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ENCAPSULATION PROCESSING AND MANUFACTURING YIELD ANALYSIS

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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

C-6

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

Quality and Performance Criteria

METHOD:

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

COMPONENT	CONDITION	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 EFFORT
- LINEAR ANALYSIS POSSIBLE FOR SUBSEQUENT PREDICTIVE CAPABILITY

FOR DISCRETE DATA TYPES:

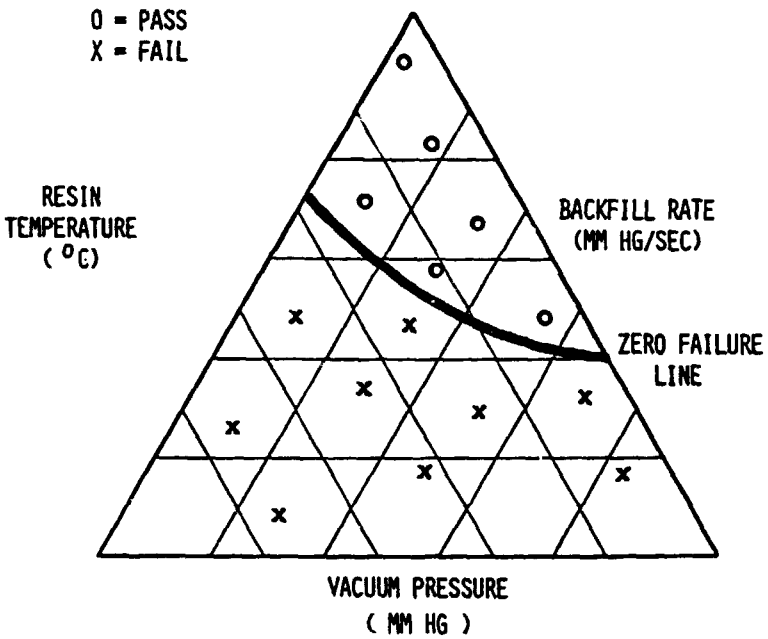
- PREPARE SCATTER PLOT VS. VARIABLE
- PLOT THE ZERO FAILURE LINE
- USE GRAPHICS TO SPECIFY BOUNDRY CONDITIONS AND ACCEPTABLE PROCESSING "WINDOWS"
- DETERMINE FAILURE PROBABILITIES - BINOMIAL DISTRIBUTION

Manufacturing Practice

DISCRETE VARIABLES

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

EXAMPLE: CELL BREAKAGE

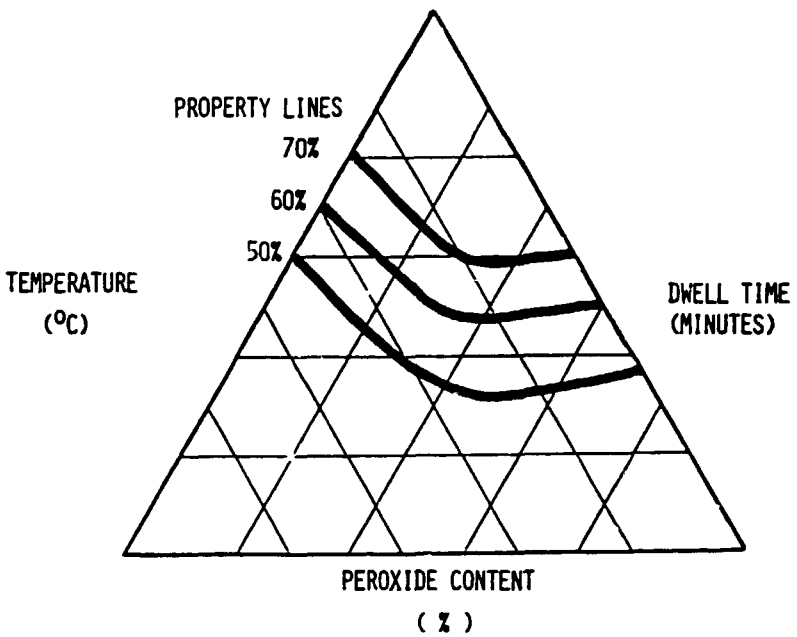


MANUFACTURING PRACTICE

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)



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