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PROCESS DEVELOPMENT FOR AUTOMATED SOLAR CELL AND MODULE
PRODUCTION

Task 4: Automated Array Assembly

Quarterly Report No. 2

By
C. R. Witham

July 14, 1978

MASTER

MASTER

Work Performed Under Contract No. NAS-7-100-954882

MBAssociates
San Ramon, California

U.S. Department of Energy

Solar Energy

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PROCESS DEVELOPMENT FOR AUTOMATED SOLAR CELL
AND MODULE PRODUCTION
TASK 4: AUTOMATED ARRAY ASSEMBLY

Quarterly Report No. 2

JPL Contract No. 954882

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PREPARED BY: C. R. WITHAM

REPORT DATE: JULY 14, 1978

The JPL Low-Cost Silicon Solar Array Project is sponsored by the U. S. Department of Energy and forms a part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DoE.

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ABSTRACT

The objective of this program is to develop the process and handling technology required to allow large volume, low cost terrestrial solar array production. During this reporting period process emphasis has been placed upon edge molding of finished panels, cell layup and inter-connection into arrays, and aluminum back contact technology. These three technologies show promise for improved panel performance at lower production costs. Work during this reporting period has also involved critical technological and economic analysis of a proposed process sequence. Analyses indicate that this processing sequence will allow production at the price goals for 1986 in the areas of cell and panel manufacturing.

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1.0 INTRODUCTION

Work during the second quarter of this contract has continued in development of automated processes for solar cell and module manufacturing lines. Development is being directed at the refinement of process sequences currently being used in production. This is done to provide cost and price reductions to photovoltaic arrays being produced now and in the near future as well as providing techniques to upgrade manufacturing facilities to meet the future high volume, low price goals. Special emphasis is being placed upon process steps which show promise for manufacturing cost reductions with equal or improved system performance. The major effort has been directed toward plasma etching techniques, back contact metalization, panel edge sealing, automated cell array layup/interconnect, and increase of manufactured cell size.

Plasma etching techniques have been exploited for automated, dry process removal of the front to back current path present after a furnace diffusion process. Contract metalization is an area of current (and future) cell production which represents a large percentage of the added cost to a wafer during cell making. Metalization also represents an area which can have an effect upon the useful life of an array through contact corrosion characteristics. Panel edge sealing (though a relatively low cost item) does show some possibilities for cost reduction and improved performance. The improved performance potential involves a vapor tight seal which can improve the life of the panel by protecting against vapor migration from panel edge to interior, and it can also guard against delamination of the panel assembly at its edges and corners. Array layup and cell interconnection has been seen to be a labor intensive process of current production facilities. Efforts with this process are therefore being directed toward short range benefits as well as development of some long range technologies. Baseline cell size directly affects the quantity throughput of materials through cell making and panel layup processes. Some process parameter variation is expected when using larger cell sizes, and therefore these variations have been the subject of some study.

Economic analysis using the SAMIS system has been initiated during this period to assure that development efforts are being directed towards the ultimate goal of price reduction.

2.0 TECHNICAL DISCUSSION

2.1 Overall Process Development

The baseline process sequence and each process step within this sequence were described relative to functions of each step, input/output requirements, materials requirements, and automation constraints, in the first quarterly report under this contract.⁽¹⁾ Some changes to these descriptions have come about as a result of further developments and experimentation of a few of the processes. These changes to the process step descriptions will be detailed and updated as the work which has been done is described below.

2.2 Plasma Etch Techniques

The proposed cell making process sequence includes a chemical vapor deposition and diffusion step to provide junction formation. The technique used to mask the back of the wafer from receiving a large quantity of dopant is to diffuse the wafers with two inserted in each quartz cassette slot. In this manner the wafers mask each other. The edges of the wafers receive a large quantity of dopant, and the backs of the wafers receive a varying dopant layer which falls off to zero at the center of the wafer back. This imperfect masking provides a current short of the cell front to back and must therefore be removed. Conventionally this has been removed through the use of a wet acid back etch. The desire to remove the requirements for an intermediate wet etch step has led to investigations of other techniques. Arco Solar, Inc. (ASI) originally proposed the substitution of plasma back etch for chemical wet etch. During experimentation with back etching, it was found that the desired performance could be arrived at by removing only the diffused edge of the wafer. This technique removes a back etch process, but adds a plasma edge etch.

Several techniques for materials handling through such a station could be used. Edge etching in a moderate size plasma etcher requires approximately a 20 minute sequence. The wafers must be placed

in the etcher, and a vacuum pulled upon the chamber. The chamber is then backfilled and a plasma is generated with the etchant. One technique which can be used to mask the front and back surfaces from being etched during the process is to design a carrier which holds a stack of wafers with the front and back surfaces of adjacent wafers in contact. Loading into and out of the plasma etcher could be done manually or with an automatic loader/ unloader.

Plasma edge etch appears to be a more convenient and lower cost process. Further study must be directed at throughput rates plausible, and etcher size and costs. ASI is currently using this technique in production with excellent results.

2.3 Back Contact Metalization

During this period work has begun in the area of back contact metalization using aluminum paste. Aluminum contact techniques bring about a greatly reduced cost over silver thick-film printing. They can also provide a P⁺ doped back for enhanced cell performance.

Using screen printed aluminum paste creates an acceptor gradient at the back surface which has been shown to cause:

- 1) an increase in open circuit voltage for resistivities greater than 0.8 ohm-cm
- 2) enhanced long wave length response
- 3) an improved curve fill factor
- 4) reduced back contact resistance from the highly doped base region
- 5) elimination of output dependence on thickness for cells greater than 0.15mm thick
- 6) elimination of high intensity voltage saturation (2),(3) without compromising efficiency due to voltage loss.

These features permit utilization of a wide range of silicon material resistivities.

The low sheet rho back allows the possibility of using the aluminum paste as an alloying media, and not as the contact itself. The aluminum paste can be printed and fired, and the aluminum which has not alloyed with the silicon would then be etched away. A gridded silver contact can then be screen printed as the back contact.

The advantages of this type of metalization system are:

- 1) Cost of the contact metalization is considerably reduced over that of a full silver contact
- 2) Cell interconnect is made to silver rather than aluminum, but the P+ aluminum situation is still present
- 3) Long wave length light that would normally be absorbed at the back contact and cause heat generation is allowed to penetrate the device. Thus the cell runs at a slightly lower operating temperature.

These processes have only been successfully applied (thus far) in a non-production basis. The paste was printed in small lot quantities and dried in a forced air convection oven. The actual alloying was performed in a quartz tube with high gas flow rates, rapid insertion and removal (one second) with dwell times on the order of 30 seconds. No more than five wafers were alloyed per cycle. Our present effort is directed towards mass production techniques for firing the aluminum paste. Significant process variables for accomplishing this transition which must be understood and controlled include:

- 1) gas flow and oxidation product removal during firing - slight variations in oxygen partial pressure can cause alterations in the alpha or beta phase formation
- 2) drying must be carefully regulated to remove almost all binder and thus prevent carbon contamination of the aluminum - silicon alloy.
- 3) a rapid heating is necessary to achieve the maximum in exothermic assisted temperature rise for the back side of the cell

- 4) a quick cool provides an optimal junction gradient to achieve maximum short circuit current response
- 5) contamination from the firing equipment should be minimized to the maximum extent possible
- 6) cooling must occur from the front side inward to promote the formation of a proper re-growth region.

This last requirement makes use of a conventional conveyor-belt furnace difficult. It is logical to place a wafer face-down on the belt; however, the belt is a heat sink which causes crystallization to be initiated from the wrong direction.

To test for the feasibility of conveyor belt firing, a small lot of 10 ohm-cm (nominal) wafers were printed and dried on in-line production equipment. The firing furnace was set to obtain a matrix of belt speeds and temperatures and the wafers were alloyed. Although a low p^+ surface sheet resistance was obtained (3 ohms per square), no voltage enhancement was observed on the completed wafers. This was probably a direct result of improper re-growth.

Since a simple one step technology transfer from tube to conveyor belt is not possible, a multiple-step set of transitions has been outlined to accomplish the task of mass production implementation.

2.4 Panel Edge Sealing

The panel edge seal, though a relatively simple element, has the potential for increasing the resistance of the array to the environmental conditions. Several types of sealants have been considered thus far, with the major driving factor being material cost. With satisfactory sealant performance, cost is the ultimate selector.

Preliminary applicability, adherence, and moisture resistance tests have been performed with a number of possible sealant types. These tests were performed by applying the sealant to strips of mylar (the more difficult element of the laminated assembly to adhere to) under various preparation conditions. Table 2.4-1 gives the sealants experimented with during this period along with preliminary results and performance judgements.

TABLE 2.4-1

SEALANTS TESTED

SEALANT	MFG.	TYPE	HOW APPLIED	RESULTS
Hydro-Seal	American Energy Group	Acrylk-Latex	Dipped	Did Not Adhere To Mylar
Acrylic Cement	Tap Plastic	Acrylic	Dipped	
12-355	Swift		Heated then Dipped	
12-069	Swift		Heated then Dipped	
Sealer 5354	3M	Synthetic Rubber	By Hand	
Industrial Sealant #612	3M	Oil Resistant Elastomer	By Hand	Adheres After 30+ Minutes
Industrial Sealant #801	3M		Spachula	Takes 7 Days to Cure
Thermo-Seal #801	Dist. By H. B. Fuller	Butyl	By Hand	Excellent Adhesion Excellent Drying Time
Butyl Rubber Sealant	National Adhesives	Gunnable Butyl Rubber	Gun Applied	Good Adhesion Remains Flexible

The hot melt systems appear to be the most applicable, with the butyl based type performing especially well. The 1081 Butyl manufactured by the HB Fuller Co., shows much promise. Appendix A gives some performance data for this type of sealant.

These sealants have also been used extensively for hermetic sealing of thermo-pane insulating windows. Performance requirements for insulated glass are similar to those for edge sealing of solar modules. Sigma (Sealed Insulated Glass Manufacturers Association) has set up accelerated weathering tests for insulated glass. CE Glass, a manufacturer of insulated glass has performed extensive testing of HB Fuller 1801 butyl sealant comparing its performance to polysulfide. Appendix B gives the Sigma weathering test procedures as well as the CE Glass test procedures used for the butyl weathering tests. The less expensive butyl (approximately \$1.25 per pound) was shown to perform better than the polysulfide in all cases.

Further testing of these sealants will be done by applying them to small pieces of the laminated solar panel assembly. This will be done during the next period.

Automation of this process is dependent upon the type of sealant considered. With some of the sealants, the panel edges must be dipped into a bath of the liquid mixture. Others can be applied by extruding the sealant onto the panel edge, and the hot melt sealants can be applied by extruding the molten sealant through a heated nozzle. Application techniques are also affected by the type of edge frame used, and how it interfaces with the sealant. If a small channel is used, the sealant may be applied to the channel, and the channel could then be assembled to the edge of the module. Experimentation using channels to contain the sealant will be performed during the next period.

Application equipment for the hot melt sealants is available in component form off-the-shelf. This equipment is well developed for high production throughput due to its use in the packaging industry (box or label gluing, automated assembly). The components available must be

integrated into the proposed production line. Components are available from various manufacturers (see Appendix C). A central location will take the raw sealant and heat it to a molten state. This station also pumps the liquid through heated lines to the extrusion heads. As a panel comes down a conveyor, its leading edge is detected by a photocell system. This initiates the extrusion of a bead of sealant on both sides of the panel simultaneously. This extrusion can be controlled as to volume and speed, and should be carefully synchronized with the conveyor motions. The trailing edge of the panel is detected by another photocell system, and a valve in the extrusion head terminates the bead. The panel ends can be sealed at the same time by a head which moves along the conveyor axis and applies a bead to the panel in a direction transverse to the conveyor. Another technique which could be used is to turn the panel 90° on the conveyor and apply the sealant to the ends in the same manner as the sides.

This type of sealant can also be applied by hand using a low cost pump unit and hand held gun. This allows this process improvement to be used in production to reach some of the interim guidelines for 1980.

Hot melt sealants become cured enough for handling in about five to ten seconds and therefore they are well suited to the high throughput desired. The target of 190 panels/hour appears to be an achievable goal with this technique.

2.5 Array Layup and Cell Interconnect

Studies have been continued during this period in the area of automated array layup. This effort has focused on reaching some of the interim guidelines by using lower cost off-the-shelf type of equipment to handle the lower production throughput. Studies indicate that programmable automation (industrial robots) is applicable to this type of production. Hard automation, however, should probably be used for the high volume goals (500 megawatts per year). Industrial robot system characteristics available and desired handling tasks have been determined. It is desired to use an

industrial robot to place cells (and possibly interconnect elements) into their panel array. The system which appears to be general enough for this handling task, and which may possibly be used for other handling tasks within the process sequence is the Unimate 2000 series industrial robot. Some performance data for this robot is given in Appendix D. Initial experimentation with this system will begin during the next period.

Conceptual studies have also been started to determine appropriate tooling and/or sensors to be used in conjunction with an industrial robot to provide wafer handling and placement capability. These studies are only preliminary at this stage, and will be continued through the next few months. Accuracy required for the desired tasks must be determined, and means of achieving this accuracy must be implemented. The work recently done at SRI International is applicable here. ^{(4),(5)} SRI has taken a Unimate robot and added tooling to the end effectors to allow active or passive detection and compensation for component inaccuracies. Sensing elements could be added to an end effector to insure that a cell is placed within the desired accuracy in the array.

Conceptualization of operating systems with appropriate end effectors is being done. A system which appears to be applicable for panel, layup would involve a special end effector (hand) which would include a cassette unloader. This technique would minimize the motions for pick and place to picking up a cassette (or a number of cassettes) and unloading the cells at each laydown location. Initial estimates indicate that a four foot by eight foot array could be layed up in this manner at an average time of approximately two sec/cell.

Development work has also been done in the area of vacuum pickup of individual cells. It has been found that the vacuum device porting must be carefully designed due to the flexible and fragile nature of the thin silicon wafers. Individual pickup is probably too slow for most of the desired tasks, however, the vacuum techniques can be used for pickup of multiple cells simultaneously.

Assembling an array of cells also requires interconnection of the cells as an integral part of the process. Two directions are possible to provide this capability. The first is to use an individual interconnection head (solder, ultrasonic bond, etc.) which travels to each cell location. This could be made cost effective if the interconnection head was made an integral part of the end effector. In this manner, a cell would be placed and interconnected during the same operation. A slightly longer time at each array location would be required.

The second approach is through the use of solder reflow techniques. In this way an array of cells and interconnect elements (if used) could be heated in a controlled atmosphere furnace, and the array would be interconnected through one operation. Cell "shingling" techniques (connecting cells back-to-front without an interconnecting element) are also possible in a reflow mode. For reflow, solder could be applied to the cells by dipping, screen printing, or applying solder paste prior to the reflow process.

Preliminary studies have been performed in the area of furnace reflow solder of shingled cells. This effort is only in the early stages, but the process shows some promise. Further experimentation will be performed and reported later.

2.6 Large Cell Production

Study has begun at ASI in the area of production parameter variation required when processing four inch cells. Major areas of focus will be in the process of etching and cleaning, diffusion, and screen print and firing. Initial results indicate that etching should not require too much process change. Recently ASI increased batch sizes of three inch wafers with only minor modifications required. No significant problems were encountered during the transition to etch tanks containing ten times the volume of solution used previously.

A new diffusion furnace capable of accepting a six inch process tube was installed during this period. Diffusion of batches of four inch wafers will be performed during the next period. Printing and firing of four inch wafers will also be initiated during the next period.

Economic Analysis

Analysis work has begun using the SAMIS Computer Program. A model has been produced of the baseline process sequence (see Reference 1), including models of the industry environment and the required companies for the 1986 production goals.

Files of these companies and processes have been implemented on the National C.S.S. system using the SAMIS Program. A number of problems have been encountered with file management of the model files. A few bugs and unit changes have also been found in the program which have caused some problems. Due to these factors, a successful simulation has not been performed as yet. It is expected that a full process simulation will be performed in the near future. A SAMICS (as opposed to SAMIS) analysis was performed previously, however, and the results were reported in the first quarterly report⁽¹⁾.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Critical review and verification studies have continued in the areas of plasma etch, aluminum back contact, panel edge sealing, automated array layup/interconnect, and production variations due to large diameter wafers.

Work in plasma etching has reached the conclusion that plasma edge etching is superior to back etching. Verification of this process has been made with production lots of 1000 being processed with a plasma edge etching technique. Performance of the resulting cells are comparable to those cells being processed in a wet chemical back etch line. Continued production lots are being run using the plasma process. It is recommended that complete economic analysis be performed in the SAMIS system to fully characterize the plasma etch process.

Aluminum p+ back contacts have been produced in small lots, but some problems have been encountered in direct application to production size lots. The required parameters will be varied in a methodical step-by-step procedure to allow firing in a belt furnace. This process has much potential for reduction of costs as well as improved performance. It is therefore recommended that the study be continued in order to implement the process.

A hot melt butyl based sealant appears to be the most applicable for low cost panel edge sealing. Automation equipment could be designed to allow rapid application of the sealant and/or frame.

Automated array assembly appears to be feasible using an industrial robot for moderate production throughputs. Further work in this area will be performed using an industrial robot to layup panels of various sizes. An advantage exists in using programmable automation in that one piece of equipment could be used to assemble various panel models merely by changing the program being used by the robot. Solder reflow in a furnace shows some promise for completing interconnections of an array in one operation, and it is therefore recommended that further work be applied in this area.

Work with four inch diameter cells in a production mode is just beginning, but initial results indicate that a transfer to four inch cells in a wet etch sequence should pose no problems.

4.0 NEW TECHNOLOGY

No new technology has been developed to completion during this period.

REFERENCES

- 1) DOE/JPL-954882-78/5 Process Development for Automated Solar Cell and Module Production, Quarterly Report No. 1, 18 April 1978.
- 2) Charles F. Gay, Development of High Efficiency, Radiation Tolerant, Thin Silicon Solar Cells, JPL Contract No. 954600, Final Report October 1977.
- 3) Charles F. Gay, Thin Silicon Solar Cell Performance Characteristics, Thirteenth Photovoltaic Specialists Conference.
- 4) C. Rosen, et al, Machine Intelligence Research Applied to Industrial Automation, Sixth Report, November 1976.
- 5) C. Rosen, et al, Machine Intelligence Research Applied to Industrial Automation, Seventh Report, August 1977.

APPENDIX A
Butyl Based Sealant Characteristics

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REQUIREMENT: Develop a new base sealant for sealed insulated glass with three primary benefits:

1. The seal should have outstanding MVT values and peel adhesion; resistance to weathering and elongation; and allow the manufacturer to extend his warranty.

2. Elapsed time between production and shipping should be significantly lower than with conventional sealants.

3. The sealant, and its method of application, should be cost-effective: that is, the sealant should be significantly lower in cost per gallon than existing sealants, and the way it is used should enable the sealed insulated glass manufacturer to produce units so efficiently that many of his manufacturing costs can be reduced.

It is the third benefit, cost-effectiveness, that can determine how efficiently insulated glass is produced.

The sealant system that combines technological advances with visible cost-effectiveness will satisfy both manufacturing demands and customer demands. It will make its own case with manufacturers, based on its efficient sealing properties and its money-saving abilities.

PRODUCT: A sealant with these three primary benefits is now available.

It's H. B. Fuller Thermo-Seal 1081, the new Butyl hot-melt sealant developed specifically for insulated glass. It includes a number of high-technology advances.

CHEMICAL BASE — Butyl. COLOR — Grey. TESTED UNDER SIGMA SPECIFICATION — 65-7-2. YEAR — 1974. STATUS — Passed.

MOISTURE VAPOR TRANSMISSION: a) Lower than the Butyl commonly used to manufacture double-seal windows.

b) A single application shows MVT values better than the combination Butyl/polysulfide construction.

DEAD LOAD SLUMP TEST: Greater resistance to Dead Load Slump than existing thermoplastic hot melts.

ELONGATION: Over 1000% elongation as measured on an Instron testing machine with corresponding tensile strength significantly better than polysulfides.

OVERLAP SHEAR TEST: Several times higher in shear strength when compared to existing thermoplastic hot melts, and approaches the values obtained with polysulfides.

PEEL ADHESION TEST: Considerably better adhesion to glass and aluminum than polysulfides and comparable to other thermoplastic hot melts. Test method: TTS-00230-C.

TOXICITY: Requires no toxic or hazardous catalyst to effect cure.

Thermo-Seal 1081 is a Butyl sealant. This sealant, used in the sealed insulated glass industry, has provided manufacturers with good adhesion, good peel strength; a high resistance to weathering and to ultraviolet breakdown; high dead load slump resistance; and more than 1000% elongation with corresponding tensile strength

significantly higher than polysulfides. Overlap shear strength is also correspondingly high.

Thermo-Seal 1081 is a one-component Butyl sealant. Unlike other sealants, Thermo-Seal 1081 has no solvent content. There is no evaporation of partial components, which eliminates toxicity. Thermo-Seal 1081 is 100% solids, which restricts sealant breakdown over long periods of time. Thermo-Seal 1081 maintains its stability, and its adhesive qualities, throughout the estimated life of the window unit.

Thermo-Seal 1081 is a hot-melt Butyl sealant. The application of the sealant in this way offers an exceptionally flexible seal that sets very quickly. The hot Butyl exhibits excellent flow characteristics, and its quick set eliminates sealant crystallization. In addition, hot-melt Butyl gives the sealed insulated glass manufacturer a seal with a considerably lower Moisture Vapor Transmission characteristic.

Thermo-Seal 1081, then, is a one-component, Butyl hot-melt sealant that offers the manufacturer the following product benefits:

- Excellent sealing qualities
- Extreme stability
- Low MVT value
- No toxicity
- Long life

SYSTEM: When Thermo-Seal 1081 is considered as part of a system, it offers the sealed insulated glass manufacturer a good opportunity to capitalize on cost-effective unit fabrication.

Because of Thermo-Seal 1081's superb qualities, double-sealing can be eliminated. This allows the manufacturer to simplify his production line. And one-component Thermo-Seal 1081 eliminates the need for complicated two-pump application systems, as well as the problems inherent in two-component sealant balancing, handling, and quality control.

Because Thermo-Seal 1081 is used in a hot-melt form, application is fast. However, the real test of effectiveness comes from the window unit's "ready time"—polysulfide sealants must be allowed to cure for several hours, perhaps longer. Thermo-Seal 1081 Butyl sets in minutes; clean-up can be accomplished at the work-station; and the window unit is ready for shipment as soon as it comes off the line.

H. B. Fuller is able to offer the equipment necessary to ensure proper and profitable application of Thermo-Seal 1081 to the sealed insulated glass industry.

Thermo-Seal 1081 allows the sealed insulated glass manufacturer to take advantage of several cost-effective system benefits.

- The ability to produce sealed window units in less total elapsed time
- The ability to control product quality on-station
- The ability to lower production costs due to equipment simplification
- The ability to lower total unit costs due to increased production-line efficiency

APPENDIX B

Accelerated Weathering Test Specifications

for Sigma and CE Glass

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COMPARISON OF CE GLASS REQUIREMENTS VERSUS SIGMA REQUIREMENTS

SIGMA Requirements

A. The new SIGMA requirements are summarized as follows:

1. No failure of 9 out of 10 units at partial vacuum of 3.0 inches of mercury for 2 1/2 hours at 75°F.
2. Initial Dew Point -60°F
3. Accelerated Weathering
 - a. 2 weeks @ 140°F and 100% R.H.
 - b. 240 cycles which include
 - i. 2 hrs. @ -20°F
 - ii. 1 hour spray @ 140°F
 - iii. 1 hour dry U.V. @ 120°F
4. Summary

The accelerated weathering summary is as follows:

- a. 2 weeks @ 140°F and 100% R.H.
- b. 240 cycles from -20 to 120°F
- c. 240 hours dry U.V. at 120°F
- d. 10 days spray @ 140°F

B. CE GLASS Requirements - 8 weeks of testing - 2 weeks in each apparatus

1. Initial Dew Point -60°F
2. 50,000 cycles at 150°F and 100% R.H. and $\pm$ 8 inches of water pressure/vacuum cycling
3. 2 weeks at 150°F and 100% saturation plus continuous U.V. exposure
4. 2 weeks at Dry U.V. at 150°F continuous
5. 70 cycles from 0°F to 105°F

C. Summary

1. Both SIGMA and CE GLASS have identical requirements for initial Dew Point.

2. SIGMA tests each unit once for partial vacuum, CE GLASS subjects each unit to 50,000 cycles of partial vacuum and pressure at 150°F and 100% R.H. which greatly exceeds the SIGMA requirement.
3. SIGMA gives each unit 240 cycles of -20°F to 140°F while CE GLASS subjects each unit to 70 cycles from 0°F to 150°F. The increase in temperature of 10°F is equivalent to a .7X factor (each 15°F rise doubles the rate of chemical activity) so that 70 cycles at 150°F is equivalent to 120 cycles @ 140°F. It is felt that the CE GLASS test is more rigorous because of the higher temperature.
4. SIGMA subjects units to a total of 240 hours at dry U.V. at 120°F - while CE GLASS subjects units to 336 hours of dry U.V. at 150°F.
5. SIGMA subjects units for 24 days at 140°F and 100% R.H. - while CE GLASS subjects units for 2 weeks at 150°F and 100% R.H. while the units are continually exposed to U.V. light.

D. Conclusion

In all aspects of testing CE GLASS subjects the units to a more rigorous test cycle than the SIGMA spec. tests. It is felt that 8 weeks of testing in the CE GLASS test cycles is considerably more rigorous than the SIGMA specification requirements.

APPENDIX C

Hot Melt Application Equipment Manufacturers Data

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UNI-FLOW

Break through in application technology for high volume — high viscosities.

The Uni-Flow system was designed to handle high viscosity thermoplastic sealants and adhesives while solving the problems associated with previously available systems. The technological advances incorporated in the Uni-Flow system allow it to melt down and deliver hot melts under nearly ideal conditions for top performance.

**If You Couldn't Pump
Before, You Can
Pump Now!**

**Pumping - Metering - Dispensing
from 55 gallon drum. Molten
viscosities from 1,000 cps to
9,000,000 cps.**

MODEL S.P.

PATENTED

Advantages of the UNI-FLOW System . . .

- positive displacement—no skips or gaps in the bead
- faster throughput than other systems—up to 20 lbs./min.
- takes standard 55 gallon drums—save expense by allowing the user to buy in less expensive bulk form
- positive heat control at all zones—virtually eliminates burn-up of material and burn-out of the equipment in hot spots and applies the hot melt at optimum temperature —100°F to 500°F continuous
- can be adapted to automatic extrusion systems

Developed & Manufactured By:

INDUSTRIAL MACHINE MANUFACTURING, CO.
1005 Holly Spring Road
Richmond, Virginia 23224

804-232-5661

Features:

METER READOUT

Provides a continuous readout of each of the eight temperature zones by use of a platinum resistance sensor common to the controller circuit (i.e. meter reads the exact temperature sensed by the controller).

RUN/STANDBY SWITCH

This switch turns the unit back to a lower pre-set "stand-by" temperature during non-use periods, making it possible to bring the unit up to operating temperature within five minutes after returning switch to the "run" position.

HEATED FLEXIBLE HOSE

The hose incorporates an internal electric resistance heater which is in direct contact with the material (not a wrap around type heater as in conventional hoses). The heater is actually inside the teflon liner of the metal braided hose. This produces much more efficient heat transfer than in conventional hoses, thus permitting higher material temperatures without overheating or degrading the teflon liner. The material temperature is precisely controlled by a platinum temperature sensing probe also located inside the hose and in direct contact with both the sealant and the heating element. The meter reading of the hose temperature is actually a direct readout of the material temperature at the nozzle.

FOLLOWER PLATE

Newly designed follower plate contains 21 replaceable cartridge heaters producing a total heating capacity of 21.3 KW over 5400 square inches of finned surface area. A low watt density of six watts per square inch prevents localized material overheating, charring, cross-linking, etc.

HAND GUN

Capable of producing variable bead diameters with low force, finger tip control. The trigger has a special 12 to 1 force multiplier linkage permitting minute valve openings for the first half inch of trigger travel. This enables the operator to fill corners or start a bead without a large, surging glob. The hand gun also has an adjustable stop for producing a fixed bead diameter at full trigger travel, alleviating operator finger fatigue.

DISPENSING PUMP

The positive displacement gear pump dispenses up to 15 lbs. per minute with non-surfing flow at rated pressure for a smooth, gap-free bead.

TEMPERATURE CONTROLLERS

These specially designed plug-in, 2" x 2" solid state temperature controllers are capable of holding each of the eight heat zones to within 3° to 4°F. of set-point. A red light on the card provides easy visual inspection for proper functioning.

Specifications:

OVERALL SIZE:	width 32 inches; length (panel face to back post) 55 inches; height (beam fully raised) 116 inches.
WEIGHT:	900 lbs (empty)
AIR REQUIREMENTS:	80 psi minimum, 100 psi recommended, 150 psi maximum.
AIR CONSUMPTION:	less than 1 scfm continuous.

ELECTRIC SERVICE REQUIREMENTS:	208/240/480 vac, 3 phase, 100 amp entrance.
POWER CONSUMPTION:	63 amps/at 240 vac (start up only, 20 min. average start-up time); 31 amps (continuous dispensing)
TEMPERATURE RANGE:	100° to 500° F (continuous).
MATERIAL FLOW RATE:	approximately 15 lbs/minute at 50,000 cps; 1.2 lbs/minute at 9 million cps.
START-UP TIME:	20 minutes average (from 65° F).

Automatic Dispensing GUN Available.

Developed & Manufactured By:

INDUSTRIAL MACHINE MANUFACTURING, CO.
1005 Holly Spring Road
Richmond, Virginia 23224

804-232-5661

Pyles[®] therm-o-flow[®] III

HOT MELT APPLICATION SYSTEMS

- ☐ Pumping
- ☐ Metering
- ☐ Mixing
- ☐ Measuring
- ☐ Dispensing

Pyles Industries, Inc. through an extensive research and development program, has perfected a system for handling materials with a wide viscosity range at elevated temperatures. Materials with molten viscosities from 500 cps to 4,000,000 cps may be applied directly to the part from the original bulk shipping containers. No longer is there a need to handle reprocessed materials in block, chip, granular or pillow form in hopper type dispensers. Pyles Industries **thermo-o-flow III** will allow you to develop tomorrow's production methods and materials today.

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thermo-o-flow[®] III

PRODUCT INFORMATION

OPERATING PRINCIPLES

Material in its bulk 55 gallon shipping container is placed on the base plate of the unit. The elevator is lowered to bring the heated follower platen into contact with the surface of the material. The upper layer of the material is melted and with the assistance of the follower ram pressure, is forced into the pump. The heated pump then pressure feeds the material through a heat exchanger, heated hose and gun to the substrate. As material is pumped from the container, the elevator lowers automatically to keep continuous contact between the material and the heated follower platen.

SYSTEM FEATURES

- Handles any meltable material direct from the original 55 gallon shipping container.
- Heats only the material about to be used to application temperature in a completely closed environment. This demand heating principle eliminates induced polymerization, thermal degradation, and oxidation caused by uneven heat, bulk heating for extended periods, and heating in open atmosphere.
- Temperature control ranges from 0 to 450° F (235 °C). Accuracy is $\pm 1\%$ of the scale reading.
- The follower platen covers the material and protects it from the contamination and wipes the container clean of material.
- The system may be used to bulk feed existing hopper type units.

TECHNICAL DATA

- Heat is transferred by a cast-in element secured to the follower platen. The platen temperature can be maintained at $\pm 2\%$ of the scale reading. Adjustable in 10° increments from ambient to 400° F (205° C).
- Heating capabilities depend on the specific heat of the materials selected. The heat available at the follower is rated at 39,000 BTU. There are 630 square inches of effective heating surface below the follower platen.
- Basic pumping unit is a Pyles' standard 716-11-200 double elevator, double-acting 21:1 ratio chopping check pump. Ratios of 38:1 and 59:1 are available.
- Start up time for an entirely cold system is 30 to 45 minutes. Start up time when changing to a new drum is 7 to 15 minutes.
- For materials with application temperatures between 400° and 450° F (205° - 235° C), the standard five zone heating system may be used to increase the material temperature from the melting point to the final application temperature.
- Output rates must be determined for each individual material and application. Completing and returning the "Request for Quotation" form sheet will enable us to do this for you.
- Special units are available on request for applications requiring output temperatures in excess of 400° F (205° C).

SYSTEM COMPONENTS

23208	Basic thermo-o-flow III complete with 3" double elevator ram, heated follower platen and pump, air and
23240	electrical heating controls. Model number indicates
23380	voltage required.
23480	

A 5½" elevator ram is available for high viscosity materials. To specify, add — 50 to the base model number (e.g. 23240—50).

ACCESSORIES

23000-45	Heat Exchanger
23000-60	Low Material Level Indicator Kit
23000-61	Automatic Dual Pump Crossover Control
23000-65	7 Day Pre-Production Start Up Timer
23000-75	Tamper Proof Control Cover Kit

SPECIFICATIONS:

Air Supply	
20 SCFM at 90 PSIG	
Electrical	
3Ø; 208, 240, 380, or	
480 VAC; 50 or 60 Hz;	
14kW	
Dimensions	
Width	46" (116.8 cm)
Depth	25" (63.5 cm)
Height	Full Up 91"
	(231 cm)
	Full Down 54"
	(137 cm)
Weight	
675 lb. (306 kg)	

GUNS AND HOSES

22000-200-R Automatic Gun

22000-100 Manual Gun

- 22000-100 Manual dispensing gun with cartridge heater. Nozzle orifice .031" standard. Other orifices and configurations available upon request.
- 22000-200-R Automatic dispensing gun with heater, controller, and thermometer. Double air operated, requires a 4-way valve to actuate. Nozzle orifice .016" standard, other orifices available.
- 22000-85 Temperature controller. One required for each hose and manual gun.

Standard Heated Hose Assemblies (2,000 PSI W.P. — 6,000 PSI B.P.)

22008-B	.312 ID x 8' long, 1/4" NPT-M	(7.9 mm x 243.8 cm)
22015-B	.312 ID x 15' long, 1/4" NPT-M	(7.9 mm x 457.2 cm)
22020-B	.312 ID x 20' long, 1/4" NPT-M	(7.9 mm x 609.6 cm)
23010-B	.500 ID x 10' long, 1/2" NPT-M	(12 mm x 304.8 cm)
23015-B	.500 ID x 15' long, 1/2" NPT-M	(12 mm x 457.2 cm)
23020-B	.500 ID x 20' long, 1/2" NPT-M	(12 mm x 609.6 cm)

High Pressure Heated Hose Assemblies (4,000 PSI W.P. 12,000 PSI B.P.). **NOTE: THESE HOSES ARE REQUIRED WITH THE OPTIONAL 38:1 AND 59:1 PRESSURE RATIOS.**

23010-C	.650 ID x 10' long, 3/4" NPT-M	(16.5 mm x 304.8 cm)
23015-C	.650 ID x 15' long, 3/4" NPT-M	(16.5 mm x 457.2 cm)
23020-C	.650 ID x 20' long, 3/4" NPT-M	(16.5 mm x 609.6 cm)

Kent-Moore

PYLES INDUSTRIES, INC.

SUBSIDIARY OF KENT-MOORE CORPORATION
28990 WIXOM ROAD ■ WIXOM, MICHIGAN 48096
TELEPHONE: (313) 349-5500

Nordson®

HOT MELT APPLICATION UNITS for Product Assembly

TANK TYPE APPLICATORS

PORTABLE
APPLICATORS

Model	IV and V	VII	IX	VIII and X	X-SA	XI	XII and XIIA	AD-25
Type System	Non-circulating	Circulating	Non-circulating	Non-circulating	Non-circulating	Internally Circulating		Self-Contained
Tank Capacity	17 lbs. 7.2 kg	20 lbs. 9.1 kg	20 lbs. 9.1 kg	8 lbs. 3.6 kg	8 lbs. 3.6 kg	20 lbs. 9.1 kg	25-40 lbs. 11.3-18.1 kg	Hopper: 5 oz.—141.8 gr.
Melt rate per hour	20 lbs.* 9.1 kg	27 lbs.* 12.3 kg	27 lbs.* 12.3 kg	8 lbs.* 3.6 kg	8 lbs.* 3.6 kg	24 lbs.* 10.9 kg	15-125 lbs.* 6.7-56.2 kg	4 lbs.* 1.8 kg
Maximum Operating Temperature	400°F 204°C	450°F 232°C	400°F 204°C	400°F 204°C	400°F 204°C	400°F 204°C	450°F 232°C	550°F 288°C
Tank heating method	Cast-in Element	Cast-in Element	Cast-in Element	Cast-in Element	Cast-in Element	Cast-in Element	Cast-in Element & Cartridge Heater	Cartridge Heater
Type of Pump	Single Piston, Dual-Acting	Single Piston, Dual-Acting	Single Piston, Dual-Acting	Single Piston, Single-Acting	Single Piston, Single-Acting	Gear	Gear	N/A
Pumping rate—max- imum per minute	0.9 lbs. 408 gr.	2 lbs. 907 gr.	2 lbs. 907 gr.	.62 lbs. 289 gr.	0.6 cu. in. (10 cc) per cycle (.34 oz. or 10 gr.)	2 lbs. 907 gr.	2 lbs. 907 gr.	4 lbs. per hr. 1.81 kg. per hr.
Operating air pressure	10-60 psi 7-4.2 kg/cm ²	20-80 psi 1.4-5.6 kg/cm ²	20-80 psi 1.4-5.6 kg/cm ²	10-60 psi 7-4.2 kg/cm ²	20-80 psi 1.4-5.6 kg/cm ²	5-80 psi 35-5.6 kg/cm ²	5-80 psi 35-5.6 kg/cm ²	N/A
Number of Hoses	4 maximum (Model IV) 2 maximum (Model V)	Depends on hose length (maximum— 40 feet)	6 maximum	1-Model X 2-Model VIII	None	6 maximum	6 maximum	N/A
Hose length in feet	Auto 4, 6, 8, 10, and 16 Hand 8, 16, and 24	1, 2, 3, 4, 5, 6, 8, and 10	4, 6, 8, 10, and 16	2, 4, 6, 8, and 10	N/A	4, 6, 8, 10, and 16	4, 6, 8, 10, and 16	N/A
Type of Gun	Automatic or Hand	Automatic	Automatic or Hand	Automatic or Hand**	Semi- Automatic	Automatic or Hand	Automatic or Hand	Hand
Number of Guns	4 maximum (Model IV) 2 maximum (Model V)	8	6 maximum	1-Model X 2-Model VIII	1	6 maximum	6 maximum	N/A
Weight	55 lbs. 25 kg	160 lbs. 72.6 kg	160 lbs. 72.6 kg	34 lbs. 15.4 kg	34 lbs. 15.4 kg	135 lbs. 61.2 kg	155 lbs. 70.3 kg	2.5 lbs. 1.134 kg
Height	19.5 in. 495 mm	20.75 in. 527 mm	20.75 in. 527 mm	14.8 in. 376 mm	14.5 in. 368.3 mm	17.8 in. 452 mm	XII 32.25 in. 819 mm XIIA 28.25 in. 718 mm	7.6 in. 279.4 mm
Width	28.5 in. 724 mm	38.5 in. 978 mm	38.5 in. 978 mm	17.5 in. 445 mm	17.5 in. 445 mm	28.8 in. 731.5 mm	28.8 in. 731.5 mm	2-11/16 in. 68 mm
Depth	12.5 in. 318 mm	13.8 in. 351 mm	13.8 in. 351 mm	11 in. 280 mm	10.5 in. 266.7 mm	13.2 in. 335 mm	13.2 in. 335 mm	11" length 290 mm
Electrical	230 VAC, 50/60 hertz	230 VAC and 460 VAC, 50- 60 hertz	230 VAC, 50- 60 hertz 3 phase only, 24 Amps	230 VAC, 50-60 hertz	230 VAC, 50-60 hertz	230 VAC, 50-60 hertz	230 VAC, 50-60 hertz	115 VAC

*Melt rates vary greatly depending on the melt characteristics of each particular adhesive. **Model VIII Automatic only. N/A Not Applicable
Figures shown are approximate for medium viscosity materials (5,000-15,000 centipoise).

Gear Pump Applicators

Model XI

Write for technical information on Nordson's complete line of hot-melt application equipment. NORDSON CORPORATION, Jackson St., Amherst, OH 44001. Phone 216-988-9411. Also available in Canada, Mexico, Europe, Asia, Australia, South Africa, and Japan.

Nordson

For Better Ways To Apply
Coatings and Adhesives

Model XII

Nordson®

Application Systems Accessories

Automatic Extrusion Heads

H-20 — Compact modular design makes the Nordson H-20 Automatic Hot Melt Gun easy to mount on most assembly lines. It is air operated and controlled by a solenoid valve. Separate service block contains all hose connections, thermostat, heater and mounting face.

AD-24 — Modular design of this hot melt gun features drop-in cartridge inserts which fit into an aluminum block drilled and ported to supply air and adhesive. Adaptable to circulating and non-circulating systems, the AD-24 can be used with virtually all Nordson hot melt units and is available with two, four, or eight drop-in cartridges.

AD-28 — The Nordson Model AD-28 Automatic Gun contains two cartridge heaters which are designed to maintain and control the adhesive application temperature within the gun. One special version of the Model AD-28 is capable of increasing heat at the gun by 100°F (37.8°C) depending on the adhesive used and the flow rate requirements. The AD-28 features a bellows assembly in the extrusion head rather than a packing cartridge assembly.

Hose Fed Hand Guns

H-21 — Light, compact, and reliable, the Nordson H-21 Hand Gun provides excellent maneuverability and easy trigger pull to minimize operator fatigue. Good visibility over the gun top makes it easy to precisely place adhesive in product assembly operations. Positive trigger action assures clean cutoff with no drip or drool, preventing adhesive waste.

AD-27 — Among the many features of the Nordson AD-27 Hot Melt Hand Gun is an "ever-cool" handle. Melted adhesive is not fed through the gun's handle, thus, it remains "ever-cool." This unique handle can be affixed to the gun in two different positions. Normal position is as illustrated, however, the handle can be detached and re-affixed at a 180° angle for easy operating when the hose is suspended from an overhead position. Additional features include: a long extended nozzle for pinpoint placement of hot melt adhesive; it is lightweight (2½ pounds — 1.13 kg); and the AD-27 has a bellows assembly at the extrusion tip rather than a packing cartridge assembly.

NORDSON'S "BETTER WAYS"

Each year, hot melt adhesives assume a larger and more important role in product assembly operations throughout the world. As the leading supplier of hot melt application equipment, Nordson Corporation is involved with the latest technology to efficiently and economically apply these adhesives.

Nordson does not manufacture hot melt adhesives. Nordson is dedicated to the engineering and manufacture of quality equipment to provide — "For Better Ways to Apply Coatings and Adhesives."

Time Controls

CST-1 Hot Stitch Control — The CST-1 Hot Stitch Control is a solid state timing device that will produce an intermittent or stitch pattern in use with Nordson hot melt application systems. It can be used on various specialized applications requiring a stitch pattern of deposition. The CST-1 can also be used with Nordson's Pnu-Bond cold glue spray systems as a skip-gap control.

CT-6 Time Interval Control — The Nordson CT-6 Time Interval Control is a solid state "delay-duration" device designed for use in applications requiring precise time delay and an off-on cycle in response to an external signal. It provides a selection of sequential timing in the range from 2 to 1,000 milliseconds.

CT-7 Time Interval Control — The CT-7 Time Interval Control by Nordson is a solid state device that is designed for use in applications for automatic, sequential triggering of hot melt guns. The CT-7 has four timers and two output channels which may operate as two separate channels in a Parallel mode, or they may operate together in a Series mode which can be programmed to provide a wide variety of application systems.

CT-8 Time Interval Control — The CT-8 Time Interval Control is a solid state device used to actuate the automatic, sequential triggering of hot melt guns and pumps. The CT-8 Timer may be used in conjunction with a single-acting pump applicator and automatic gun or guns in palletizing or other such applications.

Nordson®

For Better Ways To Apply
Coatings and Adhesives

Nordson Corporation

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APPENDIX D

Unimate 2000 Industrial Robot Characteristics

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Unimate Industrial Robots:

The flexible way to increase productivity and reduce operating costs.

Leadership through product superiority

Unimation Inc. pioneered the development of the industrial robot and is the leader in the field.

Leadership through experience

Unimate benefits have been proven through millions of hours of on-the-job experience.

Leadership in customer services

Complete services, accessories and systems assure you a high return on your investment.

Leadership in product flexibility

Model selection provides best choice at minimum cost.

Leadership through product superiority

Unimation Inc. pioneered the development of the industrial robot and has maintained its leadership role through product superiority and technological ingenuity.

Today, the industrial robot is used in manufacturing operations throughout the world to perform tasks that are too hazardous, too onerous, too boring, or simply too uneconomical for humans.

In most applications, the robot can handle heavier loads more accurately and at higher speeds for longer periods of time than its human counterpart. This results in increased productivity, lower operating costs and products with greater uniformity and precision.

The proven performance of UNIMATE[®] industrial robots is derived from millions of hours of productive work in many different industries. Their durability is attested to by the many machines that are hale and hearty and still earning their keep after 65,000 hours of operation—that's over 32 man years of work.

The diversity of applications and proven endurance of the UNIMATE illustrate its versatility and are your assurance of a sound investment.

A matter of flexibility

Flexibility is the key to what the Unimate offers. This industrial robot not only adapts to new applications but it adapts to new requirements within an existing process.

The most efficient hard or special-purpose automation can become instantly obsolete if the product or process changes. In contrast, the sophistication of the Unimate invests it with the flexibility to adapt to changes...and in no more time than it would take a human worker.

The Unimate includes up to 6 fully programmable degrees of freedom. Its motions are hydraulically actuated for heavy payloads, smoothness of operation and durability. Its solid state, non-volatile memory has a capacity for as many as 1024 program steps point-to-point (PTP) and is easily adapted to specific job requirements.

This flexibility provides built-in non-obsolescence and long term cost effectiveness. It makes the Unimate robot your best automation investment.

Features that count

There are several models of the Unimate robot and many available options designed to meet your needs at the lowest possible cost. The 2000 series Unimates can handle payloads up to approximately 125 lbs., while the 4000 series can handle up to 500 lb. loads. All models include the following proven design features that assure exceptional performance and reliability.

Muscle power: Hydraulic servoing of all degrees of freedom provides the power for high speed operation with smooth acceleration and deceleration.

Servo control: The control system is 100% digital. This assures positive positional accuracy with neither short nor long term drift nor the need for zeroing. Solid state electronic components are used throughout for high reliability.

Non-volatile memory: The solid state programmable memory (PROM) is the ultimate in reliability because there are no moving parts nor tapes to wear or

stretch. Retention of memory, regardless of electrical power loss or transients, is indefinite. Many memory sizes and functional arrangements are available.

Controls and interlocks: Operator controls are conveniently arranged in the control cabinet. Electrical connections are easily accessible to interlock the Unimate with the equipment it serves, including programmable functions to insure safe and efficient operation. In addition, interfacing within a computer controlled hierarchy is readily accomplished.

Millions of hours of field performance assure unsurpassed reliability.

Sturdy covers protect equipment and enclose all pinch points.

No. of degrees of freedom: All models are available with from 2 to 6 fully programmable degrees of freedom.

Easy to teach: The Unimate is designed for "on-the-job" training. No computer type programming preparation or cumbersome hard wire sequencing is required. Within one hour, anyone can learn to teach Unimate the job because the robot is literally led by the hand through the operations to be performed, point-to-point. Playback speeds are independent of the teaching speed. The teach control is a compact, hand held, plug-in unit.

Easy to maintain: Simple procedures help to assure proper maintenance of the Unimate. You get proper maintenance schedules and instructions for sustained, trouble free operation.

Modular construction, combined with definitive trouble shooting guides also helps you to maintain the robot.

Options and accessories: In addition to the essential features already described, many options and accessories can be selected to extend the robot's flexibility.

For example, multiple programs can be stored in the memory and called upon at random; base and sub routines can be taught to facilitate complex material handling and palletizing operations; portions of programs can be altered to accommodate external variables without interrupting the operation; motions can be synchronized with continuously moving conveyors; and programs can be

Up to 6 fully programmable degrees of freedom are available.

Hydraulic muscle power assures fast, smooth motions.

Teach control makes on-the-job programming fast and easy.

Interlock (I/O) functions are easily accessible for fast installation.

extracted from the Unimate's memory and stored on magnetic tape for future use. The control cabinet and the hydraulic power supply can be remotely located. The 2000 series can include continuous path (CP) control for arc welding, routing and similar applications which require precise path tracing and velocity control. **Environment:** All equipment is rated for ambient temperatures from 5°C (40°F) to 50°C (120°F) and humidity to 90%. Standard cooling is by forced air circulation. Water cooling can be provided. Machines rated intrinsically safe for volatile atmospheres are also available.

Leadership through experience

Unimate performance has been proven through millions of hours of experience, worldwide, in metal working, material handling, casting and forging, glass manufacturing, automotive assembly—in tasks that are monotonous, tiring, disagreeable, dangerous and debilitating to humans.

Check these Unimate benefits

Increased productivity—from 25% to 40% and more as reported by Detroit Diesel, Fiat, Doehler-Jarvis.

Increased product quality and fewer rejects—says Chrysler, Inland Die Casting Corp., Evinrude—in some cases by a factor of 70%.

Improved capital equipment utilization—Unimate “up-time” of better than 98% assures high equipment utilization says Volvo, Ford, Bauer Products, Alfa Romeo, Briggs & Stratton.

Inflation resistant—the Unimate you hire today will be working at the same hourly rate 5 years from now says Cast Specialties, Advance Pressure Castings, Texas Instruments.

Fast, easy installation—fast response time means accrued benefits sooner says Chrysler, Lunkenheimer, Twin City Die Casting.

Round-the-clock output—no second or third shift production slow down reported by Pemco Die Cast Corp., Ford, Tube Turns.

Flexibility—permits use in custom shop and batch processing environments says Dittmann Neuhauss, Doehler Jarvis, Evinrude.

Reduced in-process inventory and material handling—as experienced at Rockwell International, Texas Instruments, Tube Turns, International Harvester.

Improves competitiveness—says Lunkenheimer, Chevrolet, Superior Die Casting.

Reduces indirect and hidden costs—less die maintenance, reduced energy consumption, less lost production due to illness and absenteeism, lower costs for OSHA compliance reported by Chevrolet, Superior Die Casting, Fiat, Del Mar Die Casting, A. O. Smith.

These are but a few of the benefits that Unimate industrial robot users have reported. They are some of the reasons why our customers continue to add Unimates to their work forces. Consider the applications depicted on these pages. The answers to your automation needs may well be illustrated.

Our extensive library of application and technical bulletins and movie films is at your disposal. Our experience will serve you well.

1. Punch and stamping press transfer

A Unimate robot is a real OSHA problem-solver when operating with punch and stamping presses. A battery of Unimate robots in a press transfer line guarantees consistent throughput, shift after shift. Change over in batch run processing can be done in minutes by using Unimation's Cassette Program Storage Unit which preserves Unimate programs on magnetic tape.

2. Investment casting

Scrap rates as high as 85% have been reduced to under 5% when Unimates are used in this highly sophisticated process. The robot's dexterity and repeatability assure consistent mold quality never before achieved in the dipping process. Unimate robots are being used singly or in totally automated DNC systems in which dozens of different wax molds, weighing from a few pounds to over 300 lbs. are processed by as many as 10 robots.

3. Materials handling

From raw material in the back door to finished goods out the front door, materials handling is a necessary evil that costs money and is often labor intense. The Unimate robot becomes a real problem solver because it has the muscle, dexterity and versatile memory to pack or transfer goods in complex palletized arrays without product damage or lost counts. And it's cheaper than special-purpose equipment that is quickly made obsolete by product change.

4. Forging

One of the toughest industrial jobs is forging. Unimate robots operate forge hammers, presses, upsetters and trim presses without fatigue or the need for relief operators. In some cases a Unimate will do the work of six men per shift, yielding a handsome payout.

5. Die casting

Because productivity gains with Unimate robots are so dramatic, it is often unnecessary to invest in additional die cast machines. Scrap rate reductions of as much as 70% are common. The Unimate can unload the die cast machine, quench the part, feed a trim press, load inserts, service two die cast machines, ladle aluminum and perform die care. The robots' flexibility and consistency are cost-cutting benefits that guarantee a high return on investment for both custom and captive shops.

6. Automotive assembly

Unimation Inc.'s family of robots spot-welds automobile and truck assemblies for almost every major manufacturer throughout the world. Applications include construction of sub-assemblies, body sides, underbodies and front structures, as well as body framing and respot. Consistency of spot location and weld integrity yield automotive assemblies of the highest quality. The Unimate robot's versatile memory easily accommodates any product mix. And, with the aid of Unimation's Program Editor, program adjustment to accommodate variations such as metal fit ups are easily made without interrupting the production cycle.

7. Machine tool loading

Two-fisted Unimate robots hold the key to machine tool productivity. Rapid loading and unloading of work pieces assures high utilization of costly capital equipment. Using Unimate robots to simultaneously serve several machine tools reduces in-process inventory and costly material handling, and has reduced piece part costs by as much as 65%. A Unimate machining system is the ultimate in automated parts manufacturing.

8. Continuous path applications

Velocity and path control add to the versatility of the Unimate 2000 series. Capable of being operated in either point-to-point (PTP) or continuous path (CP) modes, this model is ideally suited to arc (gas) welding, routing, sealant application, mold spraying and bake out, degating, pad machining and grinding, flame cutting and other process tasks requiring smooth, accurate, three-dimensional paths and velocity control. In either mode, Unimation's point-to-point, lead-it-by-the-hand teaching method is retained.

Leadership in customer services:

From grippers to testers, seminars to service training, spare parts to systems, your needs are met by Unimation's experienced staff of sales, applications and service engineers, training instructors and service order dispatchers. The many services and accessories offered by Unimation Inc. are designed to give you full support and to assure you of a high return on your investment in Unimate robots.

Hand designs

The hands that can be used on the Unimate fall into three general categories: mechanical grippers, surface-lift devices and tools.

Mechanical grippers employ movable, finger-like levers, paired to work in opposition to each other. A single hand might have one or several sets of opposed fingers. Likewise, a robot might have more than one hand.

Surface-lift devices are exemplified by vacuum pick-ups and electromagnets for handling durable, delicate (glass) or ferrous materials with flat or curved surfaces. Tools that serve as robot hands include spot welding guns, impact wrenches, spray heads or arc welding torches.

Unimation engineers have accumulated a substantial library of hand-tooling designs based on these three general categories. With this kind of experience, our engineers have the know-how and ingenuity to design, build and test robot hands to meet any special requirements your application demands.

Accessories

Cassette Program Storage. This accessory unit lets you reassign the Unimate to another task at the push of a button. Once the Unimate has been taught a specific job the program sequence can be extracted from the robot's memory and stored on magnetic tape cassettes for later re-insertion. The unit is powered from the Unimate and plugs into the robot's test connector. It's as simple to use as any tape recorder.

Program Editor. This accessory is also portable and facilitates minor alterations in Unimate programs without interrupting the operating cycle. One or all degrees of freedom can be modified on any step of the program to accommodate for tool wear, fixture variations, metal fit ups and the like.

Unimate Tester. This accessory is designed to help facilitate maintenance and troubleshooting on the Unimate robot. It's portable and is supplied in a metal carrying case. A self-contained electrical cable is used to attach the tester to the Unimate test connector. The use of the tester as a valuable diagnostic tool is thoroughly covered in the Unimate training schools and equipment manuals.

Interface Controls. Several different control units are available to facilitate alternate or random selection of Unimate programs. For interfacing with a master process computer we supply the E.I.A. standard RS-232-C serial data transmitter system.

Hand Designs

Services

Robot Seminars. Unimation Inc. conducts periodic seminars on robotics tailored to specific application areas such as machine tool loading, punch and stamping press operations, resistance and arc welding, and die casting. These are hard-hitting, shirtsleeve sessions that give you the practical information you need to evaluate the use of Unimates in your operation. At your request also, we will develop a custom seminar to fit your specific company needs.

Customer Training Program. Our customer training program is designed just for you. We teach your personnel how to operate, maintain and repair the equipment, at our facility or in your plant. With qualified in-house capability, you can assure yourself of high and uninterrupted Unimate performance.

Customer Service Program. Our staff of field service engineers is available to assist you with your installation, service needs and spare parts requirements.

Systems

Unimation engineers have gained extensive experience in virtually every field of manufacturing. The result is a capability to design and build systems around the robot which offers you the most efficient, flexible means available to cut costs and improve productivity. A system can be as simple as one robot and some workpiece orienting devices, or a multiplicity of robots integrated into a totally computerized manufacturing process.

Systems supplied by Unimation range from brick handling equipment including palletizing conveyors, kiln car indexer, process controller and robot to automotive assembly lines with 15 to 30 robots, car body shuttle conveyor, supervisory control and spot weld guns.

Machining systems for processing parts from raw castings to finished goods have been developed using conventional or NC machine tools and employing the principles of group technology.

These systems provide the ultimate in flexibility, insure quality of product, can be on stream fast, and result in impressive productivity gains.

Our applications engineers stand ready to help your staff upgrade your manufacturing process. Give us a call. We welcome the opportunity to work with you.

Engineered systems designed by Unimation provide the ultimate in flexibility and productivity.

Cassette Program Storage

RS-232-C Computer Interface

Unimate Tester

Program Editor

Customer Training

Leadership in product flexibility

MODEL SPECIFICATIONS*	2000B		2000C		2100B		2100C		4000B	
Floor Space/Weight	space	weight	space	weight	space	weight	space	weight	space	weight
Manipulator	20 sq ft 1.86 m²	2800 lb 1271 kg	12 sq ft 1.11 m²	2200 lb 1000 kg	20 sq ft 1.86 m²	2900 lb 1318 kg	12 sq ft 1.11 m²	2300 lb 1045 kg	22 sq ft 2.04 m²	5000 lb 2273 kg
Hydraulic Supply (with fluid)	Integral		9.6 sq ft 0.90 m²	500 lb 227 kg	Integral		9.6 sq ft 0.95 m²	500 lb 227 kg	Integral	
Control Cabinet	Integral		6.3 sq ft 0.59 m²	300 lb 136 kg	Integral		6.3 sq ft 0.59 m²	300 lb 136 kg	6.3 sq ft 0.59 m²	300 lb 136 kg
Mounting position	Floor		Any		Floor		Any		Floor	
No. of Degrees of Freedom	2-6		2-6		2-6		2-6		2-6	
Positioning Repeatability (PTP)	0.05 in (1.27mm)		0.05in (1.27mm)		0.05in (1.27mm)		0.08in (2.03mm)		0.08in (2.03mm)	
Power requirements	460, 3Ø 60Hz, 11KVA		460, 3Ø 60Hz, 11KVA		460, 3Ø 60Hz, 11KVA		460, 3Ø 60Hz, 11KVA		460, 3Ø 60Hz, 34KVA	
Load capacity										
Max. lift (full extension)	300 lb (136 kg)		300 lb (136 kg)		300 lb (136 kg)		270 lb (123 kg)		450 lb (205 kg)	
Standard Wrist, Torque										
Bend	1000 in-lb (11.5 kg-m)								3500 in-lb (40.3 kg-m)	
Yaw	600 in-lb (6.9 kg-m)								2800 in-lb (32.2 kg-m)	
Swivel	800 in-lb (9.2 kg-m)								2300 in-lb (26.5 kg-m)	
Heavy Duty Wrist, Torque										
Bend	2000 in-lb (23 kg-m)								11000 in-lb (126.5 kg-m)	
Yaw	1200 in-lb (13.8 kg-m)								2800 in-lb (32.2 kg-m)	
Swivel	800 in-lb (9.2kg-m)								N/A	
Memory options										
Point-to-Point	UP TO 1024 POINTS, OTHER OPTIONS AVAILABLE									
Continuous Path	UP TO 500 in. OF TRAVEL								N/A	
Interlocks	UP TO A TOTAL OF 24 I/O CHANNELS									
Speeds/Travel	REQUEST DETAILED SPECIFICATIONS									
Environment	40°F (5°C) to 120°F (50°C), Humidity 0-90%									

For more detailed installation and performance data and available options, contact Unimation Inc. Unimation Inc. reserves the right to make changes in equipment specifications at any time without notice.

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