D/3

# ADVANCED RESIN MATRICES FOR COMPOSITES

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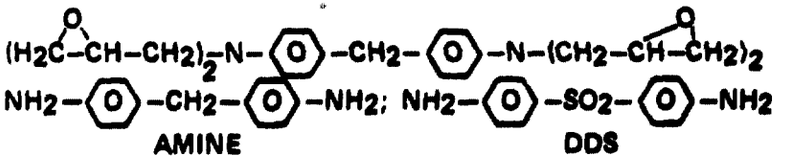
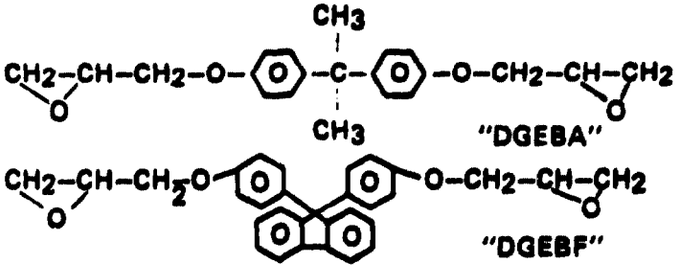
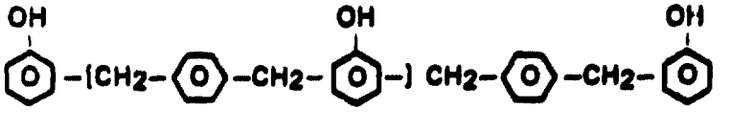
NASA - ARC

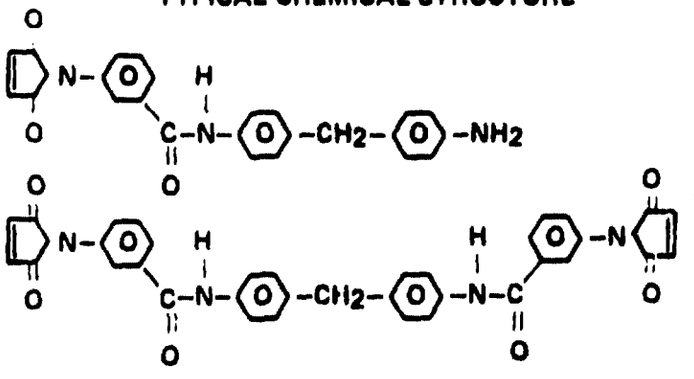
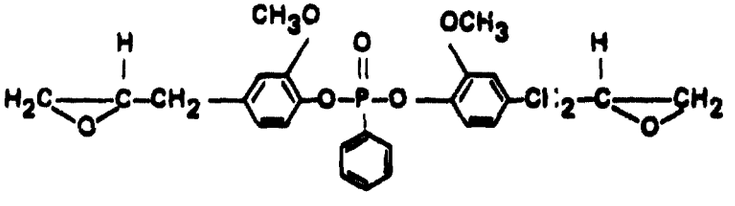
# SELECTION CRITERIA FOR RESIN MATRICES

- HIGH CHAR YIELD
- HIGH OI, LOW SMOKE & TOXICITY
- GOOD ELEVATED TEMPERATURE MECHANICAL PROPERTIES
- GOOD THERMAL OXIDATIVE STABILITY
- HIGH HUMIDITY RESISTANCE
- CHEMICAL AND RADIATION RESISTANCE
- GOOD FATIGUE AND TOUGHNESS PROPERTIES
- COMPATIBLE PROCESSING, QUALITY CONTROL, AVAILABILITY AND COST TO STATE-OF-THE ART EPOXY RESINS

# RESIN MATRICES FOR COMPOSITES

| RESIN/CURING AGENT | TYPICAL CHEMICAL STRUCTURE |
|---|---|
| EPOXY RESIN BASED ON METHYLENE DIANILINE CURED WITH AROMATIC AMINE OR 4,4' DIAMINO DIPHENYL SULPHONE (DDS) (SAMPLE 1) |  AMINE DDS |
| EPOXY RESIN BASED ON DIGLYCIDYL ETHER OF BISPHENOL A (DGEBA) OR 9,9-BIS-(4-HYDROXYPHENYL) FLUORENE (DGEBF) OR BLENDS CURED WITH TRIMETHOXYBOROXINE (TMB) OR MDA OR DDS (SAMPLE 2) |  "DGEBA" "DGEBF" |
| PHENOLIC NOVOLAC RESIN BASED ON CONDENSATION OF DIMETHOXY-P-XYLENE AND PHENOL CURED WITH HEXAMINE (SAMPLE 3) |  |

# RESIN MATRICES FOR COMPOSITES

| RESIN CURING AGENT | TYPICAL CHEMICAL STRUCTURE |
| --- | --- |
| POLYBISMALEIMIDE PREPOLYMER (SAMPLE 4) |  |
| BIS(4-GLYCIDYL-2-METHOXYPHENYL)PHENYLPHOSPONATE EPOXY RESIN CURED WITH N,N-DIETHYLAMINOPROPYLAMINE (DEAPA) (SAMPLE 5) |  |

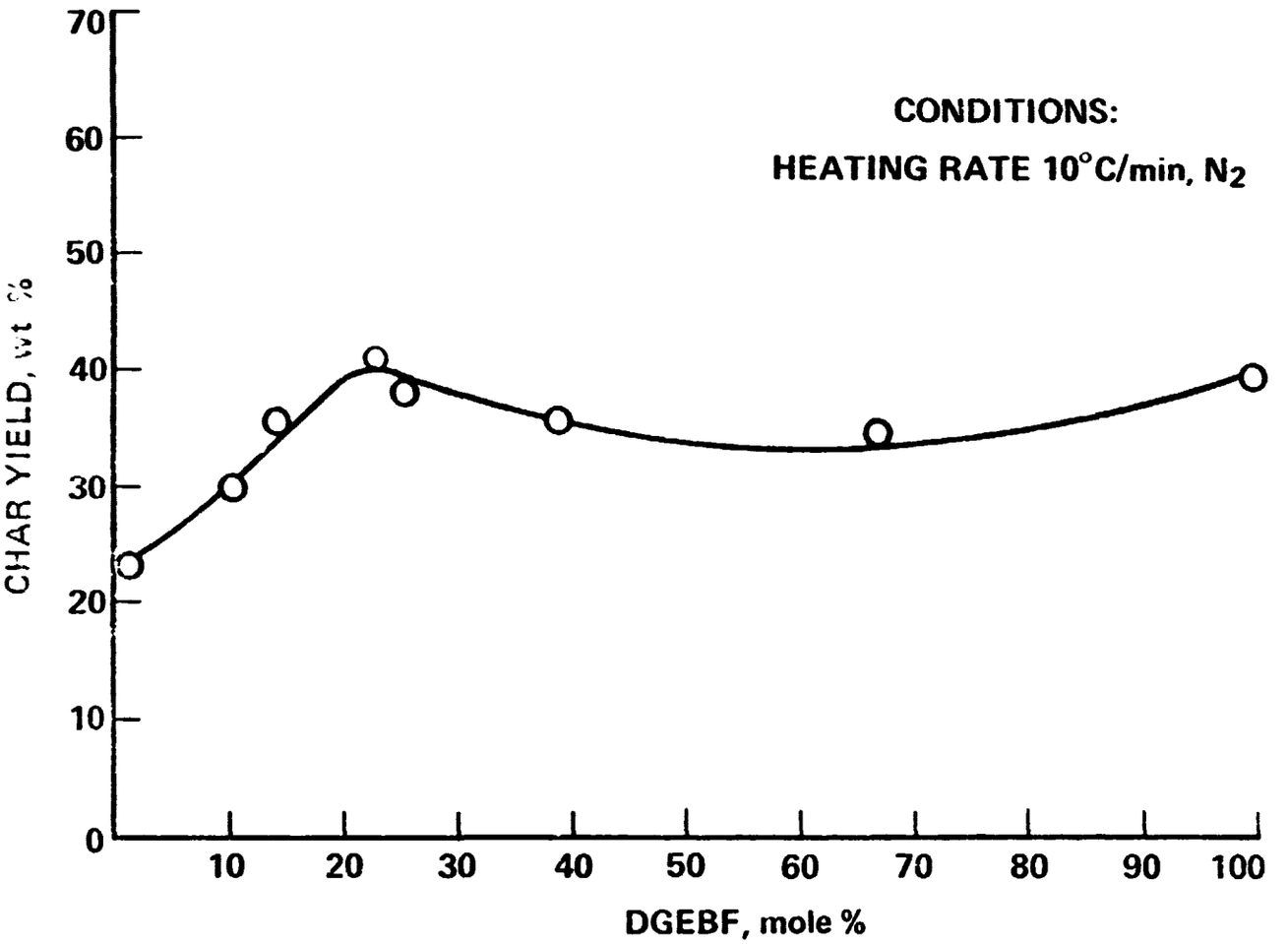
# PROCESSING CONDITIONS FOR RESINS AND LAMINATES

| RESIN | PURE RESIN | | |
|---|---|---|---|
| | CATALYST | CURE | POST CURE |
| EPOXY RESIN (SAMPLE 1) | NMA OR DEAPA OR DDS | DDS, 30 pph, 150°C – 1 hr | 190°C – 4 hrs |
| EPOXY RESIN, DGEBA/DGEBF (SAMPLE 2) | TMB OR DDS | TMB, 30 pph, 135°C – 3 hrs | 180°C – 3 hrs 218°C – 3 hrs, $N_2$ |
| **RESIN/SOLVENT** | **LAMINATE** | | |
| | PREPREG | CURE | POST CURE |
| (SAMPLE 1)/MEK | AIR DRY, 80°C – 10 min 120°C – 20 min | 163°C – 10 min, 340 KN/$m^2$ – 2 hrs | 190°C – 4 hrs |
| (SAMPLE 2)/MEK | AIR DRY, 100°C – 15 min 140°C – 20 min | 200°C – 10 min 340 KN/$m^2$ – 2 hrs | 218°C – 3 hrs, $N_2$ |

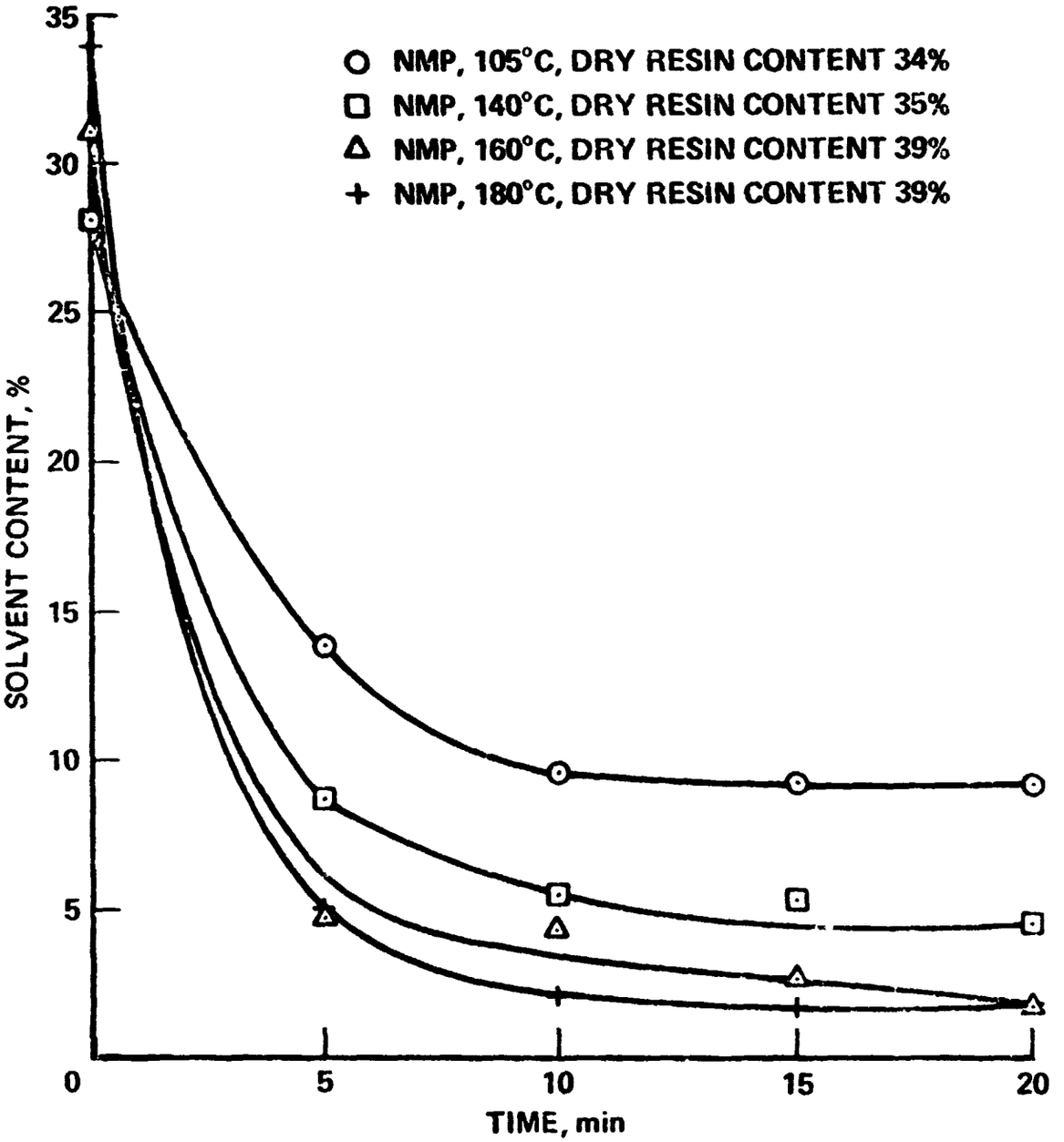
# PROCESSING CONDITIONS FOR RESINS AND LAMINATES

| RESIN | PURE RESIN | | |
|---|---|---|---|
| | CATALYST | CURE | POST CURE |
| PHENOLIC NOVOLAC (SAMPLE 3) | | 160°C – 1.5 hrs | 200°C – 1 hr |
| POLYBISMALEIMIDE (SAMPLE 4) | | 200°C – 3 hrs | |
| PHOSPHORYLATED EPOXY (SAMPLE 5) | DEAPA | DEAPA/ BAPMP | 180°C – 4 hrs |
| RESIN/SOLVENT | LAMINATE | | |
| | PREPREG | CURE | POST CURE |
| (SAMPLE 3)/MEK | 65°C – 15 min<br>115°C – 20 min | 177°C – 1 hr<br>680 KN/$m^2$ | 188°C – 2 hrs |
| (SAMPLE 4)/MEK | AIR DRY,<br>79°C – 15 min<br>120°C – 20 min | 200°C – 3 hrs<br>680 KN/$m^2$ | |
| (SAMPLE 5)/MEK | AIR DRY,<br>80°C – 10 min<br>120°C – 20 min | 180°C – 10 min | 200°C – 4 hrs |

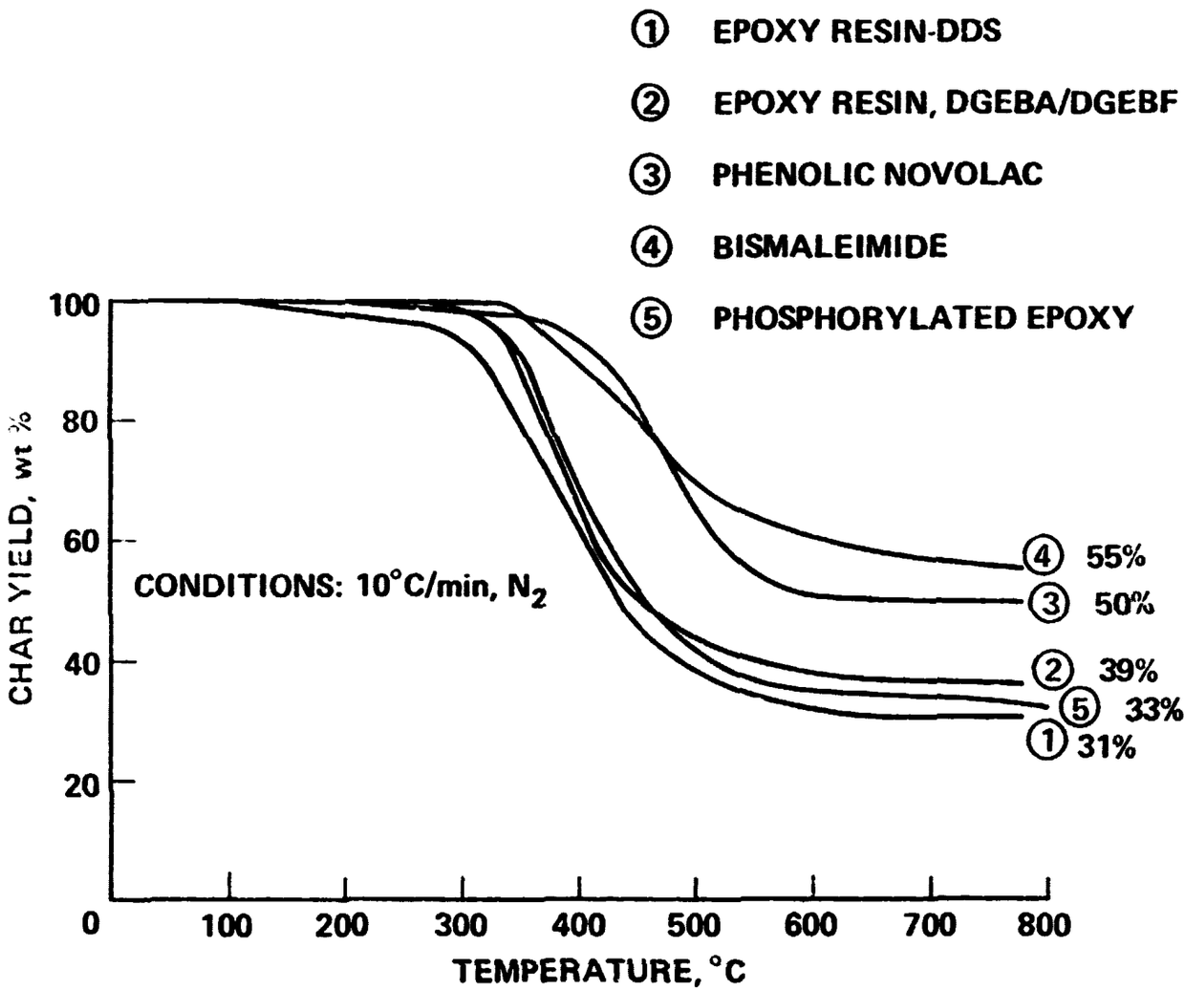
# EFFECT OF DGEBF MOLE FRACTION IN THE BLEND OF DGEBA/DGEBF ON THE CHAR YIELD OF THE COPOLYMER AT 700°C



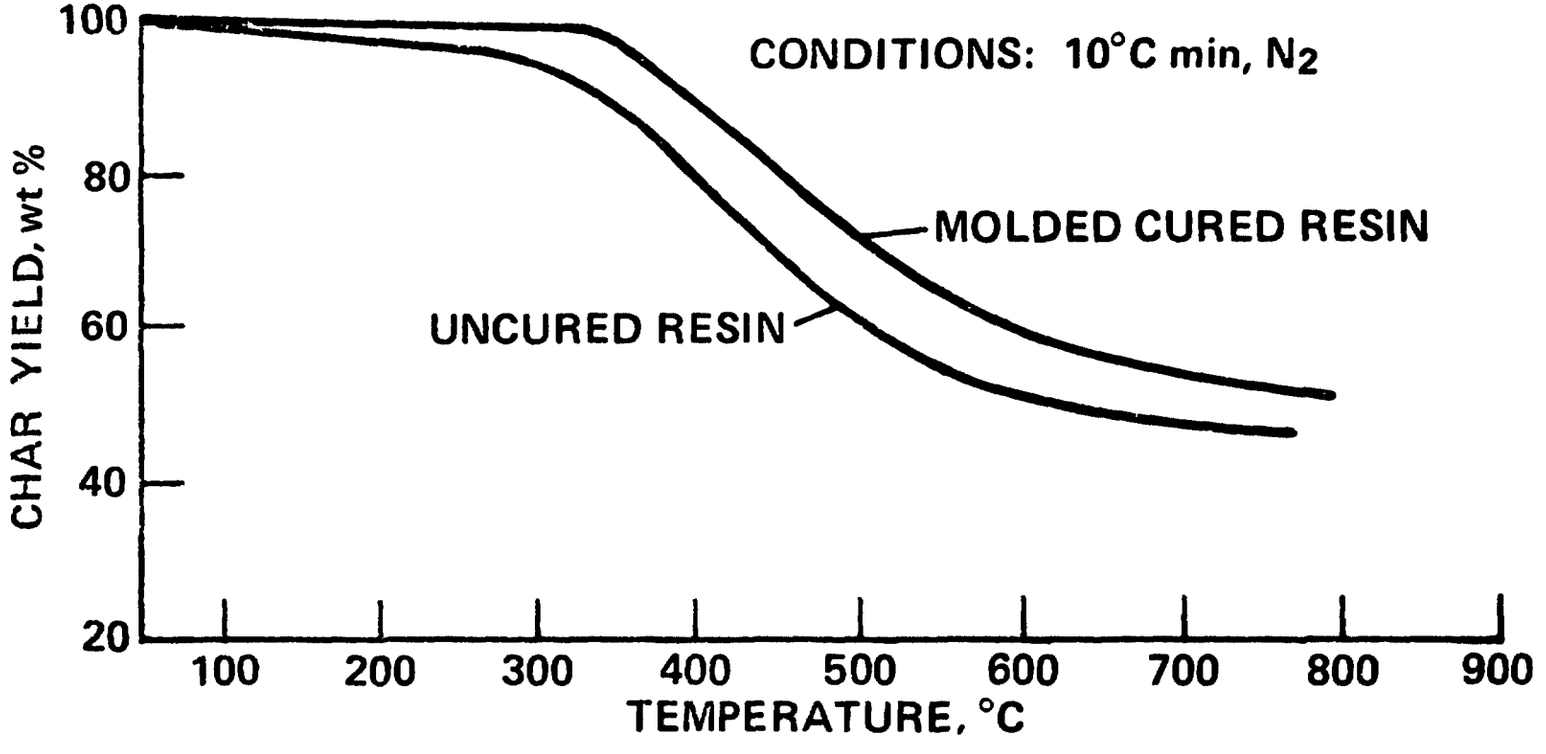
## DRYING CURVES FOR BISMALEIMIDE/181-PREPREGS



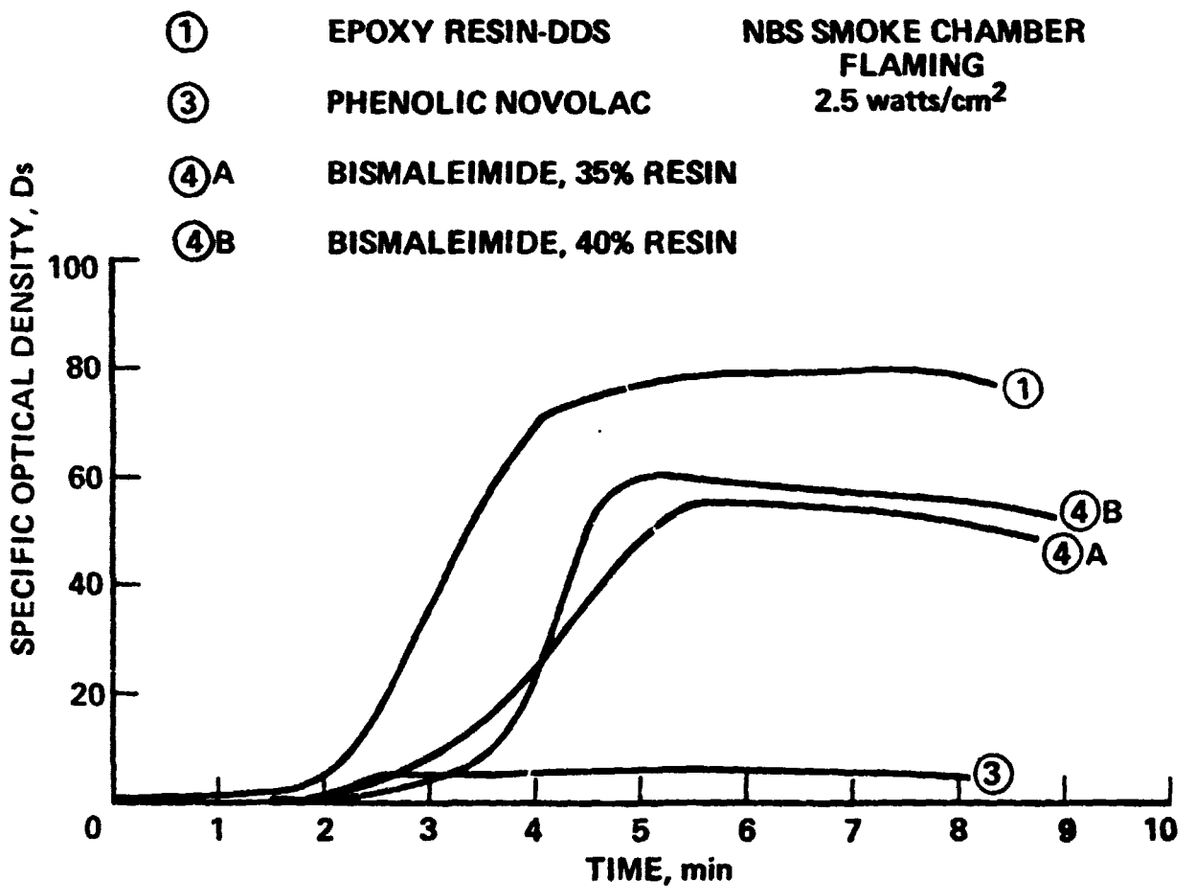
# DYNAMIC THERMOGRAVIMETRIC ANALYSES OF RESINS



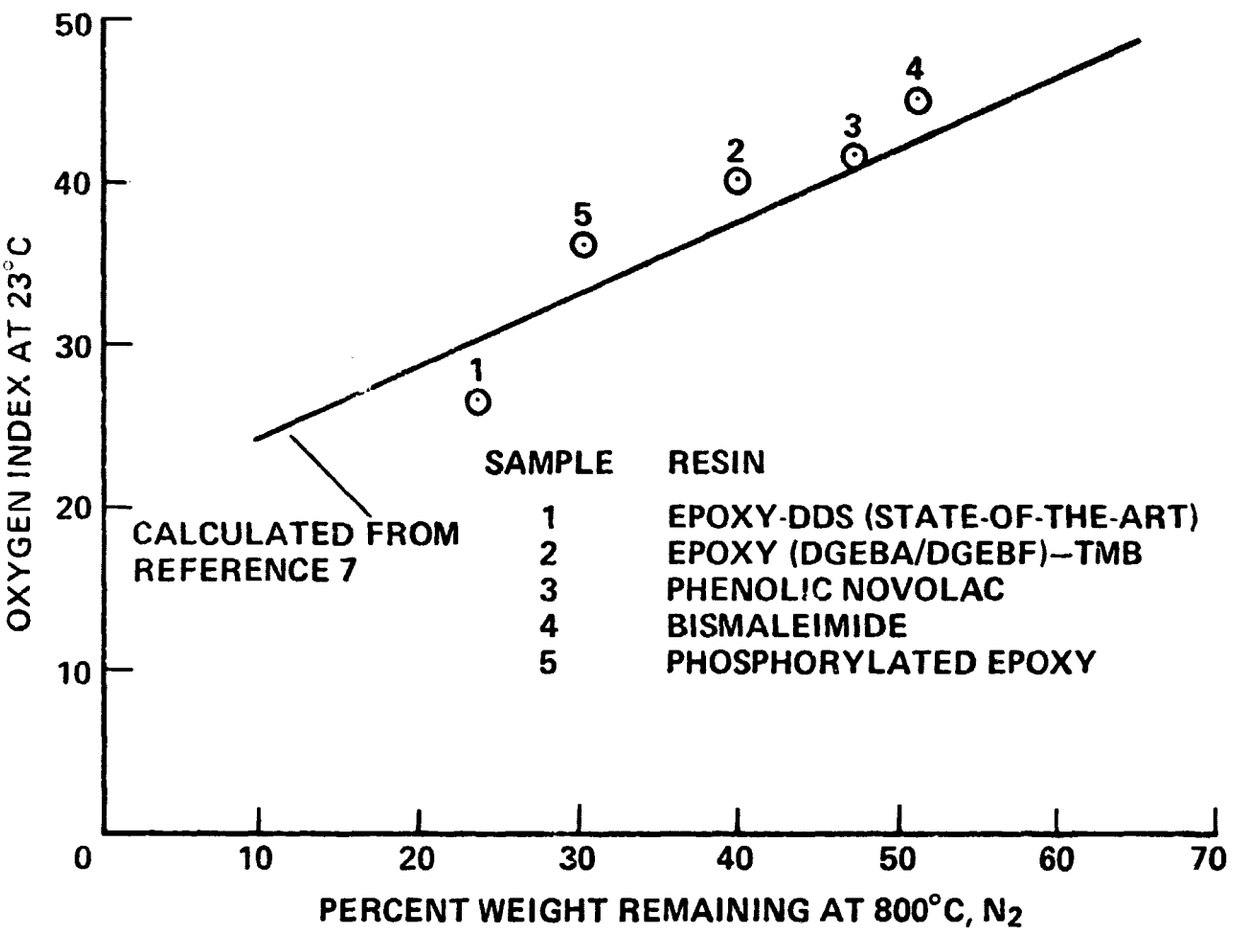
# DYNAMIC THERMOGRAVIMETRIC ANALYSIS OF BISMALEIMIDE RESIN (SAMPLE 5)



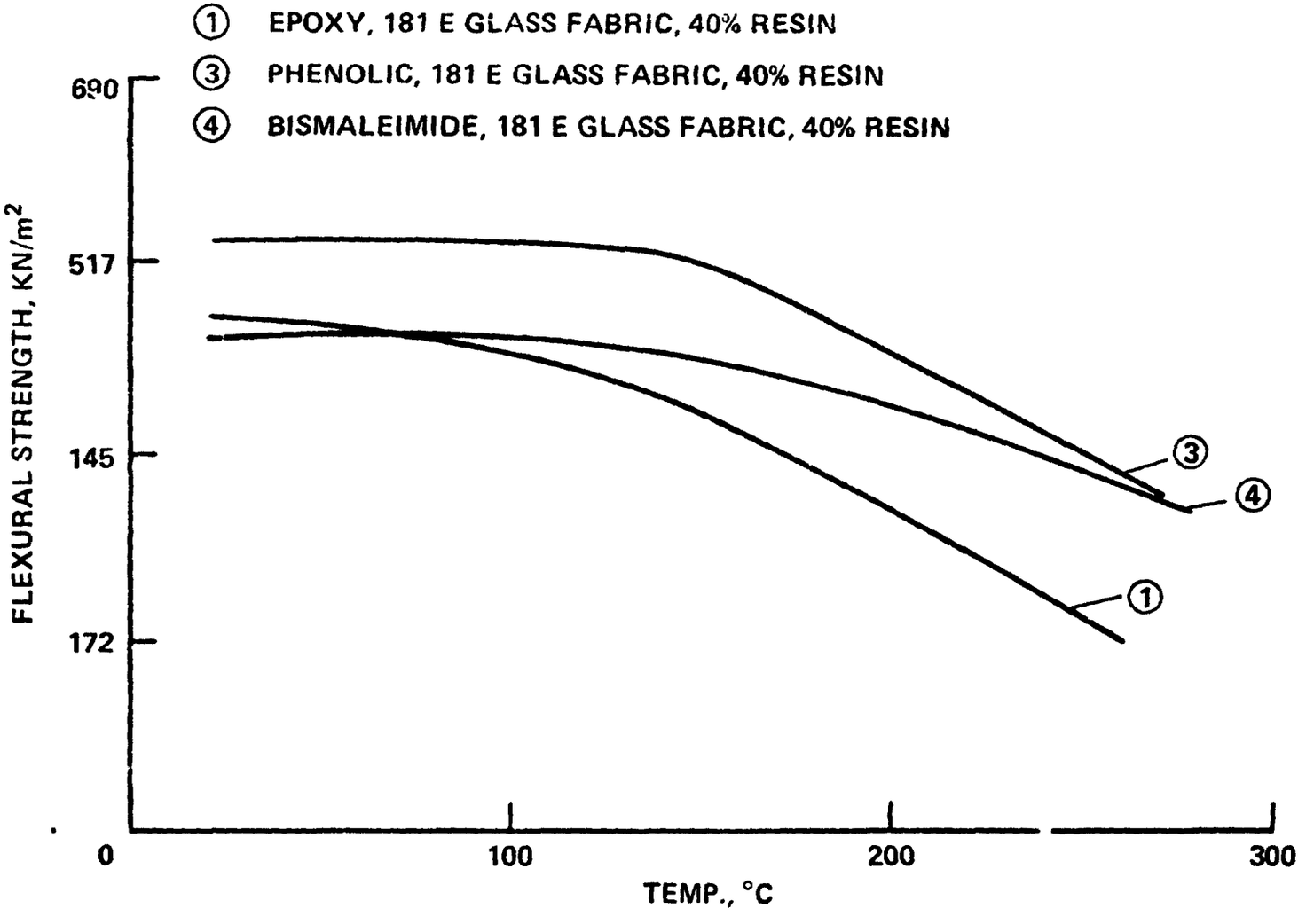
# SMOKE EVOLUTION OF RESIN/181 GLASS LAMINATES



# EFFECT OF CHAR YIELD OF THERMOSET POLYMERS ON OXYGEN INDEX



# EFFECT OF TEMPERATURE ON FLEXURAL STRENGTH OF COMPOSITES



CO CONCENTRATION HISTORY

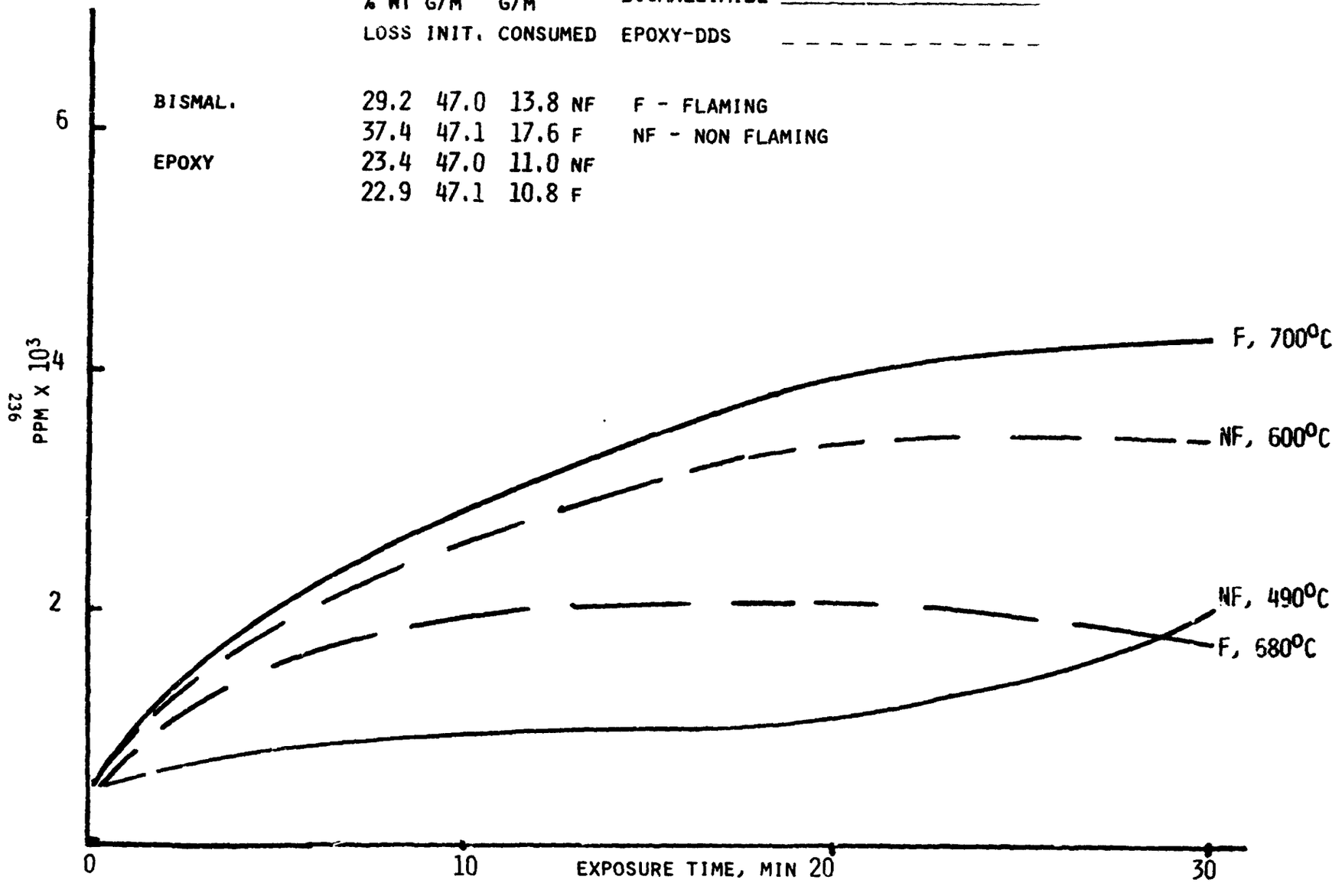
| | % WT LOSS | $G/M^3$ INIT. | $G/M^3$ CONSUMED | |
|---|---|---|---|---|
| BISMAL. | 29.2 | 47.0 | 13.8 | NF |
| | 37.4 | 47.1 | 17.6 | F |
| EPOXY | 23.4 | 47.0 | 11.0 | NF |
| | 22.9 | 47.1 | 10.8 | F |

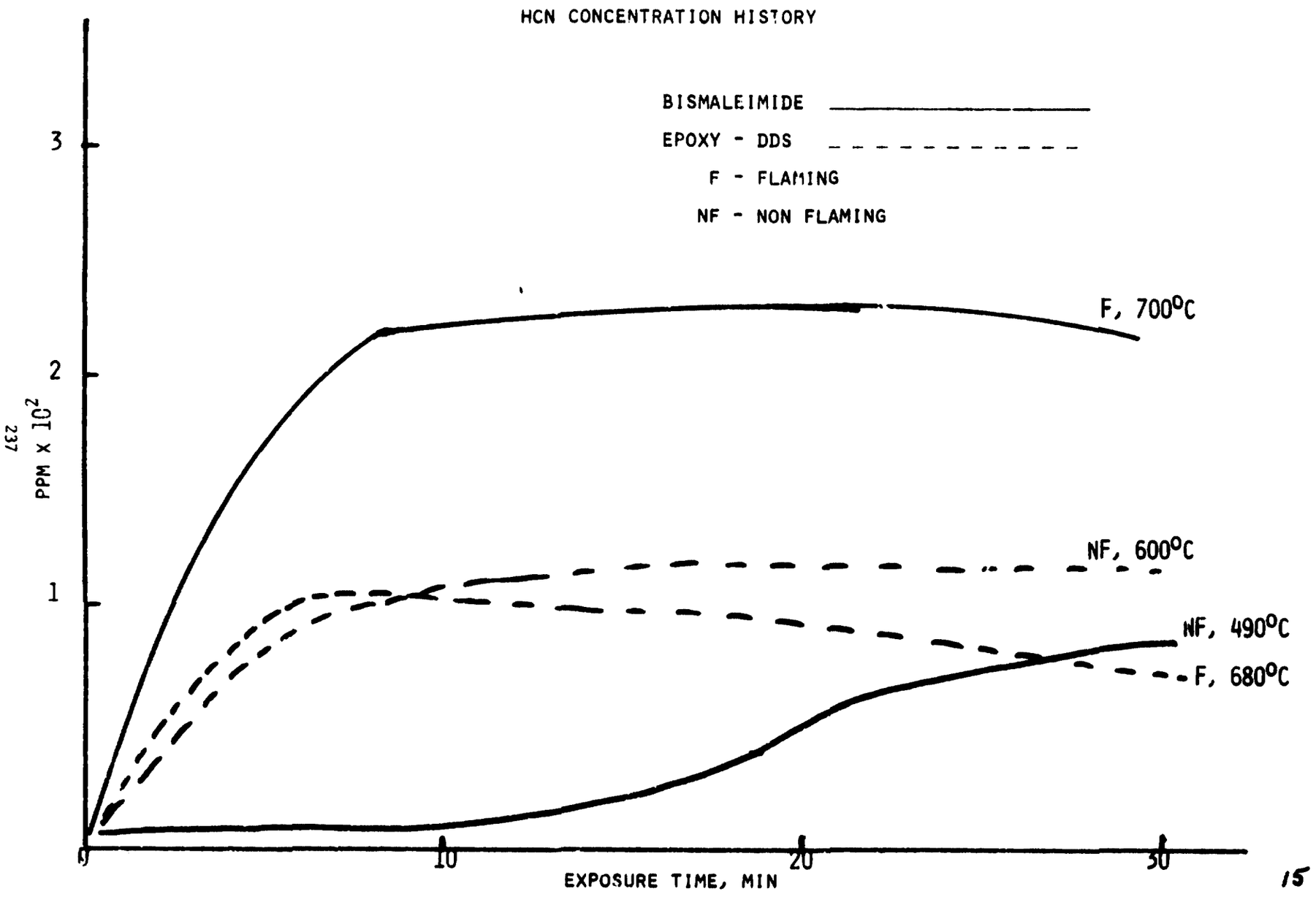
BISMALEIMIDE _____

EPOXY-DDS - - - - - - - - - - -

F - FLAMING

NF - NON FLAMING




HCN CONCENTRATION HISTORY
BISMALEIMIDE
EPOXY - DDS
F - FLAMING
NF - NON FLAMING
F, 700°C
NF, 600°C
NF, 490°C
F, 680°C
PPM X 10^2
237
3
2
1
0
10
20
30
EXPOSURE TIME, MIN

## CONCLUSIONS

DGEBA/DGEBF EPOXY CURED WITH TMB EXHIBITED HIGHEST OI AND $Y_C$ THAN ALL OTHER EPOXY RESINS WITH PROCESSING PARAMETERS COMPARABLE TO CONVENTIONAL EPOXIES.

PHENOLIC-NOVOLAC RESIN EXHIBITED LOWEST Ds THAN ALL OTHER RESIN SYSTEMS.

BISMALEIMIDE RESIN EXHIBITED HIGHEST OI AND $Y_C$ THAN ALL OTHER RESIN SYSTEMS. PROCESSING PARAMETERS COMPARABLE TO PHENOLICS.

ABOVE RESINS EXCELLENT CANDIDATES FOR RESIN MATRICES FOR GLASS OR GRAPHITE COMPOSITES.