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# ENCAPSULATION PROCESSING AND MANUFACTURING YIELD ANALYSIS

SPRINGBORN LABORATORIES, INC.

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- ADD - ON ACTIVITY TO BASELINE CONTRACT ON DEVELOPMENT OF ADVANCED ENCAPSULATION MATERIALS (PHASE III)
- NOT YET FUNDED

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

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**Material Variables**

**LAMINATION POTANTS**

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

**CASTING POTANTS**

- ALIPHATIC POLYURETHANE (PU)

**ADHESIVES/PRIMERS**

- THREE BASIC PRIMER SYSTEMS

**COVER FILMS**

- TEDLAR, ACRYLICS, 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 ANALYTICAL 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 DEVELOPMENT

## Quality and Performance Criteria

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

<u>COMPONENT</u>	<u>CONDITION</u>	<u>TEST</u>
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)

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**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)

CELL FRACTURE  
 INTERCONNECT BREAKAGE  
 TRAPPED BUBBLES  
 THERMAL CREEP  
 GLASS FRACTURE

CONTINUOUS

GEL CONTENT  
 PEEL STRENGTH  
 STABILIZER LOSS

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 EFFORT
- LINEAR ANALYSIS POSSIBLE FOR SUBSEQUENT PREDICTIVE CAPABILITY

FOR DISCRETE DATA TYPES:

- PREPARE SCATTER PLOT VS. VARIABLE
- PLOT THE ZERO FAILURE LINE
- USE GRAPHICS TO SPECIFY BOUNDARY CONDITIONS AND ACCEPTABLE PROCESSING "WINDOWS"
- DETERMINE FAILURE PROBABILITIES - BINOMIAL DISTRIBUTION

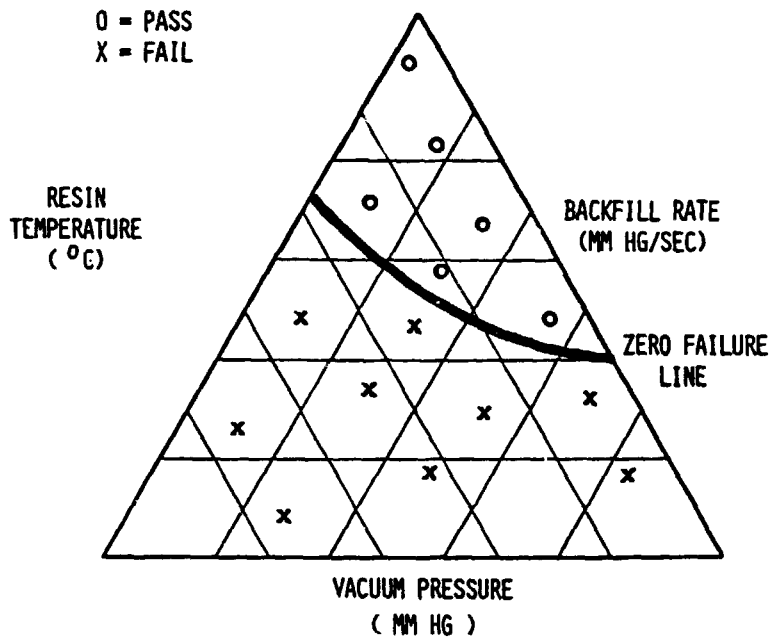
# PROCESS DEVELOPMENT

## Manufacturing Practice

### DISCRETE VARIABLES

- PREPARE GRAPHICAL INTERPRETATION OF DATA
- DETERMINE "ZERO FAILURE" LINE
- DEFINE BOUNDARY CONDITIONS FOR DEFECT-FREE MANUFACTURING

EXAMPLE: CELL BREAKAGE

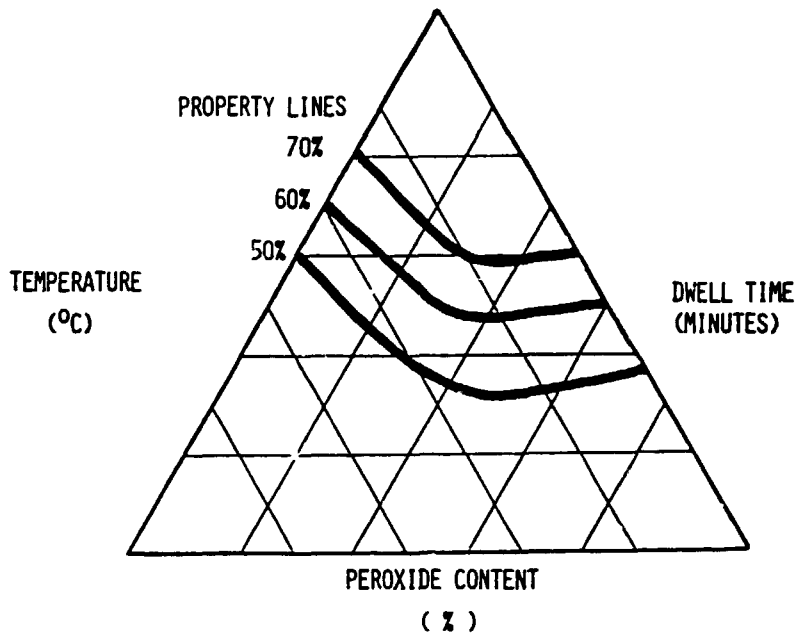


# MANUFACTURING PRACTICE

## 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)



## PROCESS DEVELOPMENT

### Future Work

- IDENTIFY SIGNIFICANT VARIABLES
  - FORMULATION
  - PROCESSING
- DETERMINE MATERIALS SPECIFICATIONS AND QUALITY CONTROL METHODS
- ASSESS EFFECT OF VARIABLE(S) AND RANK ACCORDING TO IMPORTANCE
- DEFINE FORMULATION AND PROCESSING "WINDOWS" (ZERO FAILURE)
- CONVERT DATA TO PRACTICAL ENGINEERING FORMAT
- RELATE DATA TO MANUFACTURING YIELD
  - ASSIGN PROBABILITY OF FAILURE
  - NORMAL DISTRIBUTION (?)
  - WEIBUL (?)
- PREPARE TROUBLE-SHOOTING GUIDE:  
"WHAT'S WRONG IF . . . .?"



### JPL Process Sensitivity Analysis

