N86-29389

ENCAPSULATION PROCESSING AND MANUFACTURING YIELD ANALYSIS

SPRINGBORN LABORATORIES, INC.

P. Willis

Goals

- UNDERSTAND THE RELATIONSHIPS BETWEEN:
  - FORMULATION VARIABLES
  - PROCESS VARIABLES
- DEFINE CONDITIONS REQUIRED FOR OPTIMUM PERFORMANCE
- RELATE TO MODULE RELIABILITY
- PREDICT MANUFACTURING YIELD
- PROVIDE DOCUMENTATION TO INDUSTRY

Material Variables

LAMINATION POTTANTS

- ETHYLENE/VINYL ACETATE (EVA)
- ETHYLENE/METHYL ACRYLATE (EMA)

CASTING POTTANTS

- ALIPHATIC POLYURETHANE (PU)

ADHESIVES/PRIMERS

- THREE BASIC PRIMER SYSTEMS

COVER FILMS

- TEDLAR, ACYRLICS, FEP

FORMULATION VARIABLES:

TYPE AND AMOUNT OF:

- CURING AGENTS (PEROXIDES)
- ANTIOXIDANTS
- ULTRAVIOLET SCREENERS
- ULTRAVIOLET STABILIZERS (HALS)
- SELF PRIMING AGENTS

STORAGE CONDITIONS:

- TIME, TEMPERATURE, HUMIDITY, LIGHT AIR EXPOSURE

QUALITY CONTROL:

- DETERMINE ANLYTICAL METHODS TO VERIFY COMPOSITION
- PUBLISH QC SPECIFICATIONS FOR MATERIAL CERTIFICATION

Process Variables

(VACUUM BAG LAMINATION)

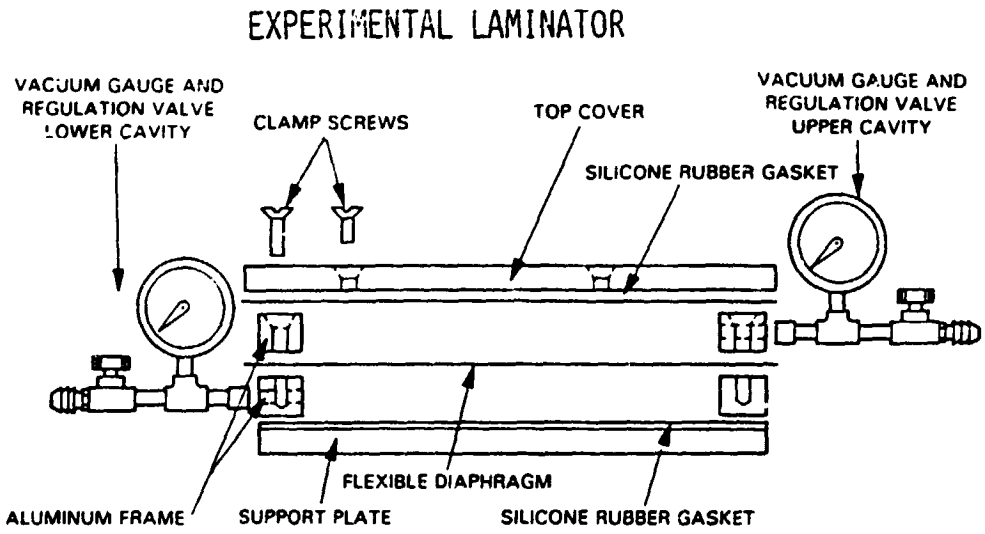
- AMBIENT CONDITIONS:
  - TEMPERATURE
  - HUMIDITY
  - BAROMETRIC PRESSURE
- VACUUM PRESSURE (INITIAL) AND TIME OF EVACUATION
- TEMPERATURE - - RATE OF RISE
- TEMPERATURE - - ULTIMATE
- DWELL TIME, AT TEMPERATURE
- RATE OF COOLING
- TIME/TEMPERATURE/PRESSURE INTER-RELATIONSHIP

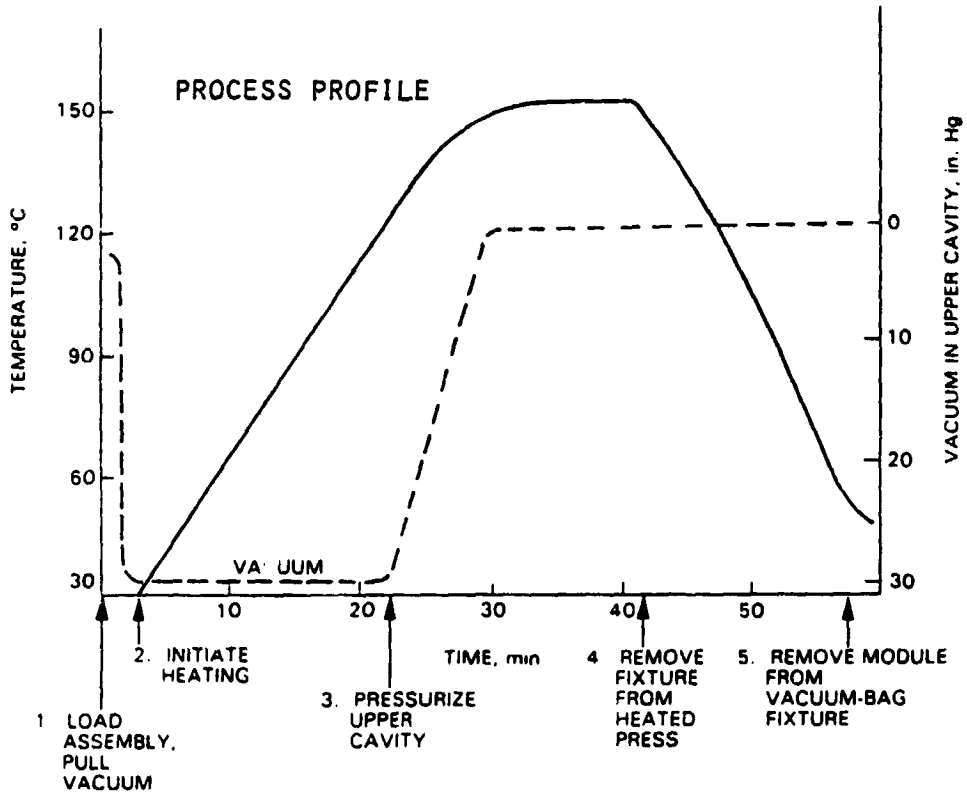
(CASTING LIQUID SYSTEMS)

ABOVE VARIABLES, PLUS:

- 2 COMPONENT MIX TIME
- DEGASSING PRESSURE
- PUMP AND FILL TIMES
- MIX UNIFORMITY
- GEL TIME

Process Equipment





- MICROPROCESSOR CONTROLLED EXPERIMENTAL LAMINATOR CONSTRUCTED
- STUDIES STARTED ON PROCESSING PROFILES
  - RATE OF HEATING (HOW SLOW, HOW FAST ?)
  - VACUUM TIMING
  - RATE OF COOLING

Quality and Performance Criteria

METHOD:

- PREPARE TEST MODULES AND/OR OTHER TEST SPECIMENS WITH CHANGE IN SIGNIFICANT VARIABLE(S)
- DETERMINE THE EFFECT

COMPONENT	CRITERION	TEST
POTTANT	ADEQUATE CURE	PERCENT GEL THERMAL CREEP
	TRAPPED BUBBLES	VISUAL
	DISCOLORATION	VISUAL
CELLS	BREAKAGE	VISUAL, RESISTANCE
	INTERCONNECT	RESISTANCE
	REGISTRATION	VISUAL
COVER FILMS	TEARS/PUNCTURES	VISUAL
	WARPING/SHRINKAGE	VISUAL
GLASS (SUPERSTRATE)	FRACTURE	VISUAL
ADHESION	BOND STRENGTH	PEEL TEST
	ENDURANCE	WATER SOAK (50°C)

NEED TO DECIDE ON:

- STANDARD TEST SPECIMEN(S)
- STANDARD TEST PROTOCOL
- UNIFORM DATA SETS

Data Analysis

- STATISTICAL ANALYSIS COMPLICATED BY LACK OF UNIFORMITY IN DATA TYPE
- TWO TYPES OF DATA:

DISCRETE (PASS/FAIL)	CONTINUOUS
CELL FRACTURE	GEL CONTENT
INTERCONNECT BREAKAGE	PEEL STRENGTH
TRAPPED BUBBLES	STABILIZER LOSS
THERMAL CREEP	
GLASS FRACTURE	

FOR CONTINUOUS DATA TYPES:

- TWO LEVEL FACTORIAL EXPERIMENTS (MOST INFORMATION, FEWEST EXPERIMENTS)
- NO. EXPERIMENTS = 2^K, K = NO. VARIABLES
- DETERMINES EFFECT OF SINGLE VARIABLE AT TWO LEVELS
- DETERMINES FACTOR INTERACTIONS (SEVERAL VARIABLES)
- PERMITS RANKING OF VARIABLES ACCORDING TO MAGNITUDE OF EFFECT
- LINEAR ANALYSIS POSSIBLE FOR SUBSEQUENT PREDICTIVE CAPABILITY

FOR DISCRETE DATA TYPES:

- DETERMINE "X SUCCESSES IN N TRIALS" FOR SUITABLY LARGE SAMPLE
- SCATTER PLOT - FOR FIRST ESTIMATE OF ACCEPTABLE PROCESSING RANGE
- BINOMINAL DESTRIBUTION - DETERMINE PROBABILITY OF FAILURE

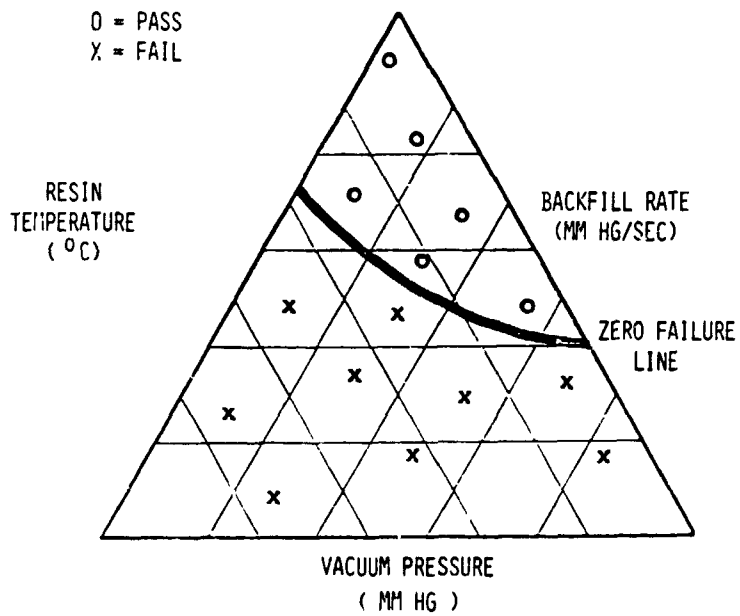
IN GENERAL:

1. DETERMINE THE DOMINANT FAILURE MODE
2. DETERMINE VARIABLE(s) RESPONSIBLE
3. DETERMINE EXPERIMENTAL CONDITIONS THAT RESULT IN A RANGE OF FAILURES
4. DETERMINE THE MEAN AND STANDARD DEVIATION OF THE DISTRIBUTION
5. USE PROBABILITY DISTRIBUTION FUNCTION TO CALCULATE PROBABLE FAILURE AT OTHER STRESS LEVELS

Manufacturing Practice: Discrete Variables

- PREPARE GRAPHICAL INTERPRETATION OF DATA
- DETERMINE " TOLERABLE FAILURE " LEVEL
- DEFINE BOUNDRY CONDITIONS FOR DEFECT-FREE MANUFACTURING (FIRST ESTIMATE)

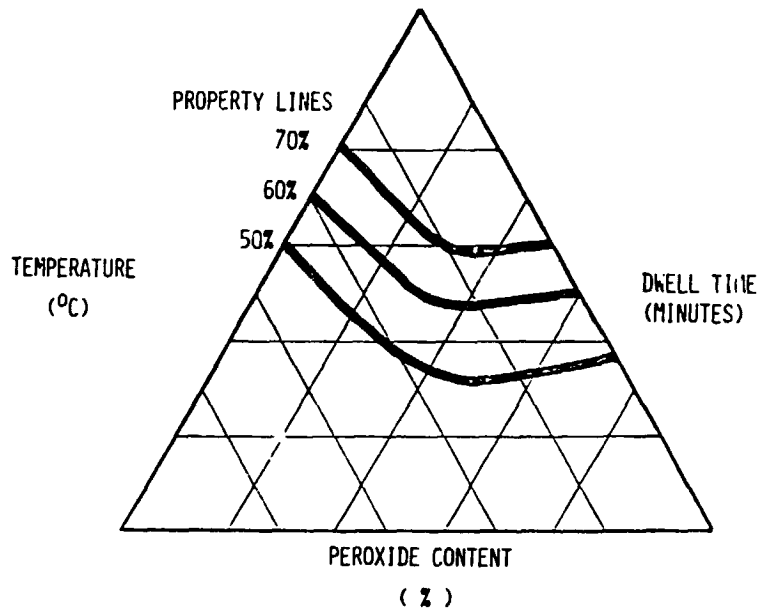
EXAMPLE: CELL BREAKAGE



Manufacturing Practice: Continuous Variables

- GRAPHICAL PRESENTATION ALSO GOOD FOR CONTINUOUS VARIABLES
- PROVIDES BOUNDRIES FOR PROCESS/FORMULATION VARIABLES BASED ON CRITERIA OF ACCEPTABILITY
- EASILY USED IN MANUFACTURING PRACTICE

EXAMPLE: PERCENT GEL
(DEGREE OF CURE)



Formulation Sensitivity

- UV SCREENERS AND OTHER STABILIZERS - SLOW DOWN CURE RATE SLIGHTLY. NO ENORMOUS DIFFERENCE BETWEEN TYPES
- ANTIOXIDANTS CAN HAVE MAJOR EFFECT ON CURE. NOT USED/UNNECESSARY

CURE VERSUS PEROXIDE CONTENT
(TIME TO GEL CONTENT >65%, MINUTES)

	EVA 9918			
	130°	140°	150°	160°
LUPERSOL 101:				
1.5%	NC	20	10	5
0.5%	NC	30	20	10
	EVA 15295			
LUPERSOL TBEC:				
1.5%	8	<5	3	1
0.5%	NC	10	5	<5

(NC = NO CURE)

- ONE THIRD THE STANDARD PEROXIDE CONCENTRATION DOUBLES THE REQUIRED TIME
- EVA FORMULATIONS NOT SENSITIVE TO MINOR VARIATIONS ON PEROXIDE CONTENT

Process Sensitivity

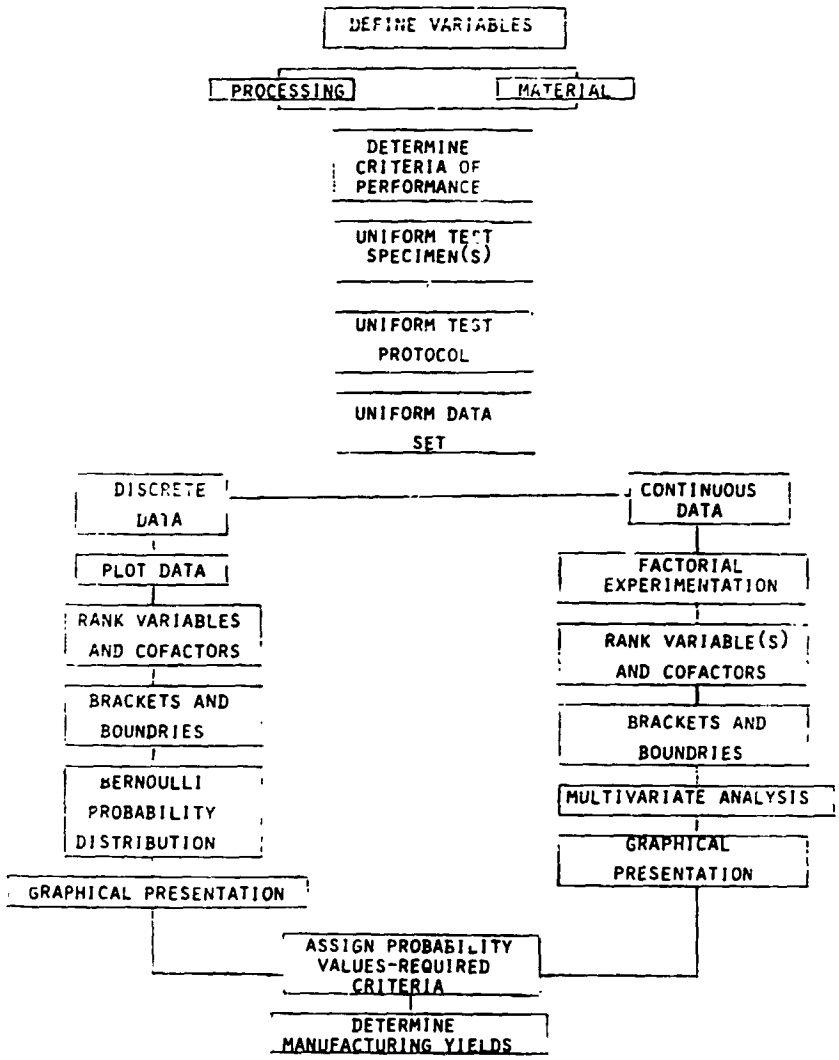
EVA STORAGE / AIR EXPOSURE

	EVA NUMBER 9918	EVA NUMBER 15295
PEROXIDE:	LUPERSOL 101	LUPERSOL TBEC
CURE CONDITIONS:	150° / 20 MIN 140° / 20 MIN	150° / 5 MIN 140° / 5 MIN

AIR EXPOSURE	GEL CONTENTS:	
CONTROL, 0	80 % 64 %	93 % 91 %
24 HOURS	82 % 71 %	85 % 78 %
48 HOURS	78 % 0 %	81 % 72 %
72 HOURS	70 % 0 %	83 % 82 %
168 HOURS (ONE WEEK)	0 % 0 %	70 % 0 %

- EVA FORMULATIONS STRONGLY AFFECTED BY AIR EXPOSURE. AIR EXPOSURE .
- FORMULATION WITH TBEC PEROXIDE MUCH LESS AIR SENSITIVE
- EVA STORED IN ROLL FORM - APPEARS TO HAVE LONG STORAGE LIFE
- CUT EVA SHEET ONLY BEFORE USE, DISCARD FIRST WRAP OF ROLL

JPL Process Sensitivity Analysis



Conclusions

- EVA FORMULATIONS RELATIVELY INSENSITIVE TO QUANTITY OF PEROXIDE BUT VERY SENSITIVE TO AIR EXPOSURE
- UNWRAP/CUT EVA JUST BEFORE MODULE MANUFACTURING - LIMIT AIR EXPOSURE

Accomplishments

- ANALYTICAL METHODS DEVELOPED FOR PEROXIDE CONTENT
- MICROPROCESSOR CONTROLLED EXPERIMENTAL LAMINATOR CONSTRUCTED
- EXPERIMENTAL TEST METHODOLOGY DEVELOPED (FIRST CUT)
- REVISED EVA PRODUCT BROCHURE AVAILABLE INCLUDES " TROUBLE SHOOTING " SECTION

Future Work

- DETERMINE DOMINANT FAILURE MODES
- CONVERT DATA TO PRACTICAL ENGINEERING FORMAT
- RELATE DATA TO MANUFACTURING YIELD
  - ASSIGN PROBABILITY OF FAILURE
  - NORMAL DISTRIBUTION (?)
  - WEIBUL (?)