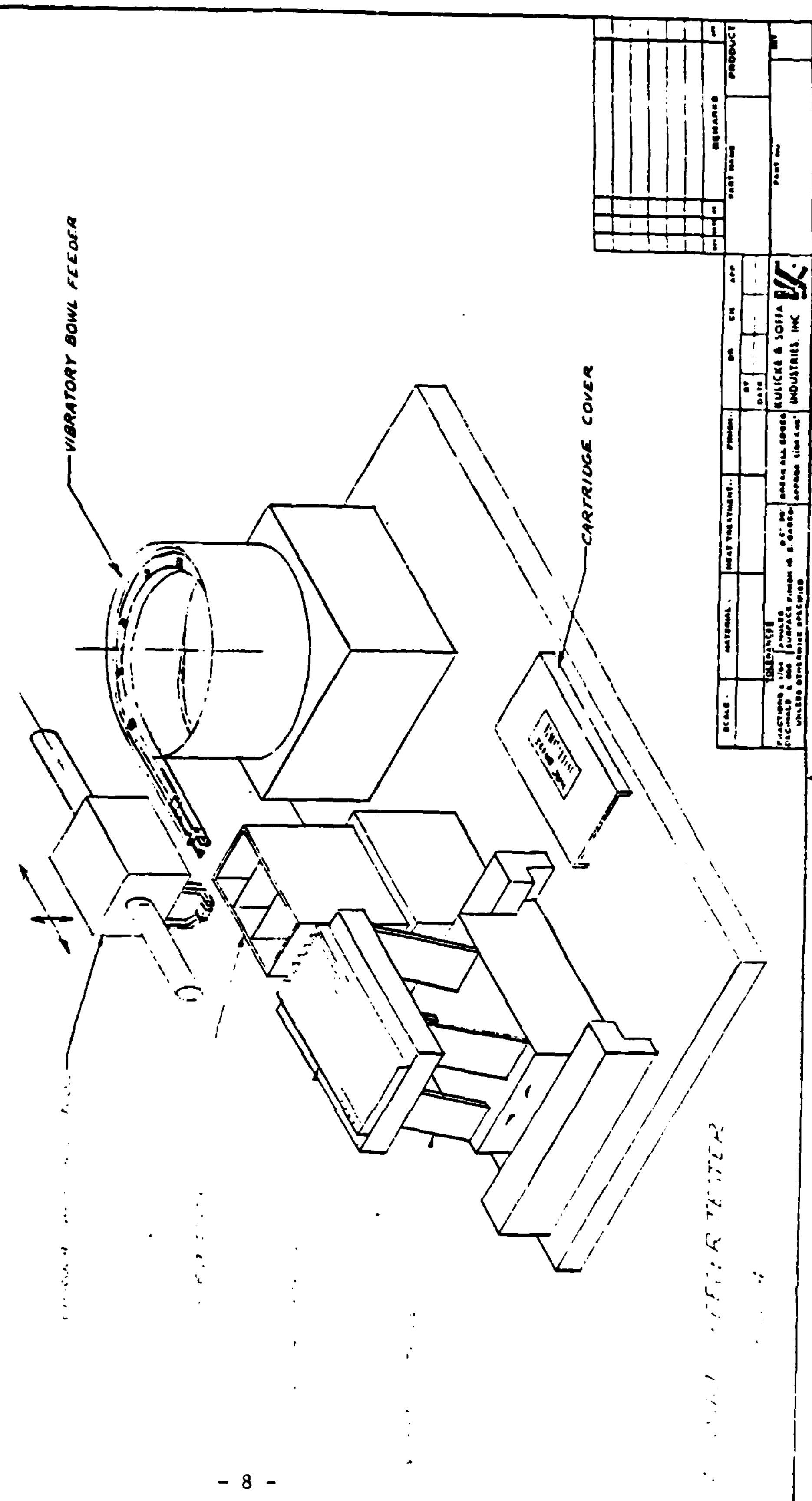
The waffle pack locations will be on trays under the cover that protects the operator from the moving robot arm. This permits an operator to easily and safely replace waffle packs.

Passive components such as chip capacitors will be brought to the system in specially designed component cartridges. The cartridges will have a single track or several tracks depending on the size of the component and its potential usage. A snap-on cover will be provided to hold the components in the tracks. All components will be picked up from one end of the cartridge. To insure that the components are always at the pick up end of the cartridge it will be mounted onto a vibratory stand designed to urge the components to the pick up point.

To prevent component jams in the track, all components will be gauged before they are loaded into the cartridge. The gauging will be done by a specially designed automatic feeder/tester. Figure 4 is a concept drawing of such a device. Capacitor width and height will be gauged by means incorporated into the vibratory feeder/orientor track. Good parts that reach the end of the track will be picked up by a reciprocating pickup arm. The arm picks up the first component on the track and with a built-in probe checks the value of capacitors. If it is within tolerance the arm deposits the component in the cartridge track. If it is not acceptable, it will be dropped into an appropriate container to be scrapped or retested for other uses.

In this way all passive components that are brought to the system for assembly will have been pretested both mechanically and electrically. This should eliminate the problems normally associated with feeding these parts on automatic assembly systems, and prevent parts that look alike but have different electrical values from being mixed together. The feeding and part identification problems are thus transferred to a less sensitive area where personnel that normally kit parts for assembly can attend the feeder/tester machine.

If the user desires to place other types of components that have consistent dimensional tolerances, special feeders mounted on the system can be used. In this case the robot arm will pick up these components directly from the end of the feeder track.


VIBRATORY BOWL FEEDER
CARTRIDGE COVER
KULICKE & SOFFA INDUSTRIES, INC.

IV. SUBSTRATE HANDLING SYSTEM

Figure 5 is a concept drawing of the substrate handling system. This particular system is designed to feed rectangular substrates ranging in size from .5 inches square up to 4 inches square. Other sizes or shapes would require special modifications of the general concept described in the following sections.

A. Magazine

For automatic feed, all substrates will be carried in multilevel magazines that store one substrate per level. Each magazine will hold a minimum of 25 substrates of the same width. The magazine width will be dictated by the substrate width and the magazine will be long enough to accept the longest substrate of that width. Therefore, a different size magazine will be required for each substrate width a user plans to feed thru the system. Short substrates will be allowed to move lenthwise within the magazine.

Substrates will be held in the magazine by guides that trap the substrate along the bottom surface, two edges parallel to the length and by a .055 inch wide clear area on the edges of the component side parallel to the length. There will be a 0.200 inch vertical clearance between substrates for components.

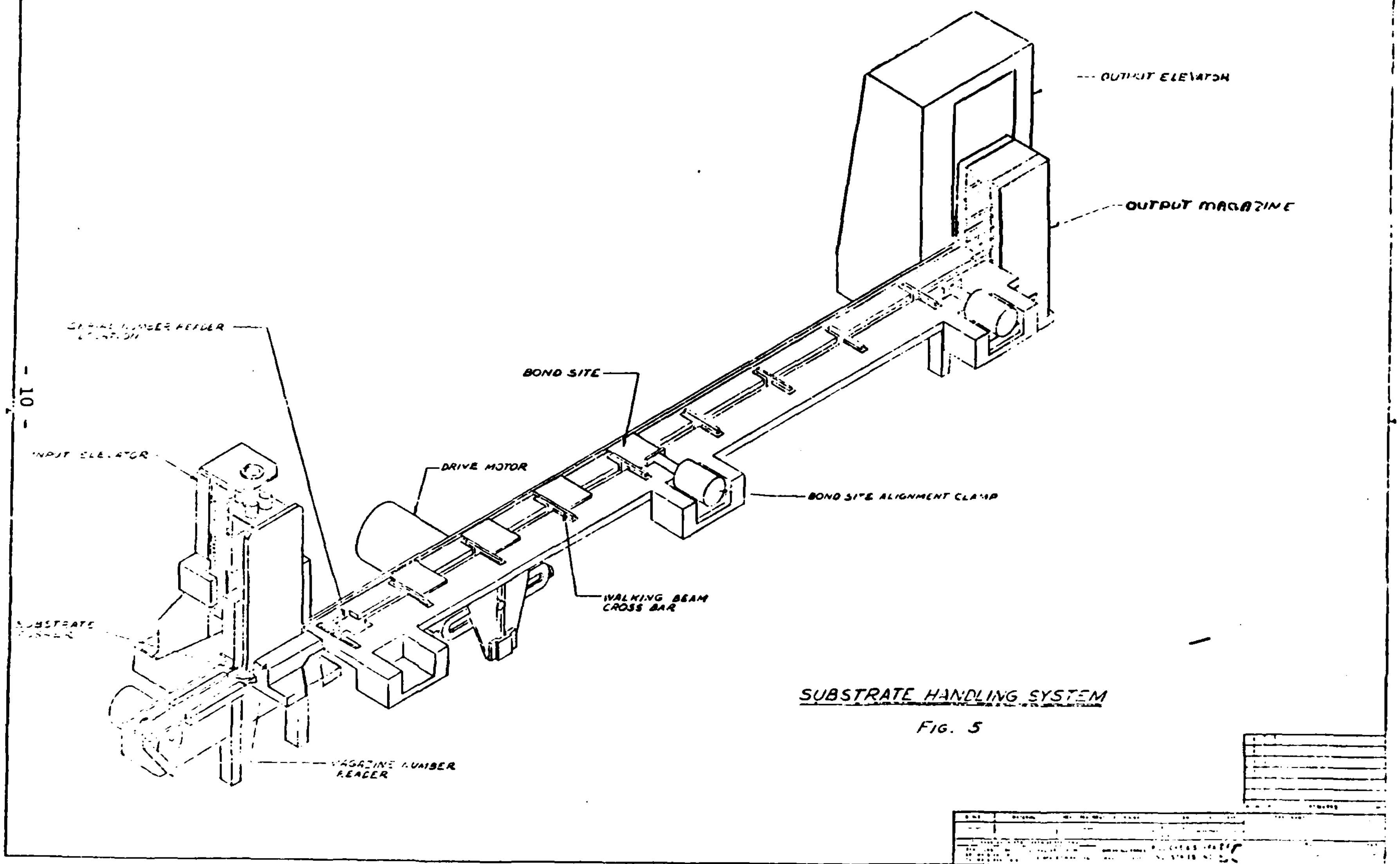
Figure 6 is a photograph of a development model of the magazine. It shows a toothed gate on each end that will prevent substrates from sliding out during handling. When magazines are placed onto the feed elevators the appropriate gate is automatically opened to allow parts to feed out of or into the magazine.

Provision will be made for an optional machine-readable serial number to be permanently inscribed into each magazine. This number is then automatically read when the magazine is placed onto an elevator. A corresponding operator readable number can also be printed on each magazine if desired.

Magazines are intended to be used to store substrates between process operations, and therefore they will be designed to stack easily and compactly. They will be made from materials selected for economical quantity production. These materials will also be capable of withstanding 150°C temperatures and emersion in cleaning solvents such as Freon TA and TF, TMC and WD603.

B. Elevators

The magazine elevator is used to raise or lower the magazines one level at a time as substrates are fed thru the system. Figure 7 shows a typical workholder with elevator. The elevator is a standard K&S assembly modified to accept the hybrid substrate magazines. On the input elevator a motor driven pusher mechanism is added to slide each new substrate out of the magazine and onto the substrate feed platform. This mechanism is adjustable so that the pusher face can be centered for various substrate widths.



SUBSTRATE HANDLING SYSTEM

FIG. 5

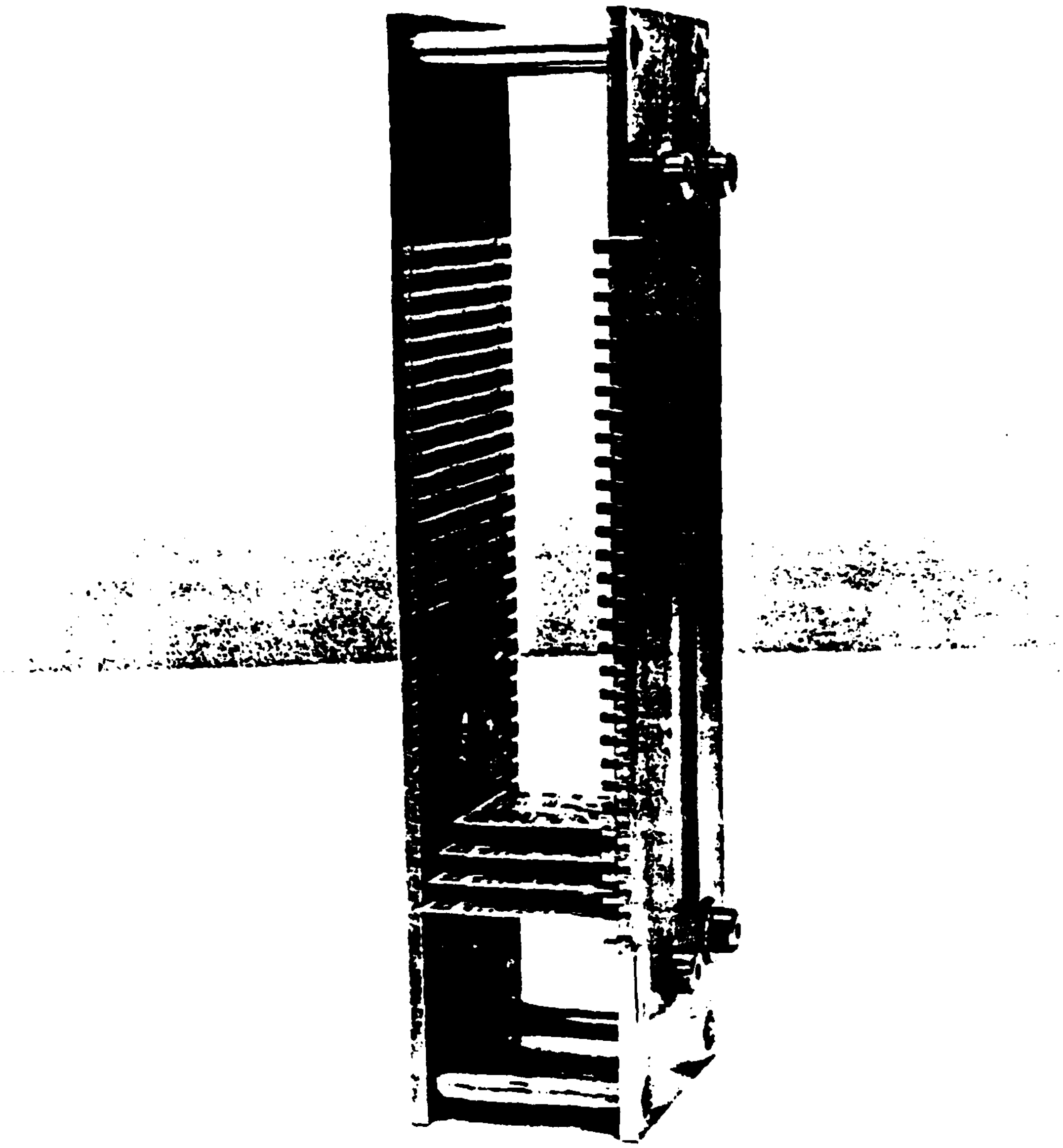


Figure 6

Photo of Prototype Magazine

An optional modification is the addition of a magazine serial number reader. The reader is a row of 12 LED transmitter and receiver pairs that will look for slots in the bottom edge of each magazine. The slots will be interpreted as binary digits. This would allow for more than 4,000 individual magazine numbers that could be read after the magazines have been placed on the elevator.

One final option not shown on Figure 5 is the addition of a reject magazine to the output elevator. In this feature two magazines, one for good and one for rejects would be mounted side by side on a moving table on the elevator platform. If the substrate is acceptable the first magazine would be lined up with the substrate feeder. If it is a reject the reject magazine would be moved into position to accept the substrate.

C. Substrate Feeders

Between the input and output magazines is the substrate feeder. Its function is to move the substrate from the input magazine to the bond site, and into the output magazine. As shown on Figure 5, the feeding element is a walking beam with crossbars that push against the back edge of each substrate and index it along one step each cycle.

In operation, a substrate is fed out of the input magazine by the pusher on the input elevator. This pusher places the substrate ahead of the first crossbar position on the feeder and over the optional substrate serial number read station. A pusher/clamp (not shown) forces the substrate up against the back guiding edge of the feeder. If a reader is installed the pusher would remain on and act as a clamp to hold the substrate in position. The read head would then move into position and sweep across the numbers on the bottom of the substrate.

If there is no reader the pusher retracts and the substrate is now aligned and ready to be fed forward. The walking beam crossbar drops down from the position shown on the drawing, moves back beneath the substrates and up into position behind them. A smooth forward motion pushes all the substrates forward one step and the feed cycle is complete.

At bond site a second pusher/clamp comes forward to align and hold the substrate while all components are placed.

At the output end of the feeder a third pusher/clamp aligns the substrate for entry into the output magazine. A smaller crossbar pushes the substrate into the magazine during the normal forward stroke of the walking beam.

The crossbars remain at the full forward position during the bonding cycle and during this time the elevators index the magazine to their new positions, and the substrate reader goes through its cycle.

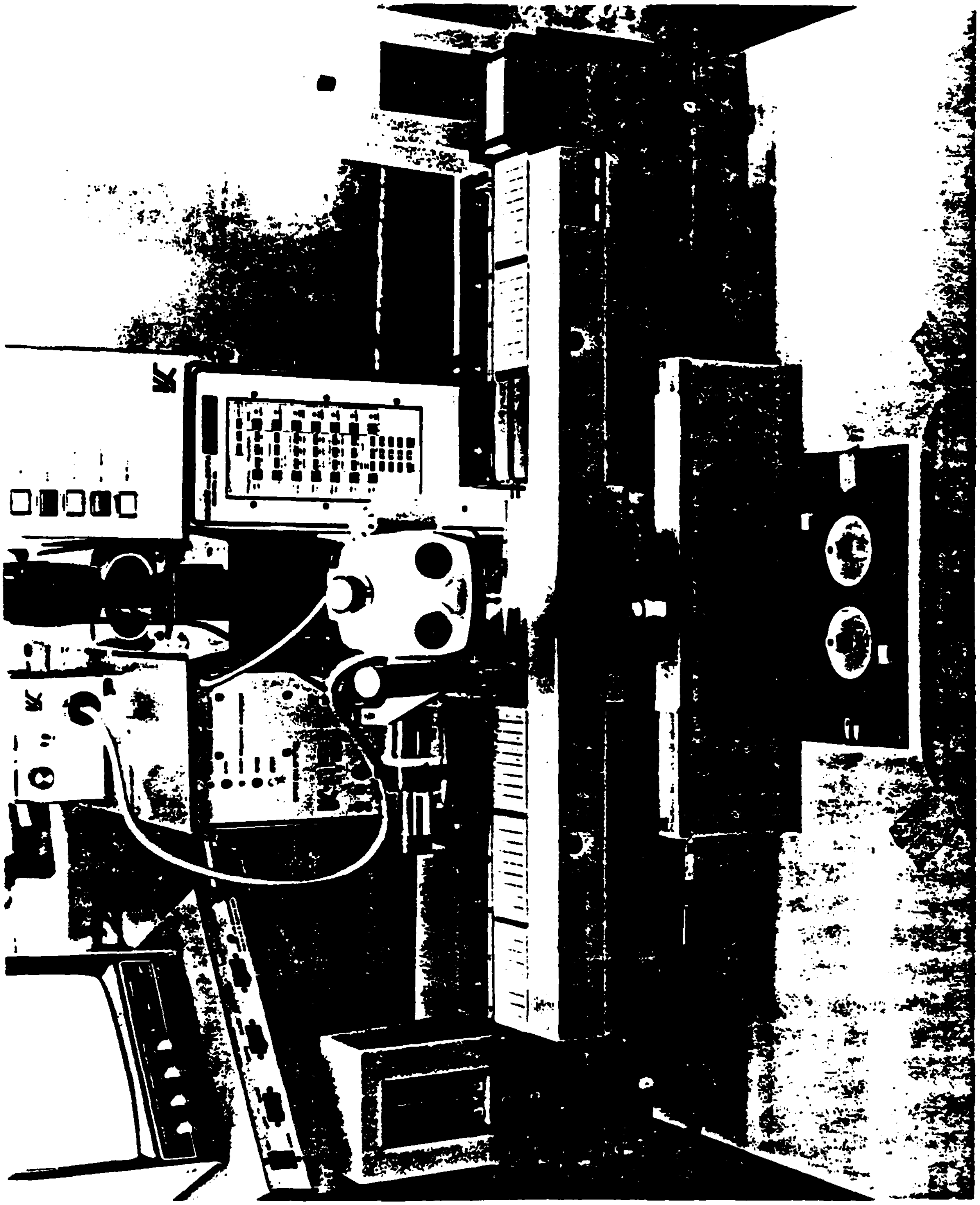


Figure 7

Typical K&S Workholder
with Elevators

The walking beam motion is produced by a pair of cams. These controlled acceleration profile cams drive the crossbar smoothly in both the vertical and horizontal direction. The long crossbar/beam assembly is supported by linear and rotary bushings.

LED sensors detect the presence of substrates at the read, bond and output alignment stations and signal the system should a jam or misalignment occur.

Changeover from one size to another is limited to a readjustment of the alignment pusher/clamps and a change in position of the the input pusher mechanism. If the substrate width remains the same and only its length changes then no readjustment would be required. It is assumed that the substrate serial numbers are printed in a common position referenced from the top and left hand edge of the substrate when viewed from the component side.

V. OPERATOR CONTROLS

In normal operation this semiautomatic system requires continuous operator interaction with the system's computer. Decisions on integrated circuit orientation, corrections for substrate misalignment and similar inputs require a simple or "friendly" operator control scheme. The two basic elements of that control scheme are: 1) the TV monitor; and 2) the control panel.

The montior will display images seen by the TV camera mounted on the end of the robot arm, and it will also display a nearly continuous series of statements or questions to guide the operator thru a job or a set up routine.

The operator will respond to the monitor images and statements by making vernier corrections in the arm's position or by entering data via the control panel keyboard.

The two main components of the control panel are the X-Y trackball and a control knob.

The trackball is a three-inch diameter plastic ball mounted into the panel that can be easily moved by the operator's fingers. The ball can be rotated continuously in any direction and drives two incremental encoders. The encoders rotate on axes that are 90° apart and generate X and Y direction signals.

When connected to the robot controller the operator can use the ball to move the end of the arm in a purely X or Y direction or any combination thereof. The output signals from the encoders are electronically enhanced to enable the operator to make very precise movements of the robot arm.

The other control knob on the panel is also coupled to an incremental encoder, and when turned it will rotate the TV camera/pickup tool. A pushbutton on the keyboard converts this knob into a control for the vertical motion of the camera/pickup tool. Again the output of this control enables the operator to make very precise rotary or vertical movements of the end of the arm.

It should be emphasized that both of these robot control elements are for small motions only. Large motions of the robot are accomplished by responding to statements on the monitor. For instance, to move the TV camera from viewing the substrate at bond site to viewing the reference position on waffle pack #12, would require a statement to that effect on the monitor to which the operator responds. Since the arm is so large relative to the size of the substrates and waffle packs, and the viewing area of the camera small, the operator will not know the exact area on the substrate or waffle pack that is on the monitor unless that information was displayed on the monitor when the move was made. In summary, all major motions of the arm are preprogrammed and the operator makes only small corrections to the final desired positions of the arm.

The balance of the control panel is the keyboard with 28 pushbuttons or momentary switch positions. The following is a brief description of the function of each position:

EMERGENCY STOP:	Push on/push off switch that stops all motions and turns on the robot brakes. After release, all robot and workholder position encoders must be reinitialized (brought back to a known position). In the normal startup routine, the operator responds to a menu-driven procedure in conjunction with the control switches to bring the system back to the start position.
ENTER:	Momentary switch used after the operator has made corrections to the arm's position or numeric data. Instructs the computer system to record this new position data.
VERTICAL:	Lighted push on/push off switch that converts the control knob from camera/tool rotate control to vertical control.
MODE SELECT:	Momentary switch used to bring to the monitor the basic menu of mode options available to the operator. Examples of modes: teach, auto run, etc.
ASSIST:	Momentary switch used to recall to the monitor the most recent display or the most convenient step in the process to restart the entry of data to the system.
RESTART:	Momentary switch used to restart a process that is incomplete.
HOME:	Momentary switch used to return robot arm to its home or to an out-of-the-way position. This moves the end of the robot clear of waffle packs and the bond site.

SINGLE CYCLE:	Momentary switch used to move robot thru a bonding cycle one step at a time. Used to test setup data prior to automatic run. Requires operator to press switch for each step.
CONTINUE:	Momentary switch used to restart a cycle that has been halted because of an error condition.
NUMERIC KEYBOARD: 0-9	Standard 10 key numeric keyboard. Used to enter substrate bond X-Y locations, to select mode options from monitor display, or select pickup locations for all components.
CHANGE/CHANGE ENTRY:	Momentary switch used to clear numeric keyboard data that is in error or delete instruction previously entered into memory.
LIGHTS:	Push on/push off switch used to override programmed setting of lights in illumination ring of camera system. Enables numeric keyboard to select desired light arrangement.
OVERLAY 1: OVERLAY 2 OVERLAY 3 OVERLAY 4	Four momentary switches to enable the operator to display video overlay graphics on the monitor. Used by the operator to determine the orientation of the integrated circuit shown on the display. When a match is found ENTER is pressed to enter that data in the computer system. If no match is found CONTINUE is pressed to move arm to next waffle pack caviety.
WORKHOLDER INDEX:	Momentary switch to move the workholder one complete cycle. Does not index elevators.
WORKHOLDER CLAMP:	Push on/push off switch to turn on and off the alignment/clamps. Used during set up or to clear jams on substrate feeder.
WORKHOLDER CLEAR:	Push on/push off switch to enable the operator to empty the substrate feeder after last substrate has been fed from input magazines. Used at end of job or end of shift.

If the optional substrate serial number readers are installed, two additional switches will be required:

READ CYCLE: Momentary switch to enable the operator to single cycle the read head during set up.

INHIBIT READER: Push on/push off switch to disable the reader if it was not to be used on a particular job.

A similar pair of switches are required to control the reject magazine features if it is added to the system. Also both elevators have a pair of momentary switches mounted on the front of the elevator.

JOG: Move the elevator down one magazine level. Used during set up with work-holder in single cycle mode.

RESET: Resets elevator to first magazine level position. Used after new magazines are placed on elevator.

In order to illustrate the use of this control scheme a brief description of the substrate bond pad set up procedure is given.

With the robot in the reset position the operator presses MODE SELECT. The monitor displays a menu of several options for the operator to select. One is "teach substrate data - ENTER 6." By pressing 6 on the numeric keyboard followed by ENTER, the operator has told the system to prepare to accept data for teaching or changing substrate size and bond pad locations.

The system computer automatically directs the robot to position the TV camera over the reference corner of the substrate at bond site. The monitor displays "FOCUS ?". If the TV image of the substrate is out of focus the operator presses VERTICAL and with the control knob moves the camera into correct focus. Pressing ENTER will teach the system the correct focus height for that substrate.

At this point a crosshair appears on the monitor and the operator checks the alignment of the substrate corner to the crosshair. If a position correction is necessary it is made by using the trackball, and when correct the operator presses ENTER.

The monitor now asks the operator to enter the X and Y dimensions of the opposite corner of the substrate. Using the numeric keyboard the operator enters this data followed by pressing ENTER. The arm then moves the camera to that location and the operator checks the corner alignment with respect to the crosshair on the monitor.

The monitor then asks the operator to provide data concerning the location of one corner of bond site #1. After this is entered the arm moves the camera to that point and it is compared to the crosshair. The location of the opposite corner is then entered and checked in the same manner. The computer can then calculate the center of the bond site and store that data for later use. In a similar manner all bond pad location data is entered and the operator terminates this task by pressing MODE SELECT.

By choosing other setup procedures from the main menu the operator can teach waffle pack data, passive component location data, illumination settings, tool change positions, quantities of parts available and etc. until a complete substrate assembly is programmed. Once this data has been entered into the computer, it can be stored on a floppy disk. Future setups of the same job would require only changing quantities of parts involved and verification of all part locations. It should be noted that all or part of the above data can be downloaded from a remote host computer via an ASCII coded serial line interface. Code format and protocol to be mutually determined.

Once a complete assembly program has been taught and verified, production can begin. The operator presses MODE SELECT and places the system in automatic mode. The following events then take place:

1. The substrate pusher feeds a substrate out of the input magazine and onto the feed platform. The pusher/clamp aligns the substrate to the fixed back edge of the feed platform. The substrate reader moves into position, reads the serial number and retracts. The clamp opens and the crossbar indexes the substrate forward.

2. When the first substrate reaches bond site the LED sensor detects it and the pusher/clamp aligns and holds it in bond position.

3. The SPAR robot moves the camera into position over the reference corner of the substrate. The operator observes its position and aligns it to the crosshair if necessary. The operator presses ENTER and the arm moves the camera to the opposite corner and the alignment procedure is repeated.

4. The operator presses ENTER to confirm this second substrate position and the arm automatically positions the camera over the first integrated circuit component to be placed.

5. The operator, using the control knob and trackball, aligns the chip to the crosshair and presses ENTER.

6. The system is now ready to display video overlay data. The operator presses OVERLAY 1 and the video graphic for that chip at that orientation is recalled from memory and displayed on the monitor. If the significant topography features do not match with the video graphic the operator presses OVERLAY 2.

7. This process continues until a match is found and then the operator presses ENTER. The arm automatically moves the pick up tool over the center of the chip, picks it up and places it on the substrate in the correct orientation.

8. The arm moves automatically from placing the chip to the next component location and the process is repeated.

VI. SYSTEM CABINET

The system cabinet is the support structure for all the previously described elements of the system plus the electronics, power supply, TV monitor, floppy disk drives, robot safety cover and the table top.

A generalized illustration of the total system is shown in Figure 8. Each system will be tailored to the individual needs of the user and can contain a variety of waffle packs or component feeders. The total number of component carriers and feeders will be limited by the maximum reach of the robot. The robot working area remains fixed regardless of the size of the user's system. The table top area and floor space requirements also remain fixed. The system size will be:

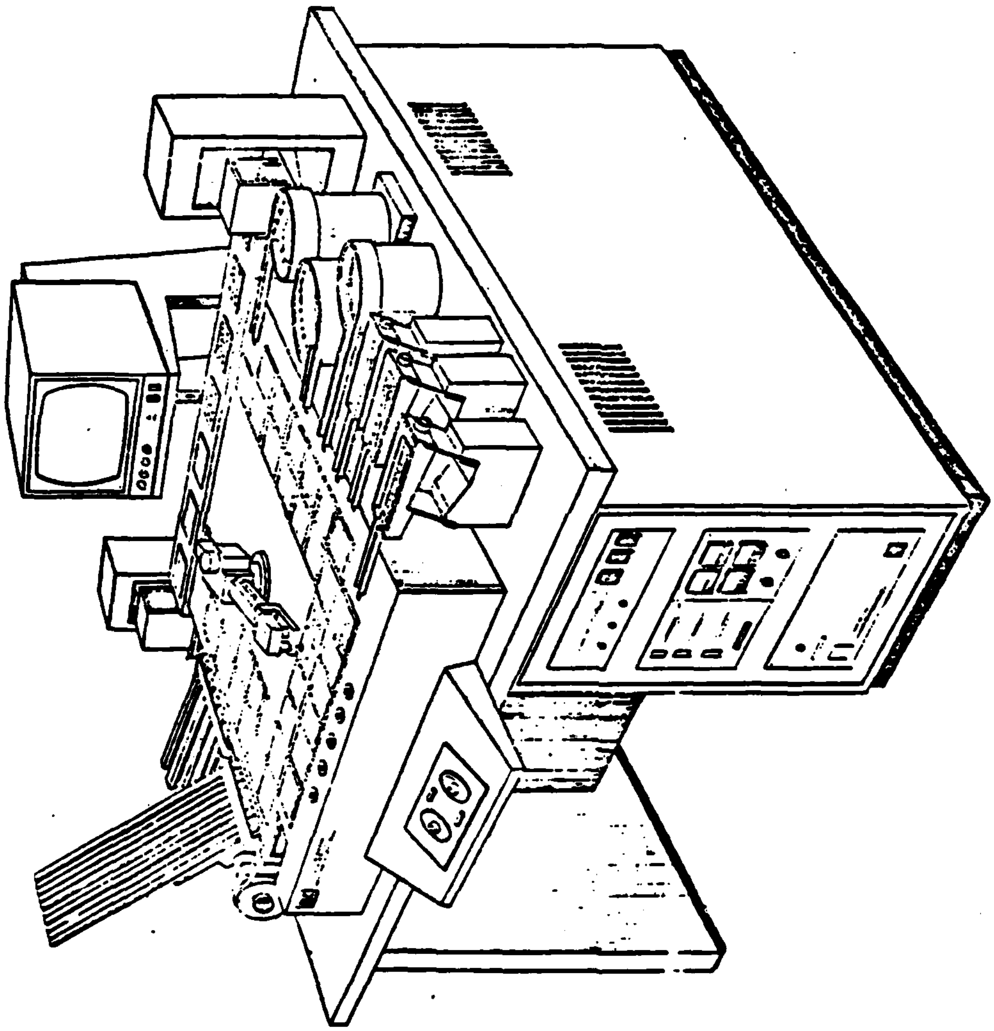
Length - 40 inches
Width - 38 inches
Table Top Height - 30 inches
Bond Plane Height - 36 inches
Vertical Height - 56 inches

The cabinet is a frame type structure built of welded 2 inch square, thin walled tubular steel. The flanged base of the robot will mount to the top of this frame structure along with the waffle pack trays and the table top. The vibratory component feeders will fasten onto the table top. The substrate handling system will also mount onto the cabinet frame.

The TV monitor is located above the robot and in line with the operator control panel. The monitor can tilt to adjust to individual operator's sight line preferences. Along side the monitor is a housing for the two floppy disk system. This monitor/disk drive assembly is supported by a tubular frame that is secured to the cabinet frame. The protective cover for the robot hinges onto the monitor frame and is counterbalanced for easy opening and closing. An interlock safety switch prevents operation of the system with the cover open.

All the system electronics are located in the cabinet beneath the table top. Access to the cabinet is thru a hinged door on the front, and removable panels on the other sides.

Most of the electronics are contained on 28 - 9" X 6" printed circuit boards. The boards are mounted in two 12" long swing out PC card modules. These modules are located directly behind the hinged front door of the cabinet. With this door open it is possible to replace or check all of the PC cards. Opening the hinged card module allows easy access to the PC board back planes.



SYSTEM CABINET

FIG. 8

Behind the card modules are the four robot servo motor amplifier boards. These are mounted to a heat sink assembly and are accessible thru the cabinet door or the side panel.

Behind the motor amplifiers is a fan housing to circulate forced air to cool the electronic components. The fan draws air from outside the cabinet, thru a filter, and a chamber in the base of the structure distributes the air to the necessary areas within the cabinet. The filter is mounted on the outside of the cabinet and is easily removed from the front of the system.

The power supply is mounted on the opposite side of the cabinet and is accessible thru panels on the left side and beneath the control panel.

Factory air and vacuum attach to input ports on the back of the system along with the AC power. The main circuit breaker, all fuses, air and vacuum controls and gages are mounted to the hinged front door of the cabinet.

The operator control panel is located on the left of center on the front of the system. The panel is 32 inches above the floor and can be conviently operated while standing or while sitting on a 21 inch high stool. Eighteen inches of leg clearance is provided under the control panel.

SECTION III
VIDEO DESIGN

SECTION III

PRELIMINARY VIDEO AUGMENTATION DESIGN

PRELIMINARY VIDEO DESIGN

Table of Contents

I. INTRODUCTION

This is the third deliverable item on Hughes purchase order 6-932254-C-W4 to Establish Preliminary Video Design for an Automatic Hybrid Die Bonder System. The Video design employs an overlay technique where die pad locations or other salient features of die are presented simultaneously as an overlay on the actual video picture of a die being viewed through the camera system. This overlay will be used by the operator to orient the die prior to placement in the semiautomatic mode. Hereinafter the system is referred to as a Video Augmentation System (VAS).

II. OVERVIEW

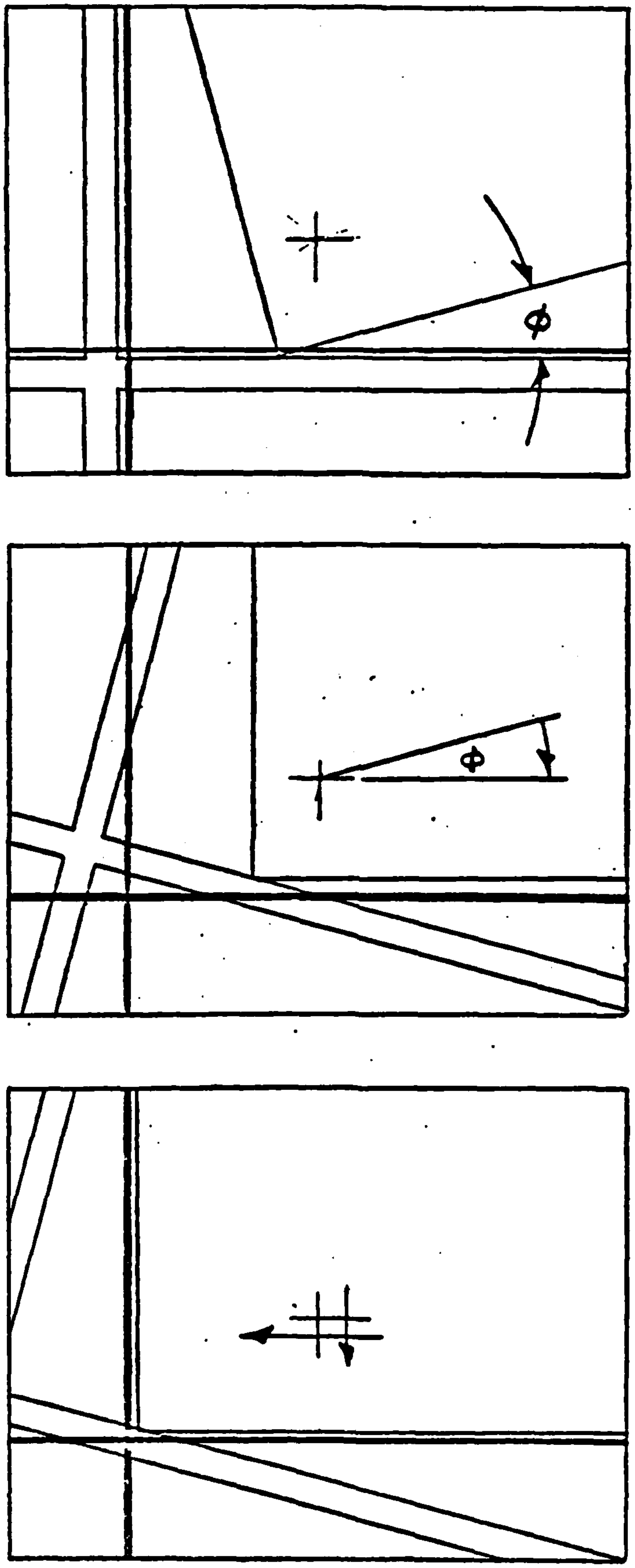
The Video Augmentation System (VAS) provides the important function of determining die location and orientation and substrate alignment. To accomplish these tasks will require a microprocessor based system with mass storage unit.

The substrate alignment will be performed by the operator aligning two known reference points on the substrate (from which all bond site locations are referenced) to crosshairs on the monitor. This is accomplished by positioning the SPAR arm with camera over the reference points and rotating the camera so as to coincide the crosshairs with the reference points. Thus, X-Y and rotational offset data from a pretaught standard can be input to the computer for any particular substrate.

The major responsibility of the video system is to determine die orientation in the waffle pack cavity. Since die can lie in a cavity with X-Y and Ø (rotational) offsets, the operator must first correct for these so the tool can pickup the die at its geometric center and place it with correct orientation on the substrate. Additionally, the die may be located in the waffle pack cavity 0°, 90°, 180° or 360° from correct pickup and, of course, upside down.

The X-Y and Ø offsets are first corrected by the operator moving the SPAR arm over the die cavity's left bottom corner. Using the crosshairs, the operator rotates the camera to correct for Ø offset and moves the arm to correct for X and Y offsets. (See figure 1.) Once these are corrected, the operator then calls up a graphic overlay feature that is used to determine die corner orientation.

For each type of die being used, there are four possible overlays. Each overlay corresponds to one-quarter of the die surface oriented so that the particular corner of the die is in the lower left of the field of view. (See figure 2.) The operator depresses one of four switches to bring up a previously stored overlay of that die. The operator then compares the overlay to the actual video picture of the die to ascertain if a match exists. If no match exists, the remaining switches are pressed in sequence. Once a match is found, the operator presses the ENTER switch and correction data is then fed to the host computer which instructs the SPAR arm as to the exact location of the die for pickup. If no match is found (wrong die or upside down), the operator presses the CONTINUE switch and the SPAR arm will automatically move to the next die cavity for the same die type.



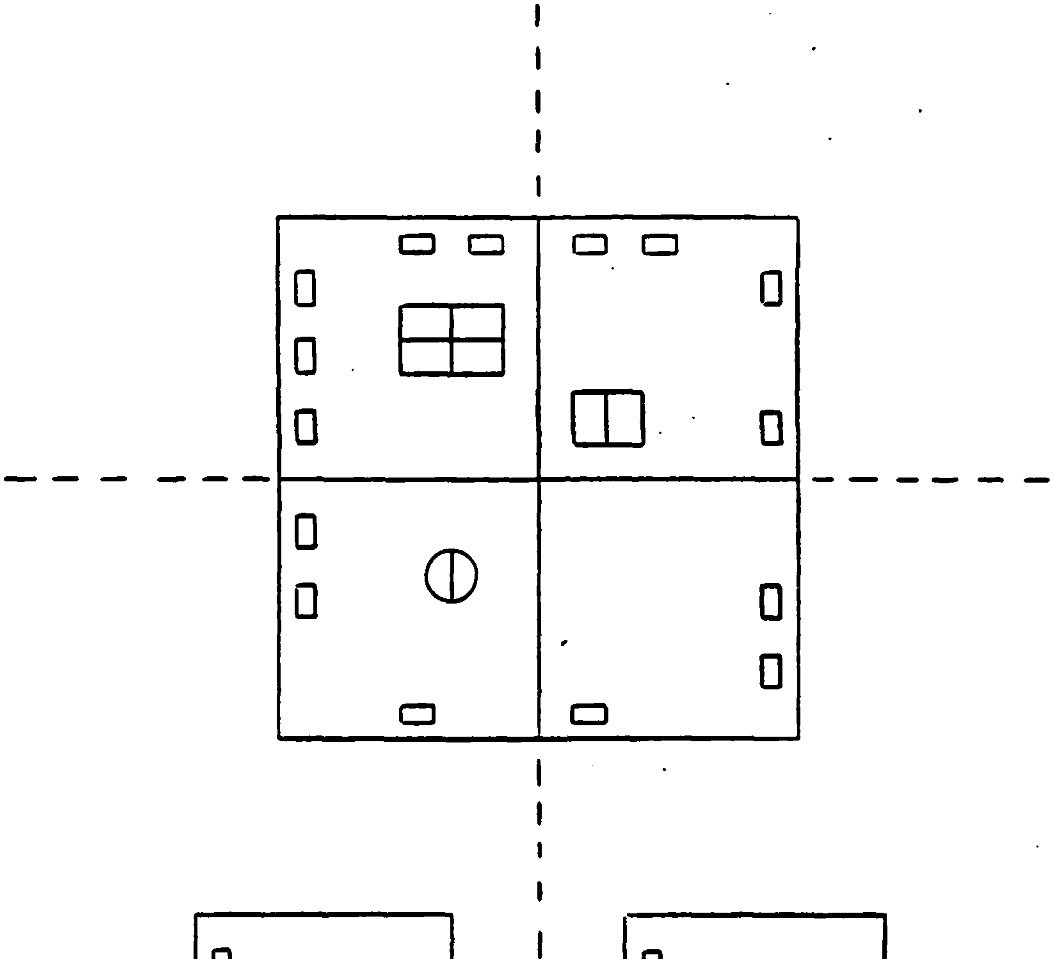
VIDEO IMAGE
AT START OF
CYCLE

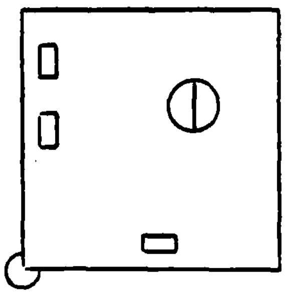
OPERATOR
ROTATES
CAMERA O DEG.

OPERATOR
MOVES ARM IN
X,Y

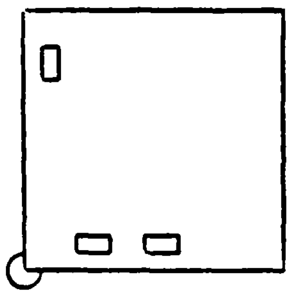
FIGURE 1. DIE/WAFFLE PACK ALIGNMENT

FIG 2 DIE OVERLAY INFORMATION

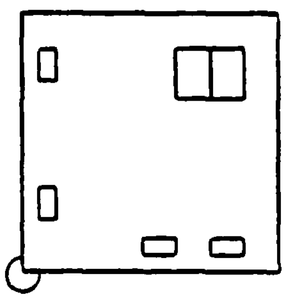




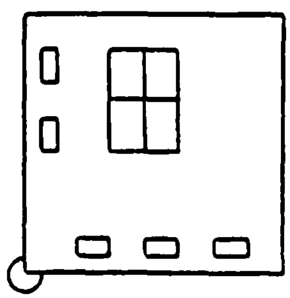
0° ROTATION



90° ROTATION



180° ROTATION



270° ROTATION

The data base for the overlays is built by constructing a series of rectangles around die pads using the chessman knobs interconnected to the video display via a software routine. This is done for each die quadrant and will uniquely identify that section of the die. Once formulated on the display screen, the operator presses the STORE QUADRANT # switch and the data is stored on a floppy disk.

The overlay technique will be capable of storing data on fifty different die through the use of the die bonder system floppy disk. Hence, once the data is taught, it will be maintained for the duration. Additionally, provisions will be made to access this information from an external host computer using CAD/CAM based information.

It should be noted that the overlay technique is intended only to provide die orientation data for the operator to use, and is not capable of reliably verifying die type by part number. This is because with hundreds of different die, the geometry of die pads and conductor lines can, in many cases, be nearly identical for the field of view being used.

The VAS will be an external peripheral slaved to the Main Processor. Communication will be through a RS-232 serial interface. The VAS program will be down-loaded from the Main Processor at system initialization. VAS will have the capacity to store and manipulate up to 50 different chip types, with each chip type having as many as 4 views. Communications protocol will be a generalized system protocol for serial links. Control of the cursor and edit features will be through the Main Processor Control Panel. Runtime storage of overlay images will be in the VAS memory.

III. MODES OF OPERATION

The system will perform its duties in four operational modes:

1. INITIALIZATION
2. DIAGNOSTIC
3. ALIGNMENT
4. TEACH / EDIT

In each of these modes the Hybrid Die Bonder will interact directly with the operator and relate operations to the Video Augmentation System. Therefore, a complete and concise set of command/response interchanges is to be defined for each operational mode. It is the responsibility of the Bonder to lead the operator through the proper operations of each mode. Therefore, the VAS will perform in a modeless fashion processing discrete commands provided by the Bonder.

IV. INITIALIZATION MODE

This mode is entered automatically at system power-up. The control program which performs the initialization operations will be contained in a Monitor Control PROM. The functions performed by initialization will be to execute a set of power-up diagnostics and facilitate the loading of the operations program by the Main Processor.

V. DIAGNOSTIC MODE

This mode is entered to evaluate the correctness of the VAS operating environment. It may be invoked by the Bonder operator or service technician if the VAS is operating in an inappropriate manner. The diagnostic tests which are available are of two classes:

A. BUILT-IN

1. Communications Link

2. Monitor Prom

3. RAM

B. LOADED FROM MAIN (These may require operator assistance)

1. Video Ram Test

2. MPU Test

3. Bonder-To-VAS Command Test

4. Video Multiplex Test

5. Other tests to be determined

VI. ALIGNMENT MODE

This mode is used to aid the operator in determining the orientation of the current chip being presented. The commands to be used for alignment are:

1. Display Chip/View

2. Remove Overlay Display

A. Display Chip/View

This command is used to select a specific overlay for display. The Bonder will anticipate which chip is expected for alignment and request the VAS to display an overlay view for this chip. The operator may request the "next" and "previous" view for display and the Bonder will issue the proper display request to the VAS. It may be possible to request alignment of a view which is not stored in the VAS memory. If this occurs the VAS will report the error to the Bonder for corrective action.

B. Remove Overlay Display

This command is used to clear all overlay information from the display screen. Use of this command will be to clear the screen in preparation for operation after the alignment process.

VII. TEACH / EDIT MODE

This mode is used to create a new overlay data set or modify details of an existing overlay set. This mode will be the most powerful and, therefore, the most complex mode of operation. Consequently, the number of commands related to teaching and editing is more extensive. The commands available to this mode are:

1. Remove Overlay Display
2. Display Chip/View
3. Load Overlay Data Base
4. Dump Overlay Data Base
5. Erase Overlay Data Base
6. Add Chip/View
7. Delete Chip/View
8. Add Box Figure
9. Delete Box Figure
10. Add Line Figure
11. Delete Line Figure
12. Move Cursor
13. Accept Point
14. Terminate Function

A. Remove Overlay Display

This command is used to clear all overlay information from the display screen. Use of this command is in preparation of creation of a new Chip/View overlay descriptor.

B. Display Chip/View

This command is used to select a specific overlay for display. This would be done in preparation of editing an existing Chip/View overlay descriptor. It may be possible to request alignment of a view which is not stored in the VAS memory. If this occurs the VAS will report the error to the Bonder for corrective action.

C. Erase Overlay Data Base

This command is used to completely remove the current overlay data set from the VAS memory. Use of this command is in preparation of initial teaching of a complete overlay data set.

D. Load Overlay Data Base

This command is used to load an entire Overlay Data Base set into the VAS from the Bonder's floppy disk storage. Use of this command causes the current overlay data set to be erased and replaced by the new overlay data set.

E. Dump Overlay Data Base

This command is used to cause the entire Overlay Data Base set to be transferred from the VAS to the Bonder for storage on floppy disk. Use of this command has no effect on the set of images currently stored in the VAS memory.

F. Add Chip/View

This command initiates action sequences in which a new view of a specified chip is taught. If the view is already stored in the VAS data set, it is replaced by the new view. If the view is not stored in the VAS data set, a new chip/view descriptor is created for it.

G. Delete Chip/View

This command is used to remove a specified view from the VAS memory. If the requested view is not stored in the VAS, an appropriate message will be returned to the Bonder by the VAS.

H. Add Box Figure

This command is used to initiate a series of actions which will add a new figure descriptor to the currently displayed overlay image.

I. Delete Box Figure

This command is used to remove a specified box figure descriptor from the currently displayed overlay image.

J. Add Line Figure

This command is used to initiate a series of actions which will add a new line figure descriptor to the currently displayed overlay image.

K. Delete Line Figure

This command is used to remove a specified line figure descriptor from the currently displayed overlay image.

L. Move Cursor

This command is used to move the displayed cursor to a new position on the display screen. The cursor may be moved to an adjacent display cell or to an "home" position.

M. Accept Point

This command is used to indicate that the cursor is at some desired position which is contextually defined by the process being performed. If the process is "Add Box", this command is used to identify to the VAS that the cursor is positioned on a corner of the desired box. If the process is "Delete Line", this command is used to identify to the VAS that the cursor is positioned on one end of the desired line.

N. Terminate Function

This command is used to designate to the VAS that termination of the current multi-step process is to be aborted. This function causes all such functions to be terminated in such a way so as to leave the previous overlay image unchanged.

END

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