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EFFORTS TO ENHANCE THE PROPERTIES OF CONVENTIONAL ELEVATED TEMPERATURE CURE EPOXY RESIN SYSTEMS BY EXPOSING THEM TO 1250 TO 8800 OERSTED MAGNETIC FIELDS WHILE THERMALLY CURING THEM

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Final Report

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14. Abstract To determine if enhancements to the properties of fully conventionally cured, conventional epoxy resin systems could be generated by thermally curing them while simultaneously exposing them to economically generated magnetic fields was this effort's objective. Stoichiometric mixes of mPDA, MDA, PACM-20, and Tonox curing agents with EPON 830 were used. They were thermally cured with one of these profiles: 20 hours at 210 ^{0}F (99 ^{0}C), 5 hours at 250 ^{0}F (121 ^{0}C), and 4 hours at 300 ^{0}F (149 ^{0}C). While being thermally cured, they were also exposed to magnetic fields of strengths between 1250 Oersted (0.1250 Tesla) and 8800 Oersted (0.8800 Tesla). Magnetic field exposed and control specimens were simultaneously generated from the same epoxy resin system in each experimental run of this effort. The resulting specimens were mechanically and thermally tested to find any differences in the significant properties of those cast exposed to a magnetic field relative to those cast as controls. This effort determined that under no reasonable conditions of elevated temperature cure and economically generated magnetic fields were there any modifications to the relevant properties of magnetic field exposed, fully thermally cured epoxy resin systems relative to their associated controls.

15. Subject Terms Magnetic Fields, Magnetic, Resins, Epoxy, Processing, Matrix

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List Of Abbreviations

A	Amps
ASTM	American Standard Testing Methods
AVG	Average
^{o}C	Degrees Centigrade
CFM	Cubic Feet Per Minute
Deg	Degrees Of Angle
DGEBA	Diglycidylether Of Bisphenyl A
Dia	Diameter
OD	Outer Diameter
ID	Inner Diameter
DSC	Differential Scanning Calorimetry
DPs	Data Points
^{o}F	Degrees Fahrenheit
Ft	Feet
Gal	Gallon
GE	GENERAL ELECTRIC
G	Gauss
mG	milligauss
KG	Kilogauss
gms	grams
Hz	Hertz
MHz	Megahertz
KHz	Kilohertz
Hr	Hour
In	Inches
J	Joules
mJ	milliJoules
KSI	Thousands of Pounds Force Per Square Inch
KVA	Kilovolt Amps
KWA	Kilowatt Amps
Lb_f	Pounds Force
L/D	Length Versus Diameter
L	Liter
mL	milliliter
MDA	4,4'- Methylene Dianaline
m	meter
mm	millimeter
cm	centimeter
Max	Maximum
mil	1/1000 Inch
Min	Minimum
mPDA	1,3 Phenylene Diamine
NBS	National Bureau Of Standards
Oe	Oersteds
OV	Overall
PACM-20	4,4'- Methylene Bis Cyclohexylamine
Pa	Pascals
MPa	MegaPascals
GPa	GigaPascals
PHR	Parts Per Hundred Resin

List Of Abbreviations Continued

PI	Principal Investigator
PPM	Parts Per Million
PSI	Pounds Force Per Square Inch
Qt	Quart
Std	Standard Of Deviation
STF	Strain To Failure
STY	Strain To Yield
T	Tesla
Tg	Glass Transition Temperature
TSY	Tensile Stress At Yield
UTS	Ultimate Tensile Stress
W	Watts
mW	milliWatts
KW	Kilowatts
MW	MegaWatts
Exposed	With Magnetic Field Exposure
Control	With Out Magnetic Field Exposure
VAC	Voltage Alternating Current
VOC	Volatile Organic Compounds
%	Percent

Executive Summary

This experimental effort's objective was to determine if enhancements to the properties of conventional high temperature epoxy resin systems could be generated by thermally curing them to full cure (conventionally defined to be 99+ percent of complete chemical reaction) while simultaneously exposing them to economically generated magnetic field strengths. Previous efforts by the Principal Investigator (PI) to 75 percent cure at room temperature with aliphatic curing agents an epoxy resin system while simultaneously exposing them to magnetic fields of the same strength as those used in this effort generated 60 to 100 percent improvements in the resultant resin system's mechanical properties. An independent effort by Dr. Mallon, then at the Aerospace Corp, to fully cure at elevated temperatures a stiochiometric mPDA epoxy resin system while simultaneous exposing it to a 90000 Oe (9T) magnetic field generated the heretofore unheard of enhancement to the resin's Tg of 45^{O}F. (Any magnetic field stronger than 35000 Oe (3.5T) can only be generated by superconducting electromagnets. They cost 250,000 dollars and up.) Also the foreign literature, primarily written by Russians and other members of the former Soviet Union, is replete with hundreds of their efforts to enhance, by processing in a magnetic field, almost every conceivable property of, almost every conceivable polymer, processed by almost every conceivable technique, into almost every conceivable end product. These previous efforts indicated that the potential to economically enhance particular properties of epoxy resin systems, by processing them with conventional production techniques into end items while simultaneously exposing them to magnetic fields of strengths that could be economically generated by permanent magnets and conventional electromagnets, was highly probable. It was also hoped that these particular property enhancements could then be economically produced in epoxies when they would be used as the matrix material in an Air Force composite, a bonding agent, or as a coating material. Unfortunately the results of this thorough experimental effort decisively proved the complete non-existance of that economic potential.

This effort used stoichiometric mixes of mPDA, MDA, PACM-20, and Tonox curing agents with EPON 830 as the base epoxy resin. These epoxy resin systems were cured with one of these cure profiles: 20 Hrs at 210 ^{O}F (99 ^{O}C), 5 hrs at 250 ^{O}F (121 ^{O}C), and 4 Hrs at 300 ^{O}F (149 ^{O}C). These resin systems were thermally cured while being exposed to magnetic fields of strengths stepped up from 1250 Oe

(0.1250 T) to 8800 Oe (0.8800 T). These step sizes were selected to be roughly 400 Oe between 1250 Oe and 5000 Oe and 1100 Oe between 5000 Oe and and 8800 Oe. These step sizes represented the robustness requirements which any prospective enhancements needed to exhibit in order to be suitable for and economically justify their incorporation into an existing processing technique.

Innovative techniques were developed to thermally cure the epoxy resin systems in finely temperature controlled nonmagnetic ovens. These ovens represented the first time that a viable mechanism had been created to generate a controlled high temperature large volume space within a 0 ^{o}C liquid cooled electromagnet generated magnetic field. These ovens were also developed to lock in the location of the curing resin specimens relative to both the magnetic field generators and to the magnetic field mapping devices. In addition to the ovens, innovative magnetic field mapping devices were developed to map out the magnetic fields to accuracies heretofore not documented. Exhaustive precautions were taken so as to exactingly regulate and control all aspects of the magnetic field's generation: range, drift, and repeatability. Unique and extremely tight toleranced testing devices were developed and the first totally computer controlled tensile-compression mechanical testing machine and data analysis device in the Air Force was acquired. These assured the acquisition of the highest quality mechanical data possible from the specimens generated in this effort.

Many technical challenges were met and overcome in the prosecution of this experimental effort. The innovative and interactive design of the ovens, magnetic field generators, the magnetic field mapping devices, and their inter-connecting support structure was an intricate, design and fabrication, engineering challenge that was successfully overcome. The redesign and refabrication of the ovens and their internal components to overcome mounting thermal cure temperature control and specimen positional repeatability problems was successfully met and overcome. The isolation, identification, redesign, and refabrication of testing jigs and fixtures, required to improve the rate of successful mechanical testing from one out of every three specimens tested to 199 out of every 200 tested was an effort that was also successfully met and overcome.

The most daunting technical challenge overcome, revolved around the necessity of isolating the causes of and

deducing resolutions to the numerous problems found to occur when California environmental legislation forced a change, which was undocumented, in the formulation of the silicon based rubber used to make the specimen generating cavities. These legislatively induced changes in the rubber caused flaws to be induced in the epoxy resin systems cast in them. These flaws rendered 20 out of 57 experimental runs useless. These runs were useless in that the rubber caused voids to occur in so many of the cast specimens that there were not enough testable specimens generated to conduct even minimum testing. Two distinct flaw generating problems had to be sequentially isolated, identified, and resolved before a continuous stream of successful runs could be accomplished to complete this effort.

In each of this effort's experimental runs, magnetic field exposed and associated control specimens were both generated from the same epoxy resin system. Both the magnetic field exposed specimens and their associated controls were fully cured by the same thermal cure profile. These specimens were mechanically and thermally tested to measure the relevant and important properties associated with these resins. These properties were also measured to determine any differences between the properties of specimens exposed to a magnetic field relative to those cast as controls. This effort decisively determined that under no conditions of elevated temperature cure and economically generated magnetic fields was there any modifications, of a technical and most critically an economically viable nature, to the important properties of fully cured epoxy resin systems relative to their associated controls.

The reason for this failure to enhance the properties of such processed epoxy resin systems was the magnetic field's inability to suppress the very energetic polymer subchain movements and their disorienting effects. As the degree of cure increased, the aromatic cured epoxy resin systems stopped behaving like simple large molecules and started behaving like a polymer. Instead of the rotations, translations, and vibrations of simple monomer sized molecules now entire cured sections of the epoxy were vibrating, but primarily translating and rotating, as a part of a large mass subsection of the overall polymer. In addition to this, the now few-and-far-between unreacted epoxy and amine groups were being moved to and driven into each other by the motion of these large subsections of the already reacted epoxy-amine polymer molecule. This reactant movement is necessary to drive the overall degree

of cure to 99+ percent. The amount of energy required to cause these subsection movements is at least larger than the activation energy of the epoxy-amine reaction. That reaction's energy of activation is between 10 and 16 Kcal/mole. (This contrasts dramatically with the kT energy of between 1 and 1.5 Kcal/mole associated with the original liquid mixture of molecules. The magnetic field had only to initially work against and to suppress the disorientating rotations of those liquid state monomers.) Collisions between these subsections are not completely elastic and would result in the repartitioning of the primarily translational energy of the moving subsections into translational and rotational energy. The rotations imparted to these subsections are almost instantaneously retarded away by the action of the external magnetic field. Unfortunately, due to the necessity of first having the current loops associated with the aromatic groups begin a flux changing rotation before the rotational damping effect can eliminate that rotation, there will be a degree of reorientation of the constituent monomers making up the collided subsections of the epoxy-amine polymer. If the original monomers were oriented to their highest degree by the shear field they experienced when they flowed into the casting cavities, then these very energetic subchain collisions would over time result in the randomizing and degrading off of this original orientation. Economically generated magnetic fields of the strength used in this effort are not strong enough to sufficiently suppress the disorientation effects of these subchain collisions; where as, uneconomically generated magnetic fields, such as those generated by Dr. Mallon's superconducting electromagnet can.

INTRODUCTION

Since the development and wide scale use of bulk artificial polymers, researchers in this field have endeavored to improve their useful properties with post synthesis processing. One processing technique that has had success revolves around dissolving the polymer in a solution and processing the result into an end item. This processing changes the physical chemical state in which the polymer is processed: from bulk to a uniformly dissolved solute through to a solution containing liquid crystals of the polymer. Another technique extrudes the melted or solvated polymer, inducing a shear flow field into the bulk which aligns the individual polymer molecules. A quick quench is then used to set this alignment into the bulk end item. To improve some properties, another technique is to blend other chemicals, up to and including other polymers, into the base polymer to modify its properties. Thermophysical processing regimes analogous to annealing a metal are also used to modify a polymer's bulk properties. And last, the mechanical stretching of a bulk polymer has been extensively used to improve the resultant polymer's properties. The properties of almost all of the presently known artificial polymers have been attempted to be improved by using these techniques to process them. These efforts have resulted in degrees of success ranging from abject failure to raging success. Not found in the above list is a processing technique that has shown some success in processing some other materials; namely the us of electromagnetic fields and, more specifically, magnetic fields.

The potential to improve the properties of bulk polymers by processing them into end items while simultaneously exposing them to magnetic fields is an area of research that has only been selectively and topically investigated by specific national research groups. Many research groups world wide have conducted extensive research on the property modification effects that processing liquid crystal polymers in a magnetic field has.(1-12) It is widely known that processing a liquid crystal polymer in a magnetic field can modify and enhance the liquid crystal's properties and do so in an orientation dependent way. A few research groups throughout the world have also demonstrated the ability to modify the molecular weight distribution and degree of branching in bulk artificial polymers which were radical addition polymerized while simultaneously exposed to a magnetic field.(13-20) But the use of magnetic fields to process and enhance the properties of bulk polymers, other than liquid crystal and radical polymerized polymers, is an area of research that

until the 1980's was exclusively investigated by researchers in the old Soviet Union (now Russia and associated states) and its allied states. (21-155)

Beginning in the early 1950's, with the efforts of a combined German-Soviet research team, and continuing into the early 1990's, Soviet-Russian(S-R) researchers have conducted extensive and diverse investigations directed at determining the potential to enhance the properties of bulk polymers by fabricating them into end items while simultaneously exposing them to magnetic fields. The S-R researchers have published the results of over two hundred research efforts conducted over this time specifically directed at exploring and defining this effect. Table 1 lists many of the polymeric materials on which they have conducted studies to determine the magnitude of this effect. Table 2 lists the polymeric material processing techniques and the various properties which S-R researchers have published claims of desirable property enhancement resulting from this effect. The simultaneous magnetic field coprocessing effect, as indicated by these lists and the published body of S-R work, certainly suggests that this effect might have potential. Unfortunately until the mid 1980s no one outside of the S-R community had conducted and published any work which either verified or refuted this.

In 1986 the author conducted and later published work which verified the existence of the mechanical property enhancement effect that occurs when an epoxy resin system is room temperature cured while simultaneously exposed to an external magnetic field.(21,25) Experimental runs 31 through 39, of the author's 1986 effort, verified many of the claims made by the S-R researchers. They claimed that the mechanical properties of a so cured epoxy resin system could be substantially enhanced. The results of two of runs 31 through 39 demonstrated that at selected magnetic field strengths the mechanical properties of the partially cured resin system could be improved by 50 to 250 percent. The S-R researchers also indicated that the enhancement effect had an orientation bias to it. They reported that the enhancement effect depended upon both the orientation in which the specimen was generated in the magnetic field and the orientation relative to that in which it was tested.(130-149) The results of runs 31 through 39 verified the existence of the orientation dependence. Enhanced mechanical properties were generated in specimens that were cast and tested such that the angle of the specimen's load bearing testing axis was cast perpendicular to the angle of the magnetic field during its curing in

Table 1: Soviet/Russian Materials Enhanced
By Magnetic Field Exposure(21-155)

Polyolefins:
- Polyvinylacetate
- Polypropylene
- Polystyrene
- Polyvinylalcohol
- Polyvinylbutral
- Polyethylene: Melts
  Crystalline
  Cooled And Crystalized
  Average Density
  High Density
  High Strength

Epoxies:
- Furan-Epoxies
- Various Epoxy Resins
- Epoxies cured with: DiEthyleneTriAmine
  TriEthyleneTetraAmine
  Hexamethylenediamine
  PolyEthylenePolyAmine+L-20
  [Dimerized Linseed Oil]
  Polyamide
  TriEthyleneAminoTitanate
- Blend Of Epoxies
- Epoxy Spheroplastics
- Epoxydian Type Bisphenyl A Epoxies

Composites:
- Epoxy Glass Fiber Reinforced Plastic T-10
- Epoxy Carbon Fiber Reinforced Plastic EDT-10
- Structural Composites
- Filled Composites
- Reinforced Plastics / Composites: Fibers:
  Glass
  Vniivlon
  Carbon
  Boron
  Matrixes:
  Silicon
  Epoxy
  Polyimide

Phenolics:
- Blend Of Polyacetal-Phenol-Formaldehyde-Alkoxysilane
- Blend Of Phenol-Polyvinylacetal
- Phenol-Formaldehyde
- Phenol-Furfural Resins

Polyamides
- Poly-p-phenyleneterephthalamide In Sulfuric Acid.

Table 1: Soviet/Russian Materials Enhanced
By Magnetic Field Exposure Continued

Poly Halogenated Olefinics:
- Polyvinylchloride
- Polyvinylidene Fluoride
- Pentaplast (Halogenated Gem Vinyl)

Fiber Forming Polymers:
- Polyacrylonitrile
- Polycarbamide
- Polyester
- Viscose Yarn
- Viscose Cellulose Xanthate
- Sulfonated Cellulose
- Cellulose Acetate
- Acetate

Imides and Azoles:
- Polyimides
- Polybenzoxazoles
- Polyoxazoles
- Polyphenyleneoxazoles

Acrylics:
- PolyMethylMethacrylate
- Water Born Polyacrylamide

Latexes:
- Liquid Mixtures Of Latex Foams
- Water-Emulsion Latexes
- Bulk Polymers On A Latex Base
- Latex Blends And Concrete

Pigments And Dyes:
- Diffusion Mobility Of Pigments
- Dyeing Textile Materials

Coating Materials:
- Enamels
- Varnish
- KP Lacquers

Miscellaneous:
- Mica Electroinsulation Paper
- Blood Flow
- Rubber Blends
- Dielectric Polymers
- Biopolymers In Polyacrylamide Gel
- Polyurethane
- Organosilicon
- Cross-Linked Three-Dimensional Polymers

Table 2: Soviet/Russian Applications And Processes Enhanced By Magnetic Field Exposure(21-155)

- Composites:
  - Static Structural
  - Aerospace
  - Marine
  - Commercial Bulk Structural
  - Noncontinuous Composites
  - Production:
    - Winding
    - Impregnation
    - Prepreg Production
    - Pultrusion Processing

- Coatings:
  - Coating Wires To Wind Electric Motors
  - Enamel Coatings To Protect Against An Acid Media
  - Beer Brewing And Wine Making Coatings
  - Painting
  - Paints Of Varnish Or Lacquer
  - Coatings On Infrastructure Ie Roads Bridges
  - Road Bed Toppings / Astringents
  - Wear Resistant Enamel
  - Latex Base Paints
  - Applying Fluid Materials Onto Tape
  - Application Of Polymer-Based Coatings

- Adhesives:
  - Producing Adhesive Tape
  - Processing Adhesives From A Latex Base
  - Bonding:
    - Articles With Seams
    - Bondlines
    - Junctions Of Steel To Steel
    - Ferromagnetic Plates
    - Nonmagnetic Materials
    - Honeycomb Filler To Shells.

- Bulk Polymers:
  - Blends
  - Bulk Solid Items
  - Foams
  - Processing Bulk Polymers
  - Foaming

Table 2: Soviet/Russian Applications And Processes Enhanced By Magnetic Field Exposure Continued

- Textiles:
  - Dyeing:
    - Clothing And Linen
    - Textile Materials
    - Hydrophilic Textile Material
  - Manufacturing:
    - Threads
    - Fibers
    - Tapes
    - Fabrics
    - Filters
    - Yarn
    - Finishing Textiles
  - Molding:
    - Hollow Fibers For Desalination
    - Films
    - Tubes
  - Fiber Spinning:
    - Technical Yarn
    - Yarn Breakage Reduction

- Biological:
  - Water Purification Ion Exchange Resins
  - Electrophoresis Of Biopolymers
  - Blood Filters
  - Blood Flow

- Chemical Processing:
  - Flow Fractionation
  - Viscosity Modification
  - Diffusion Mobility Modification
  - Solutions
  - Purifying Resins From Polymerization

- Media:
  - Magentohydrodynamic Activation

- Electronic:
  - Dielectric Components
  - Electroinsulation Paper

the magnetic field. Specimens cast parallel to the field showed no signs of enhancement. The S-R researchers also indicated that the magnitude of the enhancement generated by this effect varied sinusoidally with the magnetic field's strength as depicted in Figure 1.(100-135) The results of runs 31 through 39, while they did not decisively verify this, implied the existence of a sinusoidal relationship between the magnitude of the magnetic field strength and the degree of enhancement. In the early 1990s the author was directed to confirm the results of the efforts documented in runs 31 through 39. All of the above findings, were reconfirmed in experimental runs 40 through 59. The magnetic field strengths at which enhancements were found, for all runs 31 through 59, for these partially room temperature cured specimens, are graphed in Figure 2.

In 1992 Dr. J. Mallon conducted work which verified the existence of enhancements to the glass transition temperature (Tg) exhibited by an epoxy resin system which was fully cured while exposed to an external magnetic field.(156) Dr. Mallon cured a stoichiometric EPON 828 - 1,4 phenylenediamine (mPDA) epoxy resin system at 350 ^{o}F (175 ^{o}C) to full cure while simultaneously exposing it to a 9 Tesla (T) (90000 Oersted (Oe)) magnetic field. The Tg of the resultant was measured using Differential Scanning Calorimetry (DSC). Dr. Mallon discovered that the fully cured epoxy resin's Tg had been elevated by 45 ^{o}F (25 ^{o}C) over controls. This effort verified a very unusual claim made by the S-R researchers. In a few of their published efforts, they claimed to have increased the the Tg of some of their epoxy resin systems which had been cured while exposed to a magnetic field.(21-23) But they never claimed improvements of the degree which Dr. Mallon has found.(21-23) The enhancement associated with Dr Mallon's effort is also graphed in Figure 2.

As indicated in Figure 2 and demonstrated by the author's and Dr. Mallon's efforts, the magnetic field coprocessing effect does exist and can generate enhancements in the properties of bulk polymers so processed. Unfortunately, the combination of the thermal conditions of these epoxy resin system's cure profiles and the magnetic field strengths under which they were cured are not directly transferable to an economically viable production setting. The author's early efforts were directed at verifying the existence of the effect and only generated partially cured epoxy resin systems at economically attainable magnetic field strengths. Where as Dr. Mallon's effort generated fully cured epoxy resin systems in a quarter million

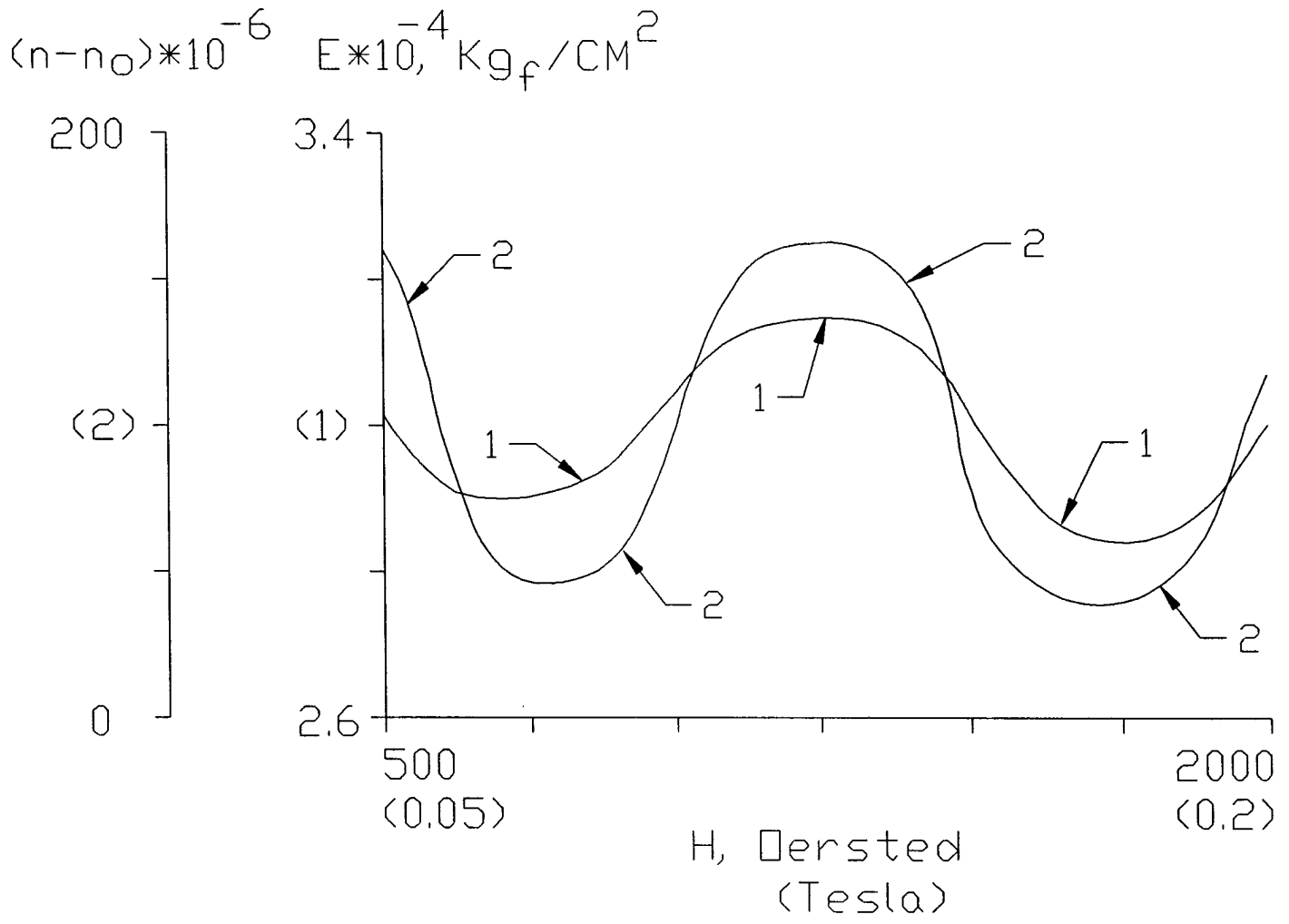


Figure 1: Sinusoidal Correlation: Property Versus Magnetic Field (133)

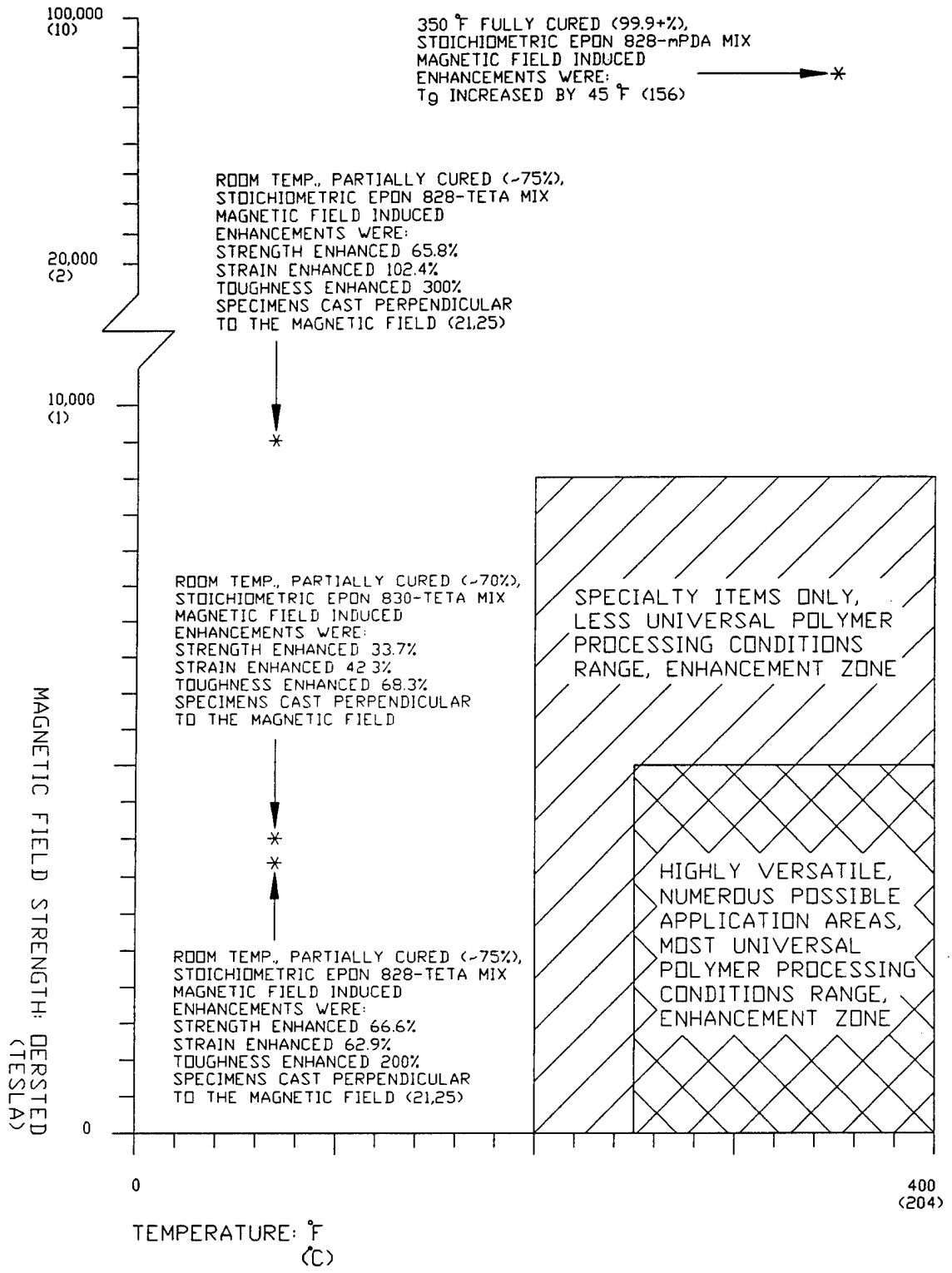


Figure 2: Property Enhancement Versus Magnetic Field Strength Versus Polymer Processing Temperature (21,25,156)

dollar superconducting electromagnet that required a day to be cooled down to operational temperature by the expenditure of nearly ten thousand dollars of liquid helium and then only had a working volume of 1 cubic centimeter. His set up was obviously not economically viable for use in production.

In order for the magnetic field coprocessing effect to be more than just a laboratory curiosity, it was necessary to find a zone or zones of thermal processing profiles versus magnetic field strengths which generated desirable enhancements in the so processed bulk polymers and were economically viable in a production setting. If enhancements to the bulk properties of epoxies could be attained by processing them in the temperature and magnetic field conditions found in the crosshatched zone depicted in Figure 2, then the results of this effect could be easily incorporated into existing production set ups. The ordinate of the crosshatched zone in Figure 2 represents temperatures commonly found in the thermal cure profiles used in the production of cured epoxies. If enhancements could be found in this temperature range, then this effect could be worked into existing production set ups without modifying those set up's cure profiles. The abscissa of this zone represents magnetic field strengths that are routinely generated by permanent magnets, electromagnets, and magnetic fields created by the flow of heavy amperages of current through conductors. This particular zone and the usage of these particular methods to generate magnetic fields are described in many published S-R works.(22-24) S-R researchers describe many devices that they say they have built, which incorporate the magnetic fields of this zone, into many production set ups.(22-24) With the many ways of creating them, the necessary magnetic fields could be effectively generated in whatever configuration was necessary to compliment and not force the redesign of existing production set ups. Overall if enhancements to the bulk properties of polymers, such as epoxies, could be found to occur in this zone, then presently available production devices could be economically and unobtrusively modified to generate these enhancements.

The hatched zone depicted in Figure 2 represents temperature and magnetic field conditions which could be incorporated into some existing epoxy speciality production set ups, if the enhancements found are both significant and robust enough. Most of the magnetic field strengths encompassed by this zone can only be generated, with sufficient working volume, by electromagnets. This limits the dimensions of the end item which could be enhanced by

the effect. Also uniform magnetic fields that encompass large working volumes of the strengths seen in the high end of the zone are very difficult to generate. Normally very steep gradients are associated with the strong magnetic fields seen at the high end of this zone. Due to these gradients, the effect would need to be seen over a large span of magnetic field strengths so as to provide for sufficient working volume and controllability. Overall, if substantial enough enhancements to the bulk properties of polymers, such as epoxies, could be found to occur in this zone, then it could be economically justifiable to modify some presently available speciality production devices to generate these enhancements.

As of mid 1992 no research group had conducted and published any work, even work of minimal repeatable detail, concerning the existence or non-existance of property enhancements in epoxies that had been magnetic field coprocessed under conditions outlined by the two zones described in Figure 2. The only work then available was the very sketchy and effectively undublicatable work published by the various S-R research groups. The objective of this effort was sequentially two fold. The prime objective was to conduct research to find a condition at which the effect generated a sufficient and robust enough degree of enhancement in the desirable properties of an epoxy resin system so as to be an economically viable addition to an existing production set up. The secondary objective, if the primary was unattainable, was to conduct a sufficient amount of research to be able to confidently dismiss the economically viable existence of the effect in the zones depicted in Figure 2.

EXPERIMENTAL

Research Tools

Numerous specialized pieces of research equipment, supporting equipment, and chemicals were acquired to accomplish this effort's objective. Table 3 lists the particulars associated with all of the equipment and chemicals required to accomplish this effort. Roughly 30 percent of the equipment used were stock purchases. Another 30 percent were specified purchases involving tightly tailored requirements along with the occasional fabrication of the principal investigator's (PI) designs. The remainder consisted of equipment that was almost exclusively designed by the PI and built in house under

Table 3: Research Tools

Testing Equipment:

Mechanical:

Load:
- Lebow Load Cell
- Made By Eaton Corp
- Procured From Sintech Corp.
- Load Capacity: 0 to 500 Lb_f
- Calibration Value: 364.1 Lb_f
- Accuracy: 0.5% Of Reading Or 0.25% Of Load Range Whichever Is Higher From 100% To 5% Of Rated Load Cell Capacity
- Model Number: 3132-149
- Serial Number: 10436

Strain:
- Extensometer
- Flat Blade Contacts
- Made By And Procured From MTS Systems Corp.
- Gage Length: 0.500 +/- 0.002 In
- Accuracy: +/- 0.5% Of Indicated Strain From 100% To 5% Of The Extensometer's Range
- Max Travel: +/- 0.075 Inch or +/- 15%
- Linearity: +/- 0.15%
- Hysteresis: +/- 0.10%
- Model Number: 632.13B - 20
- Serial Number: 503

Strain Calibration:
- Precision Micrometer Fork
- Made By Measurements Technologies, Inc.
- Accuracy: +/- 0.0001 In
- Model Number: CAL-01
- Serial Number: 861002-01

Frame:
- Tabletop Computer Integrated Testing System
- Made By And Procured From Sintech Div., MTS Systems Corp.
- Drive Mechanism: Precision Ball Screw Drive
- Position Measurement: Precision Glass Optical Encoder, 100 Microinch Resolution
- Load Range: 0 to 1000 Lb_f
- Crosshead Speed: 0.02 to 20.0 In/Min Continuously Variable; Accurate To +/- 0.1% Of Set Speed For All Speeds
- Frame Stiffness: 200,000 Lb_f/In
- Controlling Computer: Compuadd System 63762
- Model Number: SINTECH/1

Table 3: Research Tools Continued

Specimen Testing Fixtures And Jigs:
Overall Assembly:
Drafting: 04-11-91; X9119705 A; FIXTURE, TENSILE TEST ASSEMBLY
Alinement Jig-Fixture:
Jig:
Material Of Construction: 4340 Steel
Drafting: X9119706; BLOCK, ALIGNMENT, TENSILE TEST FIXTURE
Spacer:
Material Of Construction: 4340 Steel
Drafting: X9119709; SPACER, TENSILE TEST FIXTURE
Lower Grip:
Material Of Construction: 4340 Steel
Drafting: X9119707 A; GRIP, LOWER, TENSILE TEST FIXTURE
Upper Grip:
Material Of Construction: 4340 Steel
Drafting: X9119708 A; GRIP, UPPER, TENSILE TEST FIXTURE
Alignment Pins:
Material Of Construction: Case Hardened Steel Dowel Rod
Drafting: X9119712; PIN, ALIGNMENT, TENSILE TEST FIXTURE
Clevis:
Material Of Construction: 304 Stainless Steel
Drafting: X9119710 A; CLEVIS, TENSILE TEST FIXTURE
Designed By Mr Roger H. Gerzeski And Mr Bud Bocock
Fabricated In House By Mr Gerzeski And Support Technicians

Mechanical Data Analysis & Testing Equipment Control:
Runs Prior To Number 77:
Made By And Procured From Sintech Corp.
Load Frame Control and Data Analysis Software:
TESTWORKS (TM) 1989
Version Number: 1.35
Runs After Number 76:
Made By And Procured From Sintech Div., MTS Systems Corp.
Load Frame Control and Data Analysis Software:
TESTWORKS II (TM) 1991
Version Number: 2.11a
Serial Number: 6321

Constant Voltage Transformer:
SOLA Mini/Micro Computer Regulator
Made By Sola Electric, Unit Of General Signal
Procured From Sintech Corp
Type: Harmonic Neutralized Type CVS
Output: 120 VAC
4.17 A Max
Model Number: LR44950
Serial Number: 83AFP

Table 3: Research Tools Continued

Mobile Testing Machine Bench:
Casters:
Self Lube Bearing Swivel Caster.
Dimensions: 4 In Dia
1.5 In Wide
5 In Wheel Mount
Load Capacity: 225 Lb_f
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 2492T57, Pg 413
Machine Leveling Mounts:
Neoprene Base Pads
Dimensions: Base: 3.5 In Dia
Bolt: 1/2-20
Load Capacity: 1000 Lb_f
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 6011K13, Pg 1370
Frame:
Dimensions: 96 In Long,
67.25 In High,
36 In Wide
Drafting: 15-04-90; MOBILE TESTING MACHINE BENCH
Materials Of Construction: Unistrut Channel And Fittings
Paneling Grade Plywood
Heavy Gage Sheet Steel
Acrylic Sheets
Designed By Mr Roger H. Gerzeski And Mr Neil Vaughn
Fabricated In House By Mr Gerzeski And Support Technicians

Specimen Inspection:
Hand Held Magnifier
Made By And Procured From Edmund Scientific
Type: Hastings Triple Element
Power: 10X
Field Of View: 20 mm
Focal Length: 25 mm
Working Distance: 20 to 25 mm
Part Number: C30,452

Mensuration, Calibration, And Alinement Equipment:

Torque Wrench:
Capacity: 0 to 800 In-Lb_f
Drive: 3/8 In
Made By Stanley-Proto Industries
Procured From DoAll
Model Number: J6066A
Serial Number: WRH 37227
Accuracy: +/- 5 In-Lb_f

Table 3: Research Tools Continued

Micrometer:
Made By Mitutoyo
Procured From Rutland
Accuracy: +/- 0.0001 In
Model Number: M120-1
Serial Number: 103-260

Square:
Dimensions: 3 In Solid
Made By And Procured From DoALL
Squareness: +/- 0.0015 Deg
Part Number: 7000-003

Gage Blocks:
Dimension: 0.078125 In
Part Number: 25807
Dimension: 0.170000 In
Part Number: 23170
Made By And Procured From DoALL
Gage Block Accuracy: +/- 0.000005 In

Surface Roughness Gage:
Capacity: 22 Precision Surfaces
Finish Ranges: 2 to 500 Micro-In
Accuracy: Meeting ASA Std B46.2 1955.
Procured From Rutland
Part Number: 2468 1918 Rutland 91 Cat Number HS91, Pg 86

Caliper:
Precision Dial Caliper
Capacity: 0 - 6 In
Accuracy: +/- 0.001 In
Made By NSK
Procured From Rutland

Magnetic Field Measurement:

Hall Effect Probe:
Transverse Hall Probe Style I-10X
Made By And Procured From Walker Scientific Inc.
Capability: 0 to 10 KG
Linearity Of Reading: +/- 0.1% From 0 to 10 KG
Model: HP-73R
Design Type: T-640859
Serial Number: HP114HT

Gaussmeter:
Hall Effect Gaussmeter
Made By And Procured From Walker Scientific Inc.
Range: 10 to 100,000 G
Resolution: +/- 0.1% or 10 mG
Accuracy: +/- 0.1% or 10 mG
NBS Traceable Calibration
Model Number: MG-3D-4
Serial Number: K7070-14

Table 3: Research Tools Continued

Calibration Magnets:
Transverse Magnetic Field Reference Magnets:
Made By And Procured From Walker Scientific Inc.
Model Number: MR-10T-2 Calibrated To 10099 G
MR-5T-1 Calibrated To 5043 G
MR-3T-1 Calibrated To 3010 G
MR-2T-1 Calibrated To 1991 G
MR-1T-1 Calibrated To 986.8 G
MR-05T-1 Calibrated To 505.7 G
Calibration Accuracy: +/- 0.25% NBS Traceable
Zero Gauss Chamber:
Made By And Procured Walker Scientific Inc.
Model Number: ZG-1

Positioner:
3 Axis Linear Positioner:
Drafting: 08-06-89; THREE AXIS POSITIONER SYSTEM:
X = 12, Y = 12, Z = 12: ASSEMBLY
Made By And Procured From Daedal Positioning Tables And Controls
Z Axis:
Rail Table
Standard Grade
Travel: 12 In
Positional Repeatability: +/- 0.0002 In
Positional Accuracy: +/- 0.00025 In/In
Linear Accuracy: +/- 0.0002 In/In
Model Number: 506121S-LH
Z Axis Bracket:
Designed By Mr Roger H. Gerzeski
Made By And Procured From Daedal Positioning Tables And Controls
Drafting: 08-06-89; THREE AXIS POSITIONER SYSTEM:
X=12, Y=12, Z=12: Z AXIS BRACKET
Material Of Construction: Aluminum
X-Y Axis:
Series 300000, Open Frame Linear Table
Travel: 12 In By 12 In
Squareness: 60 Arcsec
Positional Repeatability: +/- 0.001 In
Positional Accuracy: +/- 0.0002 In/In
Linear Accuracy: +/- 0.0005 In/In
Model Number: 318122S-20E-LH
Base Plate:
Designed By Mr Roger H. Gerzeski
Made By And Procured From Daedal Positioning Tables And Controls
Drafting: 08-06-89; THREE AXIS POSITIONER SYSTEM:
X=12, Y=12, Z=12: BASE PLATE
Material Of Construction: Aluminum
Motors:
Model Number: MD23-03-202020

Table 3: Research Tools Continued

Drives and Controller:
Model Number: MC5303-202020-PS
Interface Terminal:
Compuadd Model 212 (286 PC)
Model Number: 63797

Rail Table:
Rails:
Linear Motion Rail Table System
Made By And Procured From Thomson Industries, Inc.
Model Number: 1CB-24-FAO-S X 96.00 Inchs
Rail Length: 96.00 In
Shaft Dia.: 1.5 In OD
Rail Straightness: +/- 0.001 In
Shaft Hardness: Rockwell 60-65C
Rail End Bumper Bars:
Dimensions:
Overall Bar: 4 In Wide,
1 In Thick,
44 In Long
Rail Connection Bolt Holes:
0.375 In Dia Thru Holes At: 2.625 In By 2.500 In
41.375 In By 2.500 In
Rail Car Alinement Bracket Torque Down Bolt Hole:
0.250 In Dia Thru Holes At 22.000 In By 2.500 In
Material Of Construction: 1020 Steel
Designed By Mr Roger Gerzeski
Fabricated By Mr Wayne Kellingsworth
Rails To Scaffold Connection:
Connections:
Rails To H Beams: Rails Anchored By 12 Pairs Of Aircraft Grade
0.375-24 By 2 In Long Bolts, Nuts, and Washers Per Rail
Spaced Every 8 In Beginning 9.5 Inchs In From The Beams' Ends
Scaffold To H Beams: Two 6 In Welds On Each End Of Each H Beam
Dimensions: H Beams: Depth 5.125 In
Width 5 In
Web 0.375 In
Length 107 In
Designed By Mr Roger Gerzeski
Mobile Rail Car:
Overall Assembly:
Drafting: 30-01-91; RAIL CAR: ASSEMBLY
Long Arm Support Channel:
Materials Of Construction: 6 Inch 1020 Steel Channel
Drafting: 29-01-91; RAIL CAR: LONG ARM SUPPORT CHANNEL/BEAM
Short Arm Support Channel:
Materials Of Construction: 6 Inch 1020 Steel Channel
Drafting: 29-01-91; RAIL CAR: SHORT ARM SUPPORT CHANNEL/BEAM

Table 3: Research Tools Continued

Alinement Bracket:
Material Of Construction: 4340 Steel
Drafting: 29-12-91; RAIL CAR: ALINEMENT BRACKETS
Designed And Fabricated By Mr Roger H. Gerzeski
Leveling Pad Receiver Blocks:
Material Of Construction: 4340 Steel
Drafting: 15-02-91; RAIL CAR: LEVELING PAD RECEIVER BLOCKS
Dowel Alinement Pins:
Dimensions: 2.00 In Long
0.25 In Dia
Material Of Construction: Case Hardened Ground Steel
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 98381A552, Pg 2243
Fasteners:
Dimensions: 1/4-20 By 1.5 Inch Socket Head Cap
Screws And Associated Nuts and Washers
Dimensions: 3/8-16 By 1.5 Inch Bolts And Associated Washers
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski, Mr Wayne Kellingsworth,
And Support Technicians

3 Axis Positioner To Hall Probe Extension Arm:
Overall Assembly:
Drafting: 13-09-91; NONMAGNETIC HALL PROBE EXTENSION: ASSEMBLY
Designed By Mr Roger H. Gerzeski
3 Axis Positioner Attachment:
Drafting: 20-08-91; NONMAGNETIC HALL PROBE EXTENSION:
LINK PLATE TO 3 AXIS POSITIONER
Designed By Mr Roger H. Gerzeski
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: 6061 T651 Aluminum Tooling Plate
Link Plate To Box Beam Connector:
Drafting: 06-09-91; NONMAGNETIC HALL PROBE EXTENSION: BAR:
LINK PLATE TO BOX BEAM CONNECTOR
Designed By Mr Roger Gerzeski And Mr Wayne Kellingsworth
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: 6061 T6 Aluminum
Box Beam:
Drafting: 06-09-91; NONMAGNETIC HALL PROBE EXTENSION: BAR:
BOX BEAM CONNECTOR
Designed By Mr Roger Gerzeski and Mr Wayne Kellingsworth
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: Aluminum
Box Beam To Hall Probe Attachment:
Drafting: 06-09-91; NONMAGNETIC HALL PROBE EXTENSION: BAR:
BOX BEAM TO HALL PROBE CONNECTOR
Designed By Mr Roger Gerzeski and Mr Wayne Kellingsworth
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: 6061 T6 Aluminum

Table 3: Research Tools Continued

Hall Probe Attachment:
Drafting: 23-08-91; NONMAGNETIC HALL PROBE EXTENSION:
LOWER HOLDER CLAMP
Designed By Mr Roger H. Gerzeski
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: Fiber Glass Phenolic Composite
Hall Probe Grip:
Drafting: 05-09-91; NONMAGNETIC HALL PROBE EXTENSION:
UPPER HOLDER CLAMP
Designed By Mr Roger H. Gerzeski
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: Teflon
Removable Alinement Pins:
Dimensions:
Shaft: 1.50 In Long,
0.25 In Dia
Top Knurl: 0.5 Inch Long,
0.75 In Dia
Overall: 2.00 In Long
Drafting: 13-09-91; NONMAGNETIC HALL PROBE EXTENSION: ASSEMBLY
Designed By Mr Roger H. Gerzeski
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: Brass
Dowel Alinement Pins:
Dimensions: 2.50 In Long,
0.25 In Dia
Material Of Construction: Case Hardened Ground Steel
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 98381A552, Pg 2243
Grip Fasteners:
Dimensions: 6-32 Screws, Washers, and Helicoils
Designed By Mr Roger Gerzeski And Mr Wayne Kellingsworth
Fabricated By Mr Wayne Kellingsworth
Material Of Construction: Brass

Magnetic Field Generators:

Small Electromagnet:
Rebuilt By Alpha Scientific Magnetics Inc.
Acquired From Wright-Patterson AFB
4 In Dia Flat Pole Faces
0 to 5 In Variable Air Gap
Model Number: 1290

Small Generator Power Supply:
Made By Kepco Inc.
Acquired From Shut-Down F-15 Launch ASAT Program
Constant Current Regulation

Table 3: Research Tools Continued

0 to 30 A
0 to 1 KWA
Current Regulation: 0.25% of I_o Max
Ripple: 0.3% of I_o Max
Drift: 0.02% of I_o Max
Model Number: ATE36-30M
Serial Number: F31926

Large Electromagnet:
Made By And Procured From Walker Scientific Inc.
7 In Dia Flat Pole Faces
0 to 7.25 In Variable Air Gap
Model Number: HV-7H
Serial Number: 501591

Large Generator Power Supply:
Made By And Procured From Walker Scientific Inc.
0 to 8.5 KWA
Power Regulation: +/- 0.01%
0 to 65 A
Current Stability: +/- 0.001%
Model Number: HS-1365-3A
Serial Number: X-4644

Small Electromagnet Stand:
Materials Of Construction: Unistrut Channel And Fittings
Drafting: 9-3-92; ALPHA SCIENTIFIC ELECTROMAGNET: SUPPORT STAND
Designed and Fabricated In House By Mr Roger H. Gerzeski

Large Electromagnet Cradle:
Overall Assembly:
Drafting: 4-1-91; WALKER ELECTROMAGNET: SUPPORT STRUCTURE: ASSEMBLY
Collars:
Materials Of Construction: 1020 Steel
Drafting: 28-12-90; WALKER ELECTROMAGNET: SUPPORT STRUCTURE: CRADLE PLATES
Stand:
Materials Of Construction: Unistrut Channel And Fittings
Drafting: 2-1-91; WALKER ELECTROMAGNET: SUPPORT STRUCTURE: STAND
Third Leg Lift Hook:
Materials Of Construction: 1020 Steel,
2024 Aluminum,
1/2-13 Stainless Steel Rods and Nuts
Drafting: 20-03-91; WALKER ELECTROMAGNET: LIFTING HOOK
Drafting: 12-04-91; WALKER ELECTROMAGNET: BOLT TO MAGNET BUSHING
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Support Technicians

Table 3: Research Tools Continued

Temperature Measurement:

Wire:
Type T Thermocouple (Duplex Insulated Copper/Constantan ANSI)
Procured From Omega Engineering, Inc.
Material Of Construction:
Thermocouple Wire: Copper-Constantan(Copper-Nickel)
(Note: Most Accurate Thermocouple Material Available)
Insulation: Glass (Duplex Insulated)
Accuracy: +/- 1.0 °C or +/- 0.75% above 0 °C
+/- 1.0 °C or +/-1.0% below 0 °C
Part Number: GG-T-20
Catalog: Omega Temp Meas Handbook & Encyclopedia Sec. H, Pg 3-6, 24, Duplex Insulated Type T Thermocouple

Connector:
Subminiature Thermocouple Connector Assembly
Type: Copper-Constantan Type T
Procured From Omega Engineering, Inc.
Part Number: SMP-T-MF, Pg G-21
Catalog: Omega Temperature Measurement Handbook And Encyclopedia Vol 26

Probe:
Grounded Junction Subminiature Assembly
Type T Thermocouple
Procured From Omega Engineering, Inc.
Sheath Dia: 0.125 In Dia
Material Of Construction:
Sheath: 304 Stainless Steel
Thermocouple Wire: Copper-Constantan(Copper-Nickel)
Accuracy: +/- 1.0 °C or +/- 0.75% above 0 °C
+/- 1.0 °C or +/- 1.0% below 0 °C
Part Number: SCPSS-125G-6, Pg A-10
Catalog: Omega Temperature Measurement Handbook And Encyclopedia Vol 26

Welder:
Thermocouple Welder, Hot Spot II
Made By DCC Corp
Capability: 5 to 250 W-Sec, Welds All Wire Type Pairs Of 14 Gauge Or Finer

Table 3: Research Tools Continued

Thermal Analysis:
Differential Scanning Calorimeter (DSC)
Made By DuPont Instruments
Model Number: DuPont Thermal Analyst 2000
Program Type: DuPont DSC Calibration Data Analysis Program Ver. 5.0
Heating Rate: 10 ^{o}C/Min
Pan Type: Hermetic, Sealed in Air, Aluminum
Atmosphere: Nitrogen, 50 ml/Min
Accuracy: +/- 1.1 ^{o}C

Weight Measurement:

Classical Analytical Balance:
Model Number: AE 200S
Serial Number: L73699
Made By And Procured From Mettler Instrument Corp.
Capability: 0 to 205 gms
Readability: 0.0001 gms
Reproducibility: +/- 0.0001 gms
Linearity: +/- 0.0003 gms
Internal Calibration Weight: 100.0000 gms
Vibration Isolation Block:
Drafting: 09-02-92; AE200 PEDESTAL BLOCK

Toploading Balance:
Model Number: BB 3000
Serial Number: M07113
Made By And Procured From Mettler Instrument Corp.
Capability: 0 to 3100 gms
Readability: 0.1 gms
Reproducibility: +/- 0.05 gms
Linearity: +/- 0.1 gms
Vibration Isolation Block:
Drafting: 09-02-92; BB3000 PEDESTAL BLOCK

Mobile Balance Bench:
Overall Assembly:
Dimensions: 36 In By 24 In By 78 In
Drafting: 23-02-92; MOBILE BALANCE (VIBRATION ISOLATION) BENCH:
ASSEMBLY
Shelves:
Materials Of Construction: 1020 Steel
Upper:
Dimensions: 36 In By 24 In By 1.5 In; Top 35 In From Floor
Drafting: 14-05-92; X9227531; PLATE UPPER,
BALANCE SUPPORT, BALANCE CART
Lower:
Dimensions: 36 In By 24 In By 2.5 In; Top 13.5 In From Floor
Drafting: 13-05-92; X9227530; PLATE LOWER,
BALANCE SUPPORT, BALANCE CART

Table 3: Research Tools Continued

Panels:
Sides:
Materials Of Construction: 64 Mil Thick Steel Sheet
Top:
Dimensions: 36 In By 24 In By 0.125 In
Materials Of Construction: 1 In Open Diamond Grid Grate
Vertical Columns:
Materials Of Construction:
Unistrut Channel And Fixtures
1/2-13 Stainless Steel Bolts, Nuts, Washers
Casters:
Dimension: 6 In OD Urethane Lockable Casters
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Support Technicians

Fluid Processing Equipment:

Vacuum Pumps:
Model Number: Fast Vac DV-85
Made By J/B Industries, Inc.
Distributed By And Procured From McMaster-Carr Supply Co.
Free Air Displacement Rate: 3 CFM
Ultimate Vacuum: 25 Microns or Better

Glass Vacuum Desiccators:
Pyrex Brand; Made By Dow Corning
Dimensions: 250 mm ID
230 mm Internal Support Plate
55/38 Vacuum Connection Sleeve
Distributed By And Procured From Fisher Scientific
Catalog Number: 08-631B
Catalog: Fisher Scientific 88
Corning Part Number: 3120

Vacuum Tubing:
Heavy Walled Vacuum Tubing
Dimensions: 3/8 In ID; 5/16 In Wall Thickness; 1 In OD
Distributed By And Procured From Fisher Scientific
Part Number: 14-169-26G
Material Of Construction: Norprene Thermoplastic Elastomer

Ultrasonic Cleaner:
Capacity: 11 Qt (10.4 L) With Timer And Heater
Dimensions: 11.75 In By 9.375 In By 6 In Tank
Serial Number: T91175166T
Model Number: FS2811
Distributed By And Procured From Fisher Scientific
Catalog Number: 15-336-7, Pg 1636

Table 3: Research Tools Continued

Water Distillers:
- Kenmore Countertop Water Purifier
- Capacity: 1 Gal Per 8 Hr
- Capability: 275000 Ohm-Cm Or Better
- Model Number: 625.345000
- Part Number: 42 MR 3450
- Distributed By And Procured From Sears Roebuck And Co.

Storage Jugs:
- Nalgene Bottle
- Dimension: 5 Gal
- Distributed By And Procured From Fisher Scientific
- Part Number: 02-963BB
- Material Of Construction: Polyethylene, Polypropylene

Service Cart:
- Heavy-Duty Plastic Utility And Service Cart
- Made By Rubbermaid Commercial Products
- Capacity: 200 Lb_f Per Shelf
  400 Lb_f Total
- Distributed By And Procured From Fisher Scientific
- Catalog Number: 11-926-851, Pg 240

Gloves:
- Pylox PVC Sulfer-Free Gloves
- Made By Pioneer Industrial Products
- Distributed By And Procured From Lab Safety Supplies
- Dimension: Large; 10 Mil Thick
- Part Number: E-9494 (L) and 410034
- Model Number: V-10

Beakers:
- Disposable:
  - Tri-Pour Graduated Disposable Beakers
  - Capacity: 50 and 400 mL
  - Accuracy: +/- 5% Of Measured Volume
  - Distributed By And Procured From VWR Scientific
  - Part Number: 13915-511
  - Material Of Construction: Polypropylene
- Pyrex:
  - PYREX Brand Heavy-Duty Beakers
  - Made By Dow Corning
  - Capacity: 250 mL
  - Accuracy: +/- 5% Of Measured Volume
  - Distributed By VWR Scientific
  - Part Number: 13912-524

Table 3: Research Tools Continued

Zero Magnetic Susceptibility Resin Curing Ovens:
- Gas Heaters:
  - Leister-Hotwind <<S>>
  - Made By Karl Leister, Switzerland
  - Type: 9C2
  - Distributed By And Procured From McMaster-Carr Supply Co.
  - Model Number: 3396K4
  - Catalog Number: 95
  - Heating Capacity: 2.8 KWA
  - Air Flow: Continuously Variable Control 300 to 600 L/Min; (10.59 to 12.36 CFM)
  - Temperature: Continuously Variable Control Ambient To 800 ^{o}C; (Ambient to 1472 ^{o}F)
  - Heat Flow: 0 to 3400 W
- Gaseous Nitrogen Feed Pressure Reducers:
  - Dimensions: 6 In Long By 4.120 In OD
  - Drafting: 10-03-92; GAS PRESSURE REDUCER
  - Designed and Built By Mr Ernie Butler
  - Material Of Construction: Stainless Steel
- Ovens:
  - Type 1:
    - Overall Assembly:
      - Material Of Construction: Stainless Steel
      - Drafting: FEB 92; TYPE 1 OVEN
    - Mold Pack Support Stand:
      - Dimensions: Inverted U; 6 In By 3 In By 2.5 In High
      - Material Of Construction: 304 Stainless Steel
    - Lid:
      - Dimensions: 0.25 In Thick,
11.250 In Long,
2.750 In Wide,
45 Deg By 0.125 In Bevel On All Lower Edges
      - Distributed By And Procured From McMaster-Carr Supply Co.
      - Catalog Number: 95
      - Part Number: 8476K23, Pg 2195
      - Material Of Construction: Optically Clear, Clouding, Pitting, and Heat Resistant, Fire Polished Pyrex Flat Plate Glass
    - Insulation:
      - Material Of Construction: FiberGlass Non-Woven Sheet
    - Heater To Delivery Hose Coupler:
      - Drafting: 5 Nov 91: Gas Heater To Hose Coupler
      - Material Of Construction: 304 Stainless Steel
      - Fabricated By Mr Alan Crocker
    - Delivery Hose:
      - Corrugated Flexible Hose
      - Dimension: 2 In ID
      - Distributed By And Procured From McMaster-Carr Supply Co.
      - Catalog Number: 95
      - Part Number: 5515K41, Pg 29
      - Material Of Construction: 304 Stainless Steel

Table 3: Research Tools Continued

Hose & Coupler Insulation:
Dimension: 1/4 In Thick
Capability: Continuous Insulation To 1350 ^{O}F
K Factor Of 0.29 At 200 ^{O}F
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 9386K14
Material Of Construction: Mineral Oxide Wool Blanket Insulation
Designed By Mr Ernie Butler And Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Support Technicians
Type 2:
Overall Assembly:
Drafting: 10-12-93; X936161 A; OVEN, CURING, ASSEMBLY
Oven Block And Mold Pack Support Stand:
Material Of Construction: 6061 T651 Aluminum
Drafting: 10-12-93; X936162; OVEN BLOCK, CURING OVEN
Support Plate:
Material Of Construction: 2024 Aluminum
Drafting: X947131; SUPPORT PLATE, CURING OVEN
Jack Screws And Lock Downs:
Dimensions: 3/8 - 24 Threaded Rod,
3/8 - 24 Full Nuts,
18L Washers ID 0.310 In, OD 7/8 In, Thick 0.064 In
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97
Part Number: Threaded Rod: 98854A031, Pg 2198
Full Nut: 92174A663, Pg 2204
Washer: 92916A180, Pg 2225
Material Of Construction: Brass
Drafting: 10-12-93; X936166; SCREW, LEVELING, CURING OVEN
Tapered Alinement Nut:
Material Of Construction: 6061 Aluminum
Drafting: 24-05-94; X947154; NUT, TAPERED,
0.375-24 UNF, CURING OVEN
Spacer:
Material Of Construction: 2024 Aluminum
Drafting: 01-05-94; X947132; SPACER, CURING OVEN
Gas Entrance/Exit Walls:
Material Of Construction: 2024 Aluminum
Drafting: 06-05-94; X947133; END PLATE, CURING OVEN
Main Side Walls:
Material Of Construction: X-750 Inconel
Drafting: 06-05-94; X947134; SIDE PLATE, CURING OVEN
Lid:
Dimensions: 0.25 In Thick,
8.125 In Long,
3.375 In Wide,
45 Deg By 0.125 In Bevel On All Lower Edges
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95

Table 3: Research Tools Continued

Part Number: 8476K23, Pg 2195
Material Of Construction: Optically Clear, Clouding, Pitting, and Heat Resistant, Fire Polished Pyrex Flat Plate Glass

Insulation:
Material Of Construction: FiberGlass Non-Woven Sheet

Oven To Delivery Hose Coupler:
Material Of Construction: 2024 Aluminum
Drafting: 11-05-94; X9436135; TUBE OUTLET, CURING OVEN

Heater To Delivery Hose Coupler:
Drafting: 5 Nov 91; Gas Heater To Hose Coupler
Material Of Construction: 304 Stainless Steel
Fabricated By Mr Alan Crocker

Delivery Hose:
Corrugated Flexible Hose
Dimension: 2 In ID
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 5515K41, Pg 29
Material Of Construction: 304 Stainless Steel

Hose & Coupler Insulation:
Dimension: 1/4 In Thick
Capability: Continuous Insulation To 1350 ^{o}F
K Factor Of 0.29 At 200 ^{o}F
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 9386K14
Material Of Construction: Mineral Oxide Wool Blanket Insulation

Fasteners:
Pan Head Slotted Brass Machine Screws:
Dimensions: 8-32 X 1/2 In,
1/4-20 X 1 In,
1/4-20 X 2 In
Part Number: 8-32 x 1/2 In, 92446A194, Pg 2170
1/4 - 20 x 1 In, 92446A542, Pg 2170
1/4 - 20 x 2 In, 92446A544, Pg 2170
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97
Material Of Construction: Brass

Washers:
Dimensions:
8S: Flat Washers ID 0.172 In, OD 3/8 In, Thick 0.032 In
14S: Flat Washers ID 0.260 In, OD 9/16 In, Thick 0.040 In
Part Number: 8S: 92916A125, Pg 2225
14S: 92916A155, Pg 2225
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97
Material Of Construction: Brass

Designed By Mr Roger H. Gerzeski And Mr Bud Bocock
Fabricated In House By Mr Gerzeski And Support Technicians

Table 3: Research Tools Continued

Electromagnet and Power Supply Coolant Circuit:
- Chiller:
  - Air-Cooled Packaged Water Chiller
  - Made By And Procured From Edwards Engineering Corp.
  - Air Dump Temperatures: Equal To Or Less Than 115 ^{o}F
  - Heat Removal Capacity: 0 to 11.5 KW
  - Coolant Delivery Capacity: 1 to 6 Gal at 60 to 100 PSI
  - Delivered Coolant Temp: 30 +/- 2 ^{o}F
  - Model Number: CD-5-AHP
  - Serial Number: 895401
  - Material Of Construction: Pipes, Pumps, Relief Valves: Brass
    Coolant Reservoir: Stainless Steel
- Valves:
  - Severe Service Regulating Union Bonnet Valves:
    - Made By Whitey Co.
    - Distributed By And Procured From Bakersfield Valve & Fittings
    - Catalog: Whitey Pamphlet W-1287-8 Nov 88
    - Model: SS-12NRS12
    - Connections Type: 3/4 In To 3/4 In Swagelok
    - Material Of Construction: 316 Stainless Steel
  - Butterfly Valves:
    - Dimension: 1 In Dia Female Pipe Connections
      3/4 In Dia Female Pipe Connections
    - Part Number: 1 In Dia: 4827K63, Pg 1247
      3/4 In Dia: 4827K62, Pg 1247
    - Positive Shut-Off Valves
    - Material Of Construction: 316 Stainless Steel
    - Distributed By And Procured From McMaster-Carr Supply Co.
    - Catalog Number: 95
- Flow Meters/Viewers:
  - Direct Reading Flow-meter And Flow-viewer
  - Made By Erdco Engineering Corp
  - Serial Number: 903164
    - Type: 3/4 In Pipe Dia
    - Range: 1.5 To 15 Gal/Min
    - Erdco Model: 3211-03T0; 600 Series See-Flo Meter
    - McMaster-Carr Part Number: 4165K83, Pg 1095
  - Serial Number: 903165, and 903292
    - Type: 1/2 In Pipe Dia
    - Range: 1.0 To 10 Gal/Min
    - Erdco Model: 3211-02T0; 400 Series See-Flo Meter
    - McMaster-Carr Part Number: 4165K82, Pg 1095
  - Readout Scale: Logarithmic Flow Viewer
  - Accuracy: +/- 2% Of Full Scale
  - Distributed By And Procured From McMaster-Carr Supply Co.
  - Catalog Number: 95
  - Material Of Construction: Aluminum,
    304 Stainless Steel,
    Glass,
    Buna-N rubber

Table 3: Research Tools Continued

Pressure Gauges:
ANSI Grade B Dial Water Pressure Gauges
Supplier: McMaster-Carr Supply Co
Capacity: 0 to 160 PSI
Accuracy: +/- 2% Of Full Scale
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 4066K15, Pg 1166
Material Of Construction: Stainless Steel,
Aluminum,
Polycarbonate

Coolant Piping:
Rigid Piping:
Dimensions: 1 In Dia; Chiller To Distribution Panel
3/4 In Dia; Distribution Panel To Electromagnets
Material Of Construction: 304 Stainless Steel
Connections:
Type: Double Female Hose Nipples:
Dimensions: 3/4 In Female National Pipe Thread To
3/4 In Female National Hose Thread
Part Number: 7468T2, Pg 1004
Type: Double Male Brass Hose Nipple:
Dimensions: 1/2 In Male National Pipe Thread To
3/4 In Male National Hose Thread
Part Number: 7467T1, Pg 1004
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Material Of Construction: Machined Brass
Type: Male Connectors:
Dimensions: 1 In Tube To 3/4 In Pipe,
1 In Tube To 1 In Pipe,
3/4 In Tube To 1/2 In Pipe
Type: Female Branch Tees:
Dimensions: 3/4 In Tubes To One 3/4 In Pipe,
1 In Tubes To One 3/4 In Pipe
Type: Reducing Bushing:
Dimensions: 3/4 In Female Pipe Down To 1/4 In Female Pipe,
1 In Female Pipe Down To 1/2 In Female Pipe
Type: Union Tee:
Dimensions: 1 In Tube,
3/4 In Tube
Type: Union:
Dimensions: 1 In Tube,
3/4 In Tube
Distributed By Allan Aircraft Supply
Material Of Construction: 304 Stainless Steel

Table 3: Research Tools Continued

Pipe Insulation:
Type: Self-Sealing Pipe Insulation Sheaths
Dimensions: 6 Ft Long,
3/4 In Thick,
1 In Dia ID Tube
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 4734K68, Pg 1284
Material Of Construction: Polyolefin

Hoses:
Non-Electrically Conductive Coolant Transfer Hoses
Made By Aeroquip Corp.
Chiller To Piping And Piping To Chiller:
Dimensions: 5 Ft, 1.25 In Dia ID
Part Number:
Hose: 2580-20, Pg 36
Connectors:
1.25 In Nominal Dia Male NPT: 412-20-20B, Pg 60,
1.25 In Nominal Dia Female SAE 37: 259-411-20, Pg 60
Piping To Electromagnets And Power Supplies To Piping:
Dimensions: 10 Ft, 0.75 In Dia ID
Part Number:
Hose: 2580-12, Pg 36
Connectors:
0.75 In Nominal Dia Male NPT: 412-12-12B, Pg 60,
0.75 In Nominal Dia Female SAE 37: 259-411-12, Pg 60
Electromagnets To Power Supplies:
Dimensions: 10 Ft, 0.75 In Dia ID
Part Number:
Hose: 2580-12, Pg 36
Connectors: 0.75 In Nominal Dia Male NPT: 412-12-12B, Pg 60
Materials Of Construction:
Hose: Synthetic Rubber Tube,
Double Textile Braid Reinforcement,
Synthetic Rubber Cover
Connectors: Male NPT: Brass
SAE 37: 316 Stainless Steel
Catalog: Hose And Reusable Fittings 261C
Distributed By And Procured From Motion Industries Inc.

Thermostat Relays:
Bulb & Capillary Immersion Thermostat Actuated Relays
Distributed By And Procured From
Omega Technologies Co. Omega Engineering Inc.
Catalog: Omega Electric Heaters Handbook and Encyclopedia Vol 26
Relay Model Number: AR-2193
Piping Fittings Model Number: CCF-25A
Relay Actuation Temperature Range: 60 to 250 ^{o}F
Piping Fittings Size: 3/8-18 Male NPT Compression Fittings

Table 3: Research Tools Continued

Materials Of Construction:
Bulb & Capillary: Copper
Coolant Pipping Attachment Fittings: Nickel Plated Brass
Defined And Installed By Mr Barry Massey, And Mr Alan Goodman

Experimental Data Recorder:
MRL 488 Series Multipoint Recorder/Logger
Made By And Procured From: Esterline Angus, Esterline Co.
Data Channels: Available: 48
Used: 26
Serial Number: 89290029
Model Number: MRL488-5-BD-RC-64--C4-Y
Channel Scan Time: 1 Channel In 2.2 Sec
26 Channels In 1 Min
Calibration: Each Channel Automatically Calibrated Before Each Scan
Experimental Inputs Measured: 26 Type T Thermocouples
Common Mode Rejection Ratio: 120 dB Minimum At DC; 120 dB At Line Frequency; 85 dB Minimum Above Line Frequency To 100 KHz For Channel Setup For 1 V DC or Less; 60 dB Minimum Above Line Frequency To 100 KHz for Channel Setup For Greater Than 1 V DC
Series Mode Rejection Ratio: 50 dB At Line Frequency
Common Mode Voltage: 400 V Or Peak AC
Input Impedance: 20M Ohms For 0 To 1 V
1M Ohms For 1 To 60 V
Data Acquired: Once Every Min,
Whenever On Demand
Data Displayed: Once Every 10 Mins,
Whenever On Demand,
Once At Midnight

Resin Casting And Curing Equipment:
Silicone-Rubber Specimen Negative Molds:
Material Of Construction: 6061 T651 Aluminum
Designed By Mr Roger H. Gerzeski And Mr Bud Bocock
Fabricated In House By Mr Keith Lawson's Machinists
Drafting: X936134; TENSILE TEST SPECIMEN RUBBER CASTING MOLD
Drafting: X936134; ISOMETRIC PROJECTION, AND RUBBER MOLDS: PREPARATION AND STACKING

Overpressure Vault:
Drafting: Apr 93; OVERPRESSURE VAULT
Overall Shape: Two Handled Lid (ie. Box With No Bottom)
Air Inlet Point: Center Of 34 In By 15 In Top Plate
Baffle: 4 In Sq Plate Centered On And 1 In Below Air Inlet Point
Material Of Construction: Plexiglas
Designed And Fabricated By Mr. Roger H. Gerzeski

Table 3: Research Tools Continued

Mold Clamps:

Type 1:

Clamping Plates:
Material Of Construction: 6-6-2 Titanium
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Mr Wayne Kellingsworth
Drafting: 26-04-92; MOLD PACK: TYPE 1 MOLD CLAMP PLATES

Threaded Rods:
Size: 1/4-20 By 3 In
Part Number: 98812A029, Pg 2198
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Nuts:
Size: 1/4-20 Jam And Full
Part Number: Full: 92676A029, Pg 2206
Jam: 92174A029, Pg 2204
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Spacers:
Material Of Construction: Brass
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Mr Jason Lasley
Drafting: 04-02-91; MOLD PACK: SPACER

Washers:
Type: 18L Flat Washers
Size: ID 0.310 In,
OD 7/8 In,
Thick 0.064 In
Part Number: 92916A180, Pg 2225
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Compression Springs:
Wave Springs; Gap Type
Made By Smalley Steel Ring Co
Material Of Construction: X-750 Inconel
Capability: 13.5 To 16.5 Lb_f At 0.030 In Working Height
Drafting: 3-16-92; MOLD PACK: COMPRESSION SPRING:
SPIRAWAVE, GAP TYPE

Table 3: Research Tools Continued

Type 2:

Overall Assembly:
Drafting: X936158; MOLD PACK: ASSEMBLY

Clamping Plates:
Material Of Construction: 6-4 Titanium
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Mr Keith Lawson
Drafting: X936159; CLAMP PLATE, MOLD PACK

Threaded Rods:
Dimensions: 1/4-20 By 3 In
Part Number: 98812A029, Pg 2198
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Nuts:
Dimensions: 1/4-20 Jam and Full
Part Number: Full: 92676A029, Pg 2206
Jam: 92174A029, Pg 2204
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Spacers:
Material Of Construction: Brass
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Gerzeski And Mr Jason Lasley
Drafting: 4-02-91; MOLD PACK: SPACER

Compression Springs:
Wave Springs: Gap Type
Made By Smalley Steel Ring Co
Material Of Construction: X-750 Inconel
Capability: 13.5 To 16.5 lb_f At 0.030 In Working Height
Drafting: 3-16-92; MOLD PACK: COMPRESSION SPRING:
SPIRAWAVE, GAP TYPE

Washers:
Type: 18L Flat Washers
Size: ID 0.310 In,
OD 7/8 In,
Thick 0.064 In
Part Number: 92916A180, Pg 2225
Material Of Construction: Brass
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 97

Table 3: Research Tools Continued

Resin Handling Equipment:

Bell Jars:

Pyrex Bell Jars With Top Knob And Ground Bottom Flanges
Made By Dow Corning
Dimensions: Small Jar: 6.5 In Dia,
11 In Tall
Large Jar: 8.75 In Dia,
15 In Tall
Distributed By And Procured From Fisher Scientific
Catalog: Fisher Scientific 88
Catalog Number: Small Jar: 02-626B
Large Jar: 02-626C

Mixing Rods:

Pyrex Brand Rods
Made By Dow Corning
Dimensions: 5 mm OD X 4 Ft; For Cutting To Use Size
Distributed By And Procured From Fisher Scientific
Catalog Number: 11-377C

Pasteur Pipets:

Dimensions: 6 Inch Long Controlled Drop
Distributed By And Procured From Fisher Scientific
Catalog Number: 13-678-30
Material Of Construction: Borosilicate Glass

Dropper Bulbs:

Dimensions: 3 ml Natural Rubber Suction Bulbs
Distributed By And Procured From Fisher Scientific
Catalog Number: 13-678-9B
Material Of Construction: Natural Rubber

Flammable Liquid Storage Cabinet:

Dimensions: 18 In Deep,
43 In Wide,
65 In High
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 4477T3, Pg 163

Superla Steel Storage Cabinets:

Dimensions: 24 In Deep,
36 In Wide,
78 In High,
Material Of Construction: 16 Gage Sheet Steel Frames,
20 Gage Doors,
22 Gage Shelves Top Bottom Sides
Distributed By And Procured From McMaster-Carr Supply Co.
Catalog Number: 95
Part Number: 4587T75, Pg 158

Table 3: Research Tools Continued

Chemicals:

1,3 Phenylenediamine
Purity: 99+%
Made By And Procured From ALDRICH Chemical Co.
Aldrich Catalog Number: P2,395-4
Lot Number: 07031JW

4,4'-Methylene bis (Cyclohexylamine)
Purity: 97+% (Mixture Of Isomers)
Made By And Procured From ALDRICH Chemical Co.
Aldrich Catalog Number: 13,585-2
Lot Number: 00807KX and 01314DT

4,4'-Methylene Dianaline
Purity: 99+%
Made By And Procured From ALDRICH Chemical Co.
Aldrich Catalog Number: 13,245-4
Lot Number: 03209LV

Tonox 60/40
Made By Uniroyal Chem Corp.
Lot Number: 0034100 J.P.

Epi Rez 5022
Made By Intrez
Lot Number: LOS-67707, G-4H, 28L002, T--1, N-47

EPON 830
Made By Shell Chemical Co.
Distributed By And Procured From E.V. Roberts
E.V. Roberts Product Number: 1113755
Lot Number: 7HHJ401
Date Of Manufacture: 7-86
and
Lot Number: 01LHJ402
Date Of Manufacture: 1-89

High Vacuum Grease
Type: Silicone Lubricant Grease
Made By Dow Corning
Distributed By And Procured From Fisher Scientific
Part Number: 14-635-5D

Indicating Desiccant
Made By Drierite
10 - 20 Mesh Indicating Desiccant
Catalog: Fisher Scientific 88
Part Number: 07-578-4B
Distributed By And Procured From Fisher Scientific

Table 3: Research Tools Continued

GE 664 RTV
Made By General Electric Co.
Material Constituent: Vinyl Silicone Rubber
Distributed By And Procured From E.V. Roberts
E.V. Roberts Product Number: 2306645
Lot Number: KM705
Date Of Manufacture: 1-91 and 2-91
Distributed By And Procured From R.S. Hughes
Lot Number: BC733
Date Of Manufacture: Prior To 7-92

Acetone
Purity: 99+%
Distributed By And Procured From ALDRICH Chemical Co.
Aldrich Catalog Number: 17,997-3

Ethylene Glycol
Purity: 99+%
Made By Polarchem Co.
Distributed By And Procured From Ripley Scientific

Gaseous Nitrogen
Purity: 999995 PPM +/- 1 PPM
Water Content: 5 PPM +/- 1 PPM

Support Structures:
Electromagnets, Heaters, And Field Mapping:
Equipment Support Structure:
Overall Assembly:
Drafting: 20-05-89; SUPPORTING SCAFFOLD OVERALL
Scaffold Support Structure:
Material Of Construction:
I Beam, Steel, 4 In X 20 Ft, Flange 2.796 In, Web 0.326 In
1020 Steel Plates 0.5 In X 4 Ft X 8 Ft
3/4 - 10 Full Nut
H Beam, Steel, Depth 5.125 In, Width 5 In,
Web 0.250 In, Length 20 Ft
Drafting: 01-09-89; SCAFFOLD SUPPORT STRUCTURE: ASSEMBLY
Drafting: 01-09-89; SCAFFOLD SUPPORT STRUCTURE:
B--B PROJECTION: POSITIONER LEVEL
Drafting: 01-09-89; SCAFFOLD SUPPORT STRUCTURE:
A--A PROJECTION: ELECTROMAGNETIC LEVEL
Drafting: 05-09-89; SCAFFOLD SUPPORT STRUCTURE:
SUPPORT BASE PLATES: ELECTROMAGNETIC LEVEL
Drafting: 18-10-89; SCAFFOLD SUPPORT STRUCTURE:
LEVELING BOLT BASE PLATE
Designed By Mr Roger H. Gerzeski
Fabricated In House By Mr Rick Richards, Mr Alan Crocker,
Mr Ron Simpson, and Mr Gerzeski

Table 3: Research Tools Continued

Electronic Support:
Surge Protectors:
Console Model Surge Protectors & Noise Filters:
Capability: Switched 120V Grounded Outlets, Master On-Off, Fuse & Indicator light, 5 Stage Low Pass Filter, 30-60 dB Attenuation, 140V RMS Clamping Voltage, 15 Amp Capacity
Global Oct 89 Cat.
Part Number: C4021,
Distributed By And Procured From Global
Power Surge, Power Spike, And EMI/RFI Suppressor Power:
Control Power Directors
Made By And Procured From Proxima Corp
Capability: Sine-Wave Tracking Suppression Of Voltage, Current, And Power To Control 115 V +/-10% 50 to 60 Hz 15 A AC Powerline Feeds, Delta Mode Suppression, 0 Sec Clamping, Filters EMI/RFI Of -3 dB at 9 KHz And -50 dB at 10 MHz, Max Trans Current 6500 Amps, Pulse Trans Energy 108 J, And Peak Trans Power 5.4 MW
Model Numbers: P25 And P15

Building Power Supply And Regulation:
Twenty Five 3 Phase 250 V Twist Lock Number 2321
Plug 250 V And Twist Lock Number 2320 Receptacle
25 Circuit Breaker 20 A Two Pole Type QO120 AMP Plug On Type
25 Circuit Breaker 20 A Single Pole Type QO120 AMP Plug On Type
50 Four Sq Box 4 In NMON Body Lg 0500 Dia Knockout & 0750 Dia Knockout; Steel Body; Zinc Surface
25 Twenty A 125 VAC 3 Wire Ground Receptacle Duplex Female
Electrical Wire:
3 X 500 Ft Cont. Stranded THHN 12 AWG White
3 X 500 Ft Cont. Stranded THHN 12 AWG Red
3 X 500 Ft Cont. Stranded THHN 12 AWG Blue
3 X 500 Ft Cont. Stranded THHN 12 AWG Yellow
3 X 500 Ft Cont. Stranded THHN 12 AWG Black
2 X 500 Ft Cont. Insulation THHN Rated 600 V 2 AWG white
2 X 500 Ft Cont. Insulation THHN Rated 600 V 2 AWG Black
20 Ten Ft Galvanized Rigid Steel Conduit
Breaker Rainproof Box:
100 A Main Load Center w/Box And Interior
225 A Main Load Center w/Box And Interior
12 In By 12 In By 6 In Continuous Hinge Clamp Cover Box
Transformer:
Type: Group B, 75 KVA, 480 V, 3 Phase Delta Primary 208Y/120 Secondary 60 Hz
Made By ACME Transformer
Part Number: T-1a-53314-3S
Distributed By And Procured From Electrical Supply Dist.
Specified, Acquired, and Installed By Mr Jose Meza, Mr Rick Thompson, Mr Mike O'Conner, Mr Lorenzo Greenfield, Mr Steve Crain, and Mr Pete Cline

the PI's monitoring. However all of the equipment was set up by the PI with some technician assistance and all of it was put on line by the PI.

Resin Selection

EPON 830 was selected as the base epoxy resin for this effort. It was selected based upon the author's 1986 and early 1990s work. Those efforts used EPON 828.(21-25) Both EPON 830 and 828 are members of the Diglycidylether Of Bisphenyl A class of epoxy resins.(156) EPON 830 is the largest epoxy resin system molecule available in the Diglycidylether Of Bisphenyl A (DGEBA) class of epoxy resins that is also liquid at room temperature.(156) It also exhibits the largest, while still in a room temperature liquid form, length versus diameter (L/D) ratio of the DGEBA molecules. This aspect means that in a liquid bulk of the material, EPON 830 DGEBA molecules will be the most alined of all the liquid DGEBA molecules by a shear field, such as the shear field generated in resin flowing through a constrained casting cavity.(22)

The results of those earlier efforts indicated that exposure to a magnetic field completely damped out selected rotational motions of molecules with aromatic rings in them.(21-25) More specifically, exposure damped out rotations of molecules like DGEBA that caused the greatest magnetic field flux change through the aromatic rings on the molecule. It also indicated that the larger the length between and number of aromatic rings in the molecules the faster the damping would occur. If so, then were a magnetic field to be exerted onto an epoxy resin system that had been oriented by some other mechanism, that orientation could possibly be maintained in the resin system through to full cure inspite of thermally induced randomizations. Based on the above, EPON 830 represented the best candidate epoxy resin material for the magnetic field coprocessing effect to induce property enhancements in.

1,3 Phenylenediamine (MPDA), 4,4'-Methylene Dianaline (MDA), and Tonox 60/40 their eutectic blend, were selected as the curing agents for this experimental effort. They were selected because they are the type of aromatic curing agents which, until recent concerns made their use less desirable, are commonly used in the aerospace industry as the matrix material in composites. They were also selected because their core structures, that part of the molecule

minus their amine reactant groups, is very representative of the core structures of most available epoxy resin curing agents and other resin groups that are based on other thermosetting reaction mechanisms. The high aromatic nature of these groups would also cause them to be effected by the magnetic field and so both base resin and curing agent would be influenced by exposure to the magnetic field.

4,4'- Methylene bis Cyclohexylamine (also known as PACM-20) was also selected as a curing agent for this experimental effort.(156) It is a fully saturated analog of MDA, with its aromatic nature completely eliminated by the addition of hydrogen atoms to the ring.(156) The usage of PACM-20 in this effort was brought about by the concerns of the author that the magnetic field might restrict the full cure of the resin system by restricting the necessary movements of the resin system as it approaches full cure. Also its usage provided a partial control effect on the experiment. If enhancements were attained in a fully cured or as fully cured as possible MDA resin system then they could be compared to the prospective enhancements attained in a similarly cured PACM-20 resin system. From this comparison, a deduction could then be made as to the effect of the degree of aromaticity in the curing agent on the enhancement derived in the magnetic field coprocessing effect.

1,3 Diaminocyclohexane was also considered as a curing agent for this experimental effort. It is a fully saturated analog of MPDA. Its potential usage was brought about by the analogous concerns and desires stated for MDA in the previous paragraph. Its usage was abandoned for this experimental effort due to its prohibitively high cost, very long acquisition lead times, and its having only one source in the world.

Table 4 lists the curing agent concentrations used in all of the experimental runs conducted in this effort. All of these concentrations were as close as was practicable to the stoichiometric ratio of the selected curing agent with the base EPON 830 epoxy resin. The reported concentrations are accurate only to 2 digits instead of the 4 digits customary to this type of research effort. This was due a degradation in the accuracy of the micro-balances used to measure and proportion the epoxy resins and their curing agents. The unretarded presence of substantial background vibrations in the lab where this effort was conducted rendered free standing micro-balances by themselves

Table 4: Curing Agent Concentration

RUN	Concentration PHR	Curing Agent
65	26.98	99+% MDA (SEE iii)
66	28.02	99+% MDA (SEE iii)
67	26.04	99+% MDA (SEE iii)
68	26.01	99+% MDA (SEE iii)
69	25.51	99+% MDA (SEE iii)
70	25.54	99+% MDA (SEE iii)
71	13.97	99+% MPDA (SEE i)
72	13.95	99+% MPDA (SEE i)
73	29.92	Tonox 60/40 (SEE vi)
	24.92	Epi Rez 5022 (SEE vii)
74	29.86	Tonox 60/40 (SEE vi)
	24.98	Epi Rez 5022 (SEE vii)
75	28.00	97+% PACM-20 (SEE ii)
76	28.03	97+% PACM-20 (SEE ii)
77	28.02	97+% PACM-20 (SEE ii)
78	27.99	97+% PACM-20 (SEE ii)
81	25.49	99+% MDA (SEE iii)
87	25.55	99+% MDA (SEE iii)
90	25.52	99+% MDA (SEE iii)
91	14.01	99+% MPDA (SEE i)
94	14.02	99+% MPDA (SEE i)
95	28.01	97+% PACM-20 (SEE ii)
97	28.04	97+% PACM-20 (SEE ii)
99	25.50	99+% MDA (SEE iii)
101	25.48	99+% MDA (SEE iii)
103	27.98	97+% PACM-20 (SEE ii)
104	27.98	97+% PACM-20 (SEE ii)
105	25.49	99+% MDA (SEE iii)
106	25.49	99+% MDA (SEE iii)
107	28.03	97+% PACM-20 (SEE v)
108	28.03	97+% PACM-20 (SEE v)
109	25.48	99+% MDA (SEE iii)
110	25.48	99+% MDA (SEE iii)
111	28.00	97+% PACM-20 (SEE v)
112	28.00	97+% PACM-20 (SEE v)
113	25.51	99+% MDA (SEE iii)
114	25.51	99+% MDA (SEE iii)
115	27.99	97+% PACM-20 (SEE v)
116	27.98	97+% PACM-20 (SEE v)

Measurement Accuracy: +/- 0.01 PHR

i. 1,3 Phenylenediamine
ii. 4,4'Methylene bis (Cyclohexylamine), Lot #: 00807KX
iii. 4,4'-Methylene Dianaline
iv. EPON 830
v. 4,4'Methylene bis (Cyclohexylamine), Lot #: 01314DT
vi. Tonox 60/40
vii. Epi Rez 5022

useless as they would not stabilize. To overcome the deleterious effects of these vibrations the PI designed and fabricated various heavy balance benches and slabs and isolated them and the micro-balances that sat on them from the lab with various types of isolation pads. Even with these efforts to migitate the effect that these vibrations had on the balances their accuracy was only capable of a stable +/- 0.002 to 0.004 gms instead of the desired +/- 0.0001 gm. Due to this degraded accuracy, the PI decided to clip all PHR calculations to 2 reliable digits instead of the unreliable 3 digits or the unattainable 4 digits.

Magnetic Field Generation, Measurement, And Mapping

The magnetic fields used in this effort were generated with two different electromagnet - power supply systems. The smaller system consisted of a rebuilt Alpha Scientific Magnetics Inc. electromagnet with 4 in dia flat pole faces and a 0 to 5 in variable air gap powered by a Kepco Inc. constant current regulation power supply. The larger system consisted of a Walker Scientific Inc. electromagnet with 7 in dia flat pole faces and a 0 to 7.25 in variable air gap powered by a Walker Scientific Inc. power supply. The specifics associated with each system are delineated in Table 3.

Both electromagnets were operated while a constant flow of clean nonconductive coolant with a feed temperature of 30+/-2^{o}F (-1+/-1^{o}C) was passed through them. The coolant used was a mixture of 50 percent pure ethylene glycol and 50 percent double distilled water. The coolant component's specifics are listed in Table 3. An Edwards Chiller system was used to cool and regulate the coolant's temperature. The chiller's specifics are outlined in Table 3. The coolant was kept clean of all corrosion products by transporting it through a piping system that was meticulously set up to eliminate all potential galvanic corrosion circuits. The coolant became cleaner with usage in all compounds except copper: which increased overtime from a few PPM to 10's of PPM. The clean nonconductive coolant was necessary to eliminate the potential to drift, that the strengths of magnetic fields generated by the electromagnets tend to have over time from repeatable power settings, due to leakage currents through a conductive coolant. The specific components comprising the piping system are delineated in Table 3.

Both electromagnets were permanently and unmovably anchored in place on tailor-made stands. Table 3 provides the specifics of these stands. Both of these stands, and their associated electromagnets, were bolted down to the experimental level of an overall equipment support scaffold. Figure 3 illustrates this arrangement. A single magnetic field mapping system was positioned above the electromagnets on the mapping level of the scaffold, as also depicted in Figure 3, to measure and map out the magnetic fields generated by them.

Measurement and mapping of the magnetic fields was accomplished with a Hall Probe - Gaussmeter - Three Axis positioner set up. The Hall Probe - Gaussmeter combination was used to measure the magnetic field's strengths. The Three Axis positioner was used to move the Hall probe around in the magnetic fields to map them.

A transverse style Hall Probe was used to measure magnetic field strengths. It was made by and procured from Walker Scientific Inc. Its specifics are delineated in Table 3. The Gaussmeter was also made by and procured from Walker Scientific Inc. Its specifics are also listed in Table 3. The Hall Probe - Gaussmeter set up could accurately measure the strength of a magnetic field to 0.1 percent; which means that its accuracy was no worse, and usually much better than +/- 9 Gauss (Oersted in air and most other organic materials) for any and or all of the fields generated. The Hall Probe was inserted into the relevant zone of a magnetic field used during an experimental run at specifically selected, accurately measured, and repeatable points and the strength of the field was sampled at those points. The average of these points was then determined and adjusted as calibration requirements dictated. The resultant average and its associated extremes were then reported as the magnetic field strength used in any particular run.

The Hall Probe - Gaussmeter set up was calibrated by measuring the set up's read out when the Hall Probe was measuring a known series, usually two and occasionally three, calibrated magnet fields. This was accomplished by inserting the Hall Probe into a calibration magnet, reading the set up's read out, and comparing it with the calibration magnet's known value. The final average magnetic field strength used for any particular run was then adjusted accordingly up or down by linear interpolation as were it's extreme range boundary strengths. These calibration magnets were made and

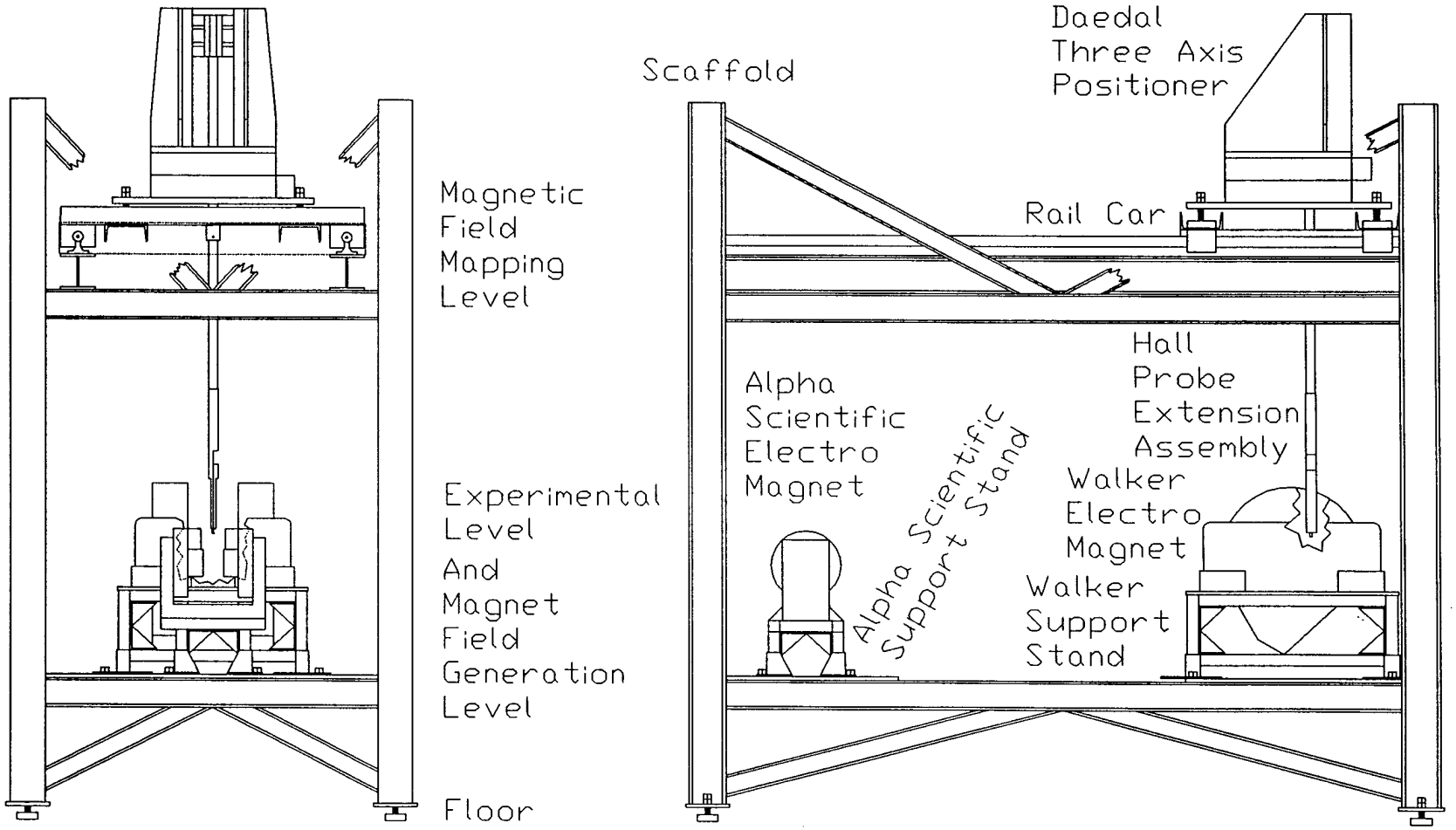


Figure 3: Supporting Scaffold Overall

procured from Walker Scientific Inc. and are certified NBS Traceable. Their specifics are listed in Table 3.

To map the magnetic fields the Hall Probe was moved, with extreme accuracy and repeatability, in the fields via an anchored, positionally repeatable, three axis positioner with a stiff zero magnetic susceptibility extension arm to which it was attached. The Hall Probe was attached to a zero magnetic susceptibility grip at the end of the extension arm. Figure 4 depicts the overall extension arm assembly and this grip. This grip was precision machined so as to assure that when the Hall Probe was attached to it it would always return to the same location within, at worst case, 5 mils. The grip and the extension arm, to which it was attached, was designed to be readily removeable and reattachable, while also being positionally repeatable. This was accomplished by match machining two sets of cross aligned dowel pin holes in the grip and the arm along their mutual overlap. Also four associated brass dowel pins were machined. Each dowel pin was tailor machined to one of the four holes. The overall result exhibited a repeatability range of no worse than 5 mils.

The extension arm was designed to be a permanently fixed attachment to the three axis positioner. This was accomplished by match machining its components and anchoring them together with press fit dowel pins. The overall arm was precision bolted to the Z axis of the positioner as shown in Figure 3. This resulted in no positional inaccuracies from this component of the positioner being imposed on the repeatability essential to measuring and mapping the various magnetic fields.

The precise and repeatable movement of the Hall Probe in and through the various magnetic fields was achieved by using a precision three axis positioner. The actual positioner used was made by Daedal Inc. from mainly stock precision sub-components of Daedal design and other structural components tailor designed by the PI and fabricated by Daedal. Figure 5 depicts the final design configuration of the three axis positioner used through out this effort. The specifics associated with it are listed in Table 3. The positioner was capable of moving the extension arm and attached Hall Probe from a set zero point to any and all necessary locations in the generated magnetic fields with a repeatability of +/- 1 mil and a measurement accuracy of +/- 2 mils. The overall effect of this positioner - extension arm - Hall Probe combination permitted the exact measurement of the strength of

Components List:
1: Link Plate To 3 Axis Positioner
2 Link Plate To Box Beam Connector
3 Box Beam Connector
4 Box Beam To Hall Probe Connector
5 Lower Nonmagnetic Hall Probe Holder Extension Clamp
6 Top Nonmagnetic Hall Probe Holder Extension Clamp
7 0.2500" Dia By 2.5" Long Case Hardened Steel Dowel Pins
8 0.2500" Dia By 1.5" Long Case Hardened Steel Dowel Pins
9 0.250" Dia By 1.5" Long Brass Pins With 0.5" Long By 0.75" Dia Knarled Knobs On Top Of The Pin Section
10 Brass 0.75" Long 6-32 Machine Screws
11 T-640859 Transverse Hall Probe

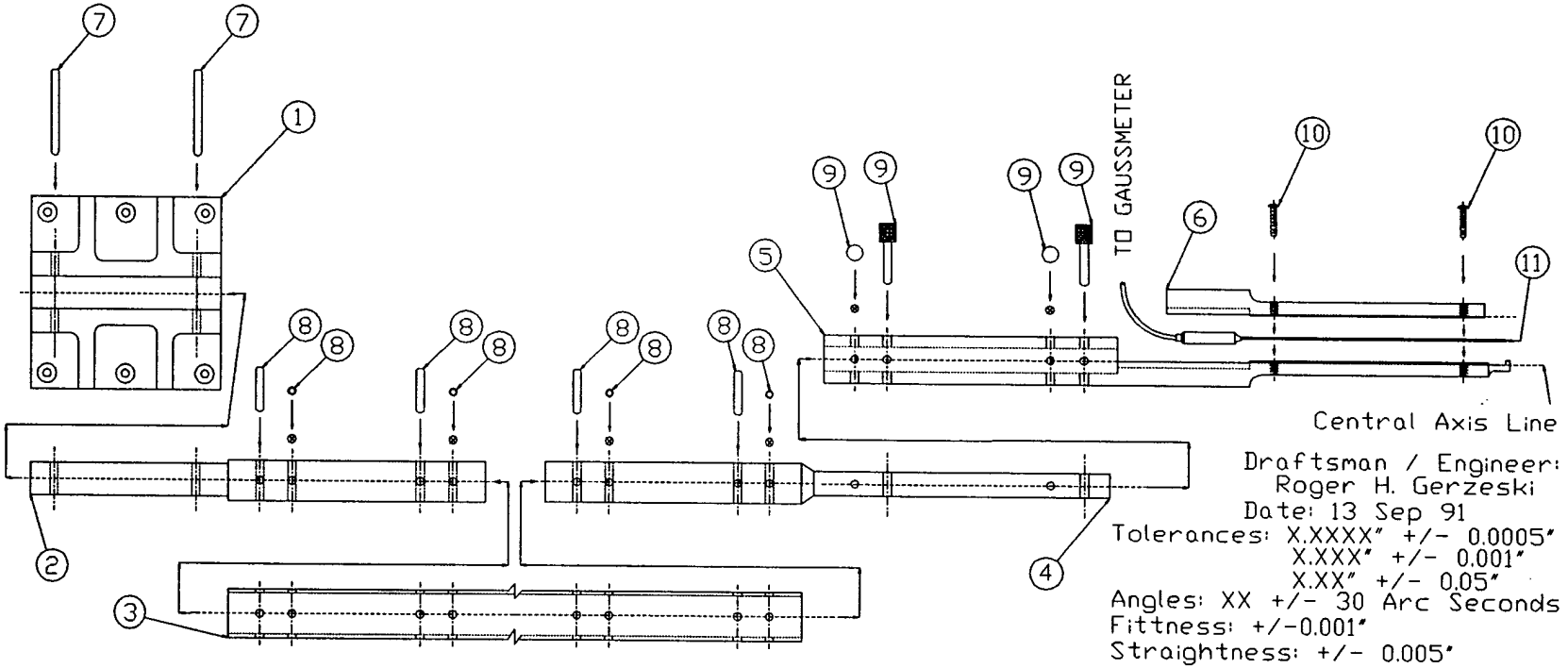
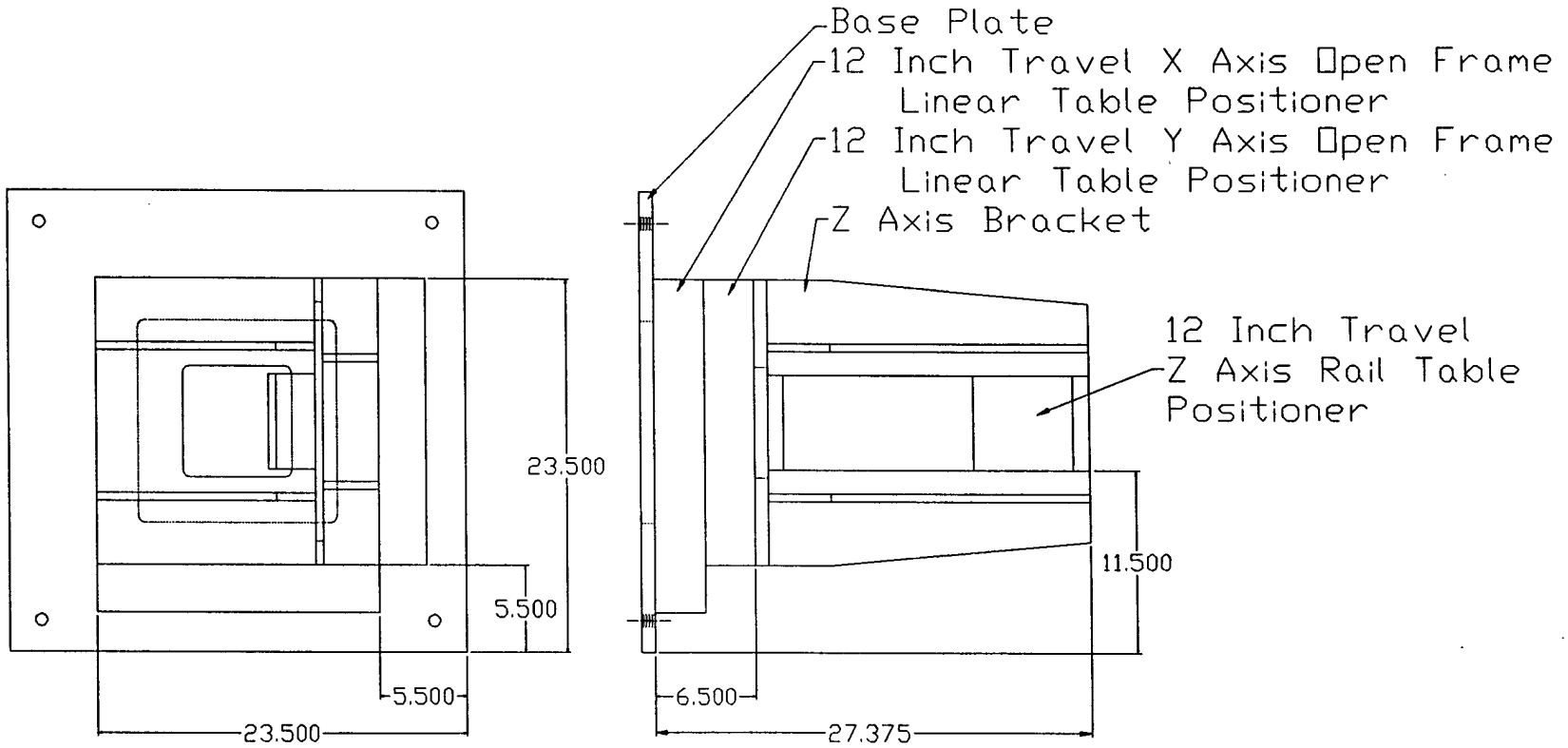


Figure 4: NonMagnetic Hall Probe Extension: Assembly



Draftsman/Engineer:
Roger H. Gerzeski

Tolerances:
X.XXX" +/- 0.001"
Fitness: +/- 0.001"

Date: 8 Jun 89

Figure 5: Three Axis Positioner System: X=12", Y=12", Z=12": Assembly

magnetic fields used at numerous, distinct, and minutely separated points through out the smallest used and most relevant sections of the fields. This precision allowed for the sampling of sufficiently numerous points within the small volume fields used at so as to accurately determine an average strength at a sufficiently low standard of deviation. It also allowed the PI to determine the extremes and subsequently the range of the fields used with a high degree of confidence.

The positioner and all of the items attached to it were set on a mobile rail car which allowed it to be safely repositioned as necessary above either of the two electromagnets. Figure 6 illustrates the rail car's assembly. Table 3 lists the specifics of the rail car's components. The positioner was accurately and immovably positioned onto the rail car by having the bases of its' leveling pads set into match machined receptacles. These receptacles were themselves bolted and press fit, dowel pinned to the rail car. The rail car's orientation and dimensional stability were also locked down by press fit dowel pins.

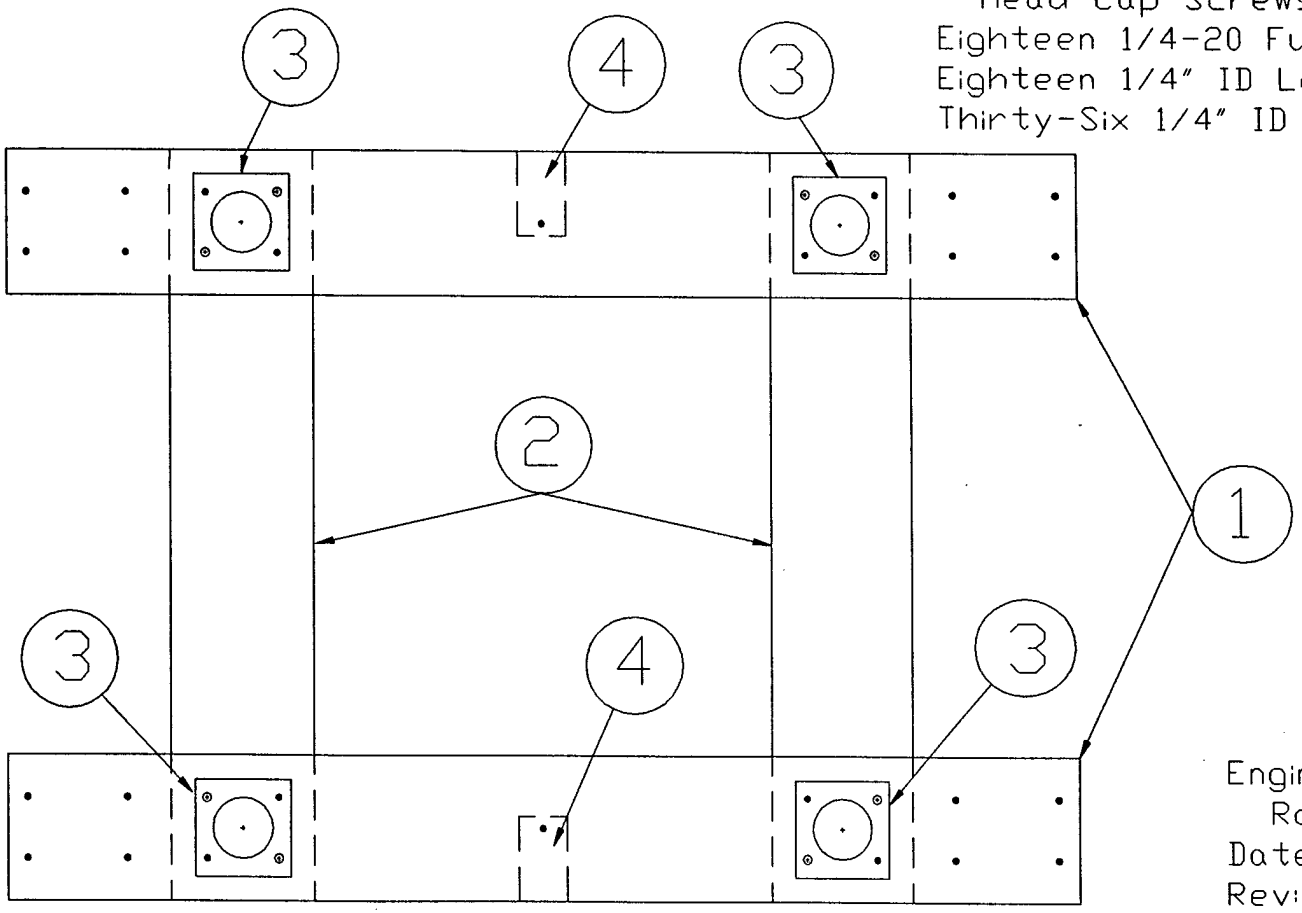
The rail car, the three axis positioner, and all of the sub-components attached to it were attached to four pillow blocks on two parallel precision rails. This linear motion rail table system was made by and procured from Thomson Industries, Inc. It is figuratively depicted in Figure 3 and its' particulars are listed in Table 3. The rails were permanently bolted down to 6 in H beams in a positionally stable fashion. The H Beams were themselves welded to the overall equipment support scaffold. This set up allowed the positioner and its associated mapping equipment to be moved from a repeatable point over one magnet to a repeatable point over the other magnet and visa versa.

During the actual measuring and mapping of any particular magnetic field, the car, positioner, and attached sub-components were bolted down to a bar that was permanently attached to each end of the rails. This bolt was torqued down to 200 In-Lb_f and gently pulled the rail car and the associated measuring and mapping equipment into a stable and repeatable position over an electromagnet of choice.

All of the magnetic field generating, measuring, and mapping equipment associated with this effort are either permanently or rigidly attached to the overall equipment support scaffold. The specifics associated with this

Notes:
1. Long Arm Support Channel Beams
2. Short Arm Support Channel Beams
3. Leveling Pad Receiver Blocks
4. Alinement Brackets

Fasteners:
Eight 0.250" Dia By 2" Dowel Pins
Eight 3/8-16 By 1.5" Bolts
Eighteen 1/4-20 By 1.5" Socket Head Cap Screws
Eighteen 1/4-20 Full Nuts
Eighteen 1/4" ID Lock Washers
Thirty-Six 1/4" ID Washers



Engineer / Draftsman:
Roger H. Gerzeski
Date: 30 Jan 91
Rev: 25 Feb 91

Figure 6: Rail Car Assembly

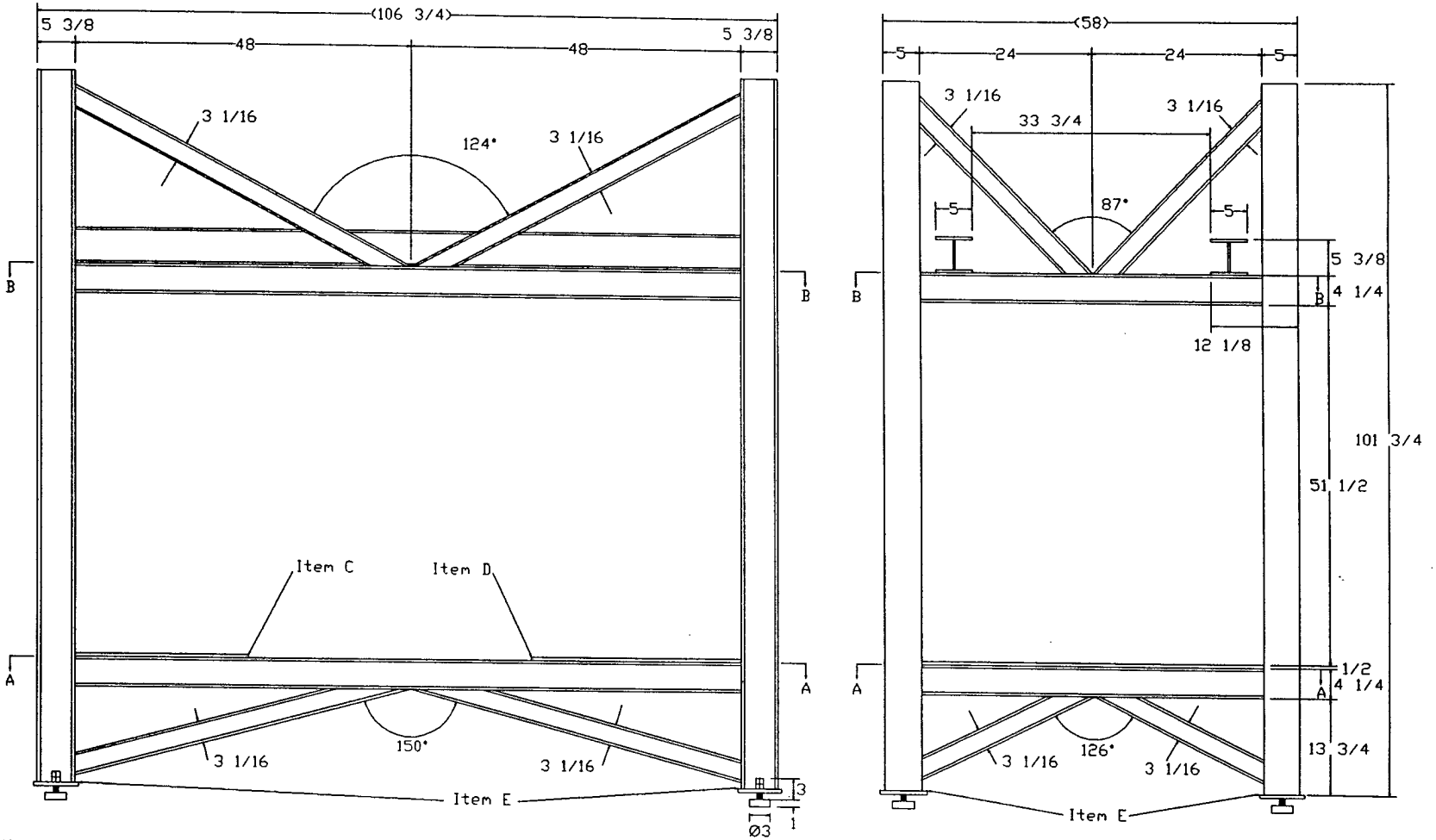
scaffold are listed in Table 3 and its overall mechanical design is depicted in Figure 7. This scaffold was specifically designed to be exceptionally stiff and could in fact support roughly 20 times the actual weight put on it. The objective of this exceptionally stiff design and of permanently anchoring all of the magnetic field related equipment to it was to rigidly link the zones in which a magnetic field was created to the mechanisms which would measure and map them. With the exception of the rail cars' ability to move from one position over one of the magnets to another position over the other magnets; all components associated with the magnetic fields were permanently fixed into place. Even the rail car and accompanying equipment was torque bolted into a stable and repeatably wedged position no matter over which magnet it resided. Overall, due to the extreme care taken by the PI in designing, fabricating, and assembling of the magnetic field related equipment, all magnetic fields generated for this effort were mapped and all specimens were positioned for magnetic field exposure to within a repeatable positional accuracy of +/- 25 mils or less.

Magnetic Field Strengths: Selection And Use

To select the appropriate and relevant number, strengths, and range of magnetic field strengths to be used in this effort four factors were taken into consideration. The first factor concerned making the steps between one field strength and the next small and frequent enough so as to avoid synchronizing with the troughs of the sinusoidal function indicated in the introduction. The second factor involved taking into account the author's previous efforts. A third factor involved the practical aspects associated with generating sufficiently large and adequately uniform magnetic fields. The final factor concerned the practicality of investigating a sufficient number of fields to reasonably locate or dismiss the effect.

As was mentioned in the introduction and also described in the referenced S-R publications there is a strongly implied sinusoidal fluctuation of property enhancement versus magnetic field strength.(26-154) An analysis of the 78 illustrated appearances of the wavelength of this sinusoidal correlation indicates that it has an average wavelength of 928 +/- 550 Oe (0.0928 +/- 0.0550 T), with a range of between 121 Oe (0.0121 T) and 2520 Oe (0.2520 T) between 0 and 9000 Oe (0.9000 T).(100-135) If this sinusoidal aspect does exist then experimental runs must be conducted at strengths whose average differences, from one

Notes: 1. All Angles Are 90 Degrees Unless Indicated Or Inferred From The Drawing.
2. All Joints Are To Be Welded Along All Contacting Faces.



Materials Of Construction: 5 Inch H Beams, 4 Inch H Beams, 3 Inch I Beams, 1/2 Inch Thick Plate.
Tolerances: Fractions: +/- 1/32", Draftsman / Engineer: Roger H. Gerzeski, Date: 1/9/89

Figure 7: Scaffold Support Structure: Assembly

field to another, will assure locating any tangible resultant of the effect. In essence the step size needs to be small enough to assure that the sampled field strengths do not succeed in just hitting the bottoms of the troughs of this prospective sinusoidal correlation. Based upon the published S-R efforts the author determined that an appropriate step size should be either the S-R average minus one standard of deviation or plus one standard of deviation: ie 378 Oe (0.0378 T) or 1478 Oe (0.1478 T).

The PI's previous work, with particular emphasis on his 1986 effort, indicated that the effect was not apparent below 1000 Oe (0.1000 T). This, even when the cure regime was very mild: room temperature with an aliphatic curing agent. Since the curing agents chosen for this effort where aromatic types, which required elevated temperatures to be fully cured, the PI decided that magnetic fields below approximately 1000 Oe (0.1000 T) had substantially limited potential for demonstrating the effect. Therefore magnetic field strengths below 1000 Oe (0.1000 T) were not investigated.

The highest magnetic field strengths used in this effort were the maximums that could be generated by the electromagnets at the 3.0 in air gap setting for the Alpha Scientific system and the 3.5 in air gap setting for the Walker system. The maximum for the Walker system was 8810 +/- 11 Oe (0.8810 +/- 0.0011 T). The maximum for the Alpha Scientific system was 5533 +/- 71 Oe (0.5533 +/- 0.0071 T).

As was mentioned in the introduction there are two distinct magnetic field strength ranges which, if the property enhancement was adequate enough, would make the incorporation of this effect into existing production processes feasible. As Figure 2 indicates, the first range was between 0 and 5000 Oe (0.5000 T), the second between 5000 and 9000 Oe (0.5000 and 0.9000 T). Below 5000 Oe (0.5000 T) reasonably large volume magnetic fields with a uniformity of roughly +/- 100 Oe (0.0100 T) can be repeatably generated with fairly simple, low cost, magnetic field generation devices and positional controls.(21-25) Above 5000 Oe (0.5000 T) and to 9000 Oe (0.9000 T) only small volume magnetic fields with a uniformity of roughly +/- 100 Oe (0.0100 T) can be repeatably generated, and fields two to three times the volume of the +/- 100 Oe (0.0100 T) uniformity volume fields tend to have uniformities of +/- 1000 Oe (0.1000 T). Unfortunately these high strength fields require sophisticated, and

expensive magnetic field generation devices and equally sophisticated positional controls. Overall the attributes associated with fields below 5000 Oe (0.5000 T) allow for the effective operational determination of the effect over small spans of the magnetic field on the order of a few 100s of Oe. Where as the attributes associated with fields over 5000 Oe (0.5000 T) and under 9000 Oe (0.9000 T) require larger spans of the magnetic field, on the order of 1000s of Oe, to be able to operationally determine the effect.

Based upon the above the PI decided to use magnetic fields below 5000 Oe (0.5000 T) that were separated by a rough average of 400 Oe (0.0400 T) steps. The ten fields used below 5000 Oe (0.5000 T) began with one at 1290 Oe (0.1290 T) and ended with one at 4841 Oe (0.4841 T). The PI also decided to use magnetic fields above 5000 Oe (0.5000 T) that were separated by an average of roughly 1100 Oe (0.1100 T) steps. The five fields used above 5000 Oe (0.5000 T) started at 5533 Oe (0.5533 T) and ended with the 8810 Oe (0.8810 T) field. For the entire effort fifteen different magnetic fields were generated, mapped and had resin system specimens cast in them. These fifteen fields and the range that they span are listed in Table 5 and further correlated to the particular experimental run in which they were used in Table 6. They represent a reasonable number and distribution of magnetic fields to either locate the effect or confidently dismiss the economically useable existence of this effect.

Specimen Configuration, Orientation, and Generation

The specimens generated in this effort were of the same configuration as those in the author's 1986 and early 1990's efforts. The exact dimensions of those specimens are those of the dogbone sections minus the sprues in the drafting depicted in Figure 8. These specimens were miniaturized ASTM tensile test specimens with 1 in gage lengths and 0.080 in thick by 0.175 in wide rectangular gage cross-sections.

For each run the same number of magnetic field exposed specimens and control specimens were generated. Table 7 lists the exact number of specimens that were generated in each run. In almost all of the runs eight exposed and eight controls were generated, but in eight of the latter runs ten exposed and ten controls were generated. The generation of so many specimens was necessary to assure

Table 5: Magnetic Field Strengths Used

Field Strength Oersted (Tesla) Mean+/-Std	Min	Max	[DPs]
8810+/-11 (0.8810+/-0.0011	**8785** 0.8785	**8829** 0.8829)	[384]
8637+/-11 (0.8637+/-0.0011	**8610** 0.8610	**8655** 0.8655)	[315]
7640+/-33 (0.7640+/-0.0033	**7611** 0.7611	**7668** 0.7668)	[273]
6871+/-20 (0.6871+/-0.0020	**6822** 0.6822	**6907** 0.6907)	[385]
5533+/-71 (0.5533+/-0.0071	**5396** 0.5396	**5653** 0.5653)	[385]
4841+/-98 (0.4841+/-0.0098	**4684** 0.4684	**5010** 0.5010)	[231]
4474+/-10 (0.4474+/-0.0010	**4456** 0.4456	**4491** 0.4491)	[75]
3965+/-52 (0.3965+/-0.0052	**3827** 0.3827	**4079** 0.4079)	[385]
3741+/-8 (0.3741+/-0.0008	**3727** 0.3727	**3756** 0.3756)	[75]
3301+/-6 (0.3301+/-0.0006	**3290** 0.3290	**3310** 0.3310)	[75]
2918+/-6 (0.2918+/-0.0006	**2907** 0.2907	**2927** 0.2927)	[75]
2748+/-37 (0.2748+/-0.0037	**2686** 0.2686	**2815** 0.2815)	[385]
2313+/-36 (0.2313+/-0.0036	**2248** 0.2248	**2357** 0.2357)	[72]
1773+/-28 (0.1773+/-0.0028	**1721** 0.1721	**1809** 0.1809)	[72]
1290+/-21 (0.1290+/-0.0021	**1251** 0.1251	**1318** 0.1318)	[72]

Measurement Accuracy: +/- 6 Oersted

Table 6: Field Strength And Specimen Orientation Within

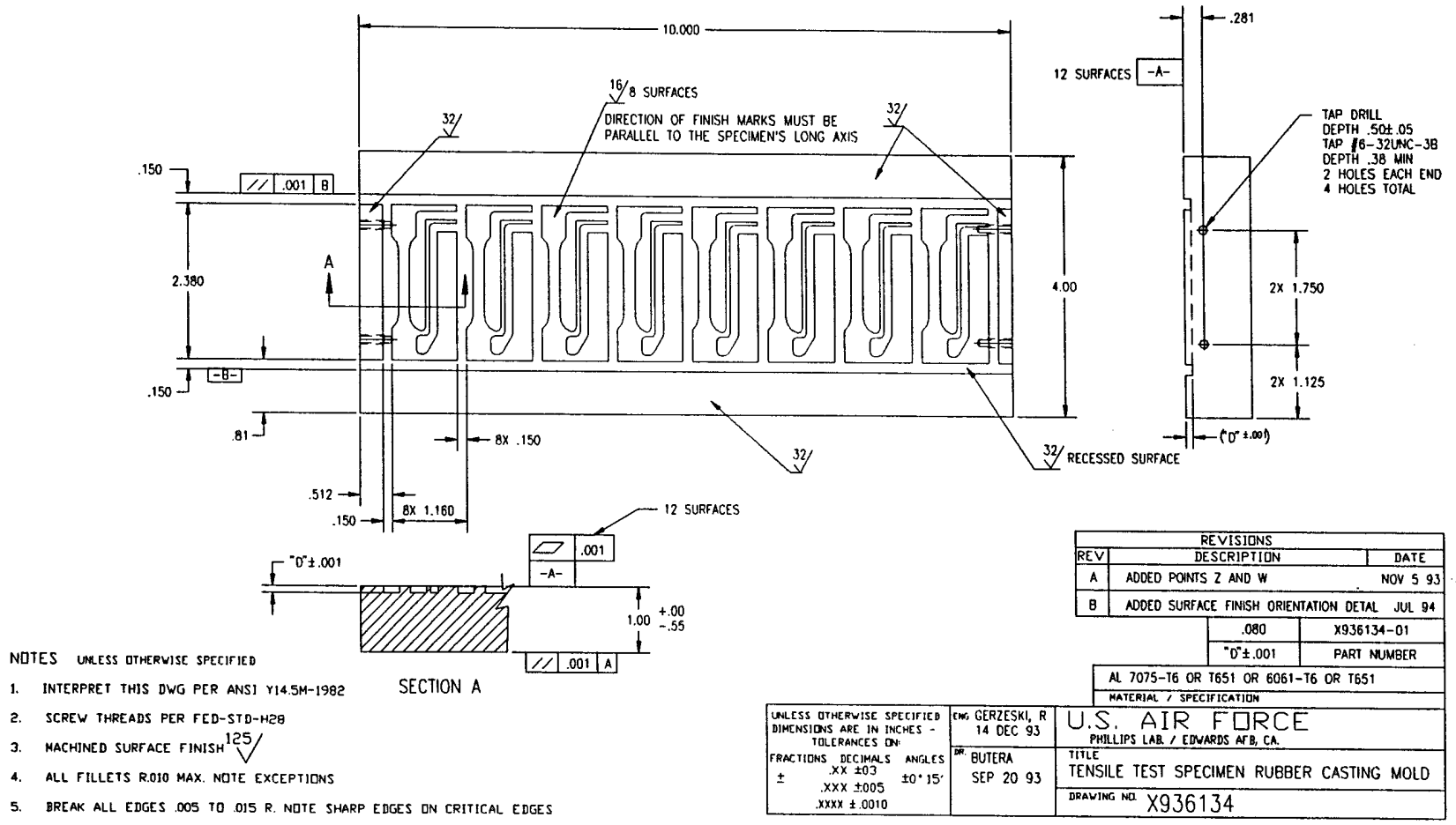
RUN	Field Strength Oersted (Tesla) Mean+/-Std	Min	Max	[DPs]	Specimen Orientation Degrees Min	Max
65	7640+/-33 (0.7640+/-0.0033	7611 0.7611	7668 0.7668)	[273]	88.92	90.00
66	4841+/-98 (0.4841+/-0.0098	4684 0.4684	5010 0.5010)	[231]	89.07	90.00
67	8637+/-11 (0.8637+/-0.0011	8610 0.8610	8655 0.8655)	[315]	89.23	90.00
68	5533+/-71 (0.5533+/-0.0071	5396 0.5396	5653 0.5653)	[385]	87.98	90.00
69	8810+/-11 (0.8810+/-0.0011	8785 0.8785	8829 0.8829)	[384]	86.61	90.00
70	5533+/-71 (0.5533+/-0.0071	5396 0.5396	5653 0.5653)	[385]	89.12	90.00
71	8810+/-11 (0.8810+/-0.0011	8785 0.8785	8829 0.8829)	[384]	88.63	90.00
72	5533+/-71 (0.5533+/-0.0071	5396 0.5396	5653 0.5653)	[385]	88.92	90.00
73	8810+/-11 (0.8810+/-0.0011	8785 0.8785	8829 0.8829)	[384]	90.00	90.00
74	5533+/-71 (0.5533+/-0.0071	5396 0.5396	5653 0.5653)	[385]	89.44	90.00
75	8810+/-11 (0.8810+/-0.0011	8785 0.8785	8829 0.8829)	[384]	89.95	90.00
76	5533+/-71 (0.5533+/-0.0071	5396 0.5396	5653 0.5653)	[385]	89.24	90.00
77	6871+/-20 (0.6871+/-0.0020	6822 0.6822	6907 0.6907)	[385]	90.00	90.00
78	3965+/-52 (0.3965+/-0.0052	3827 0.3827	4079 0.4079)	[385]	89.79	90.00
81	6871+/-20 (0.6871+/-0.0020	6822 0.6822	6907 0.6907)	[385]	89.80	90.00
87	6871+/-20 (0.6871+/-0.0020	6822 0.6822	6907 0.6907)	[385]	89.69	90.00
90	3965+/-52 (0.3965+/-0.0052	3827 0.3827	4079 0.4079)	[385]	89.95	90.00
91	6871+/-20 (0.6871+/-0.0020	6822 0.6822	6907 0.6907)	[385]	89.56	90.00
94	3965+/-52 (0.3965+/-0.0052	3827 0.3827	4079 0.4079)	[385]	89.67	90.00

Measurement Accuracy: +/- 6 Oersted
Measurement Accuracy: +/- 0.01 Degrees

Table 6: Field Strength And Specimen Orientation Within Continued

RUN	Field Strength Oersted (Tesla) Mean+/-Std	Min	Max	[DPs]	Specimen Orientation Degrees Min	Max
95	6871+/-20 (0.6871+/-0.0020	6822 0.6822	6907 0.6907)	[385]	89.64	90.00
97	3965+/-52 (0.3965+/-0.0052	3827 0.3827	4079 0.4079)	[385]	89.06	90.00
99	3301+/-6 (0.3301+/-0.0006	3290 0.3290	3310 0.3310)	[75]	89.80	90.00
101	2748+/-37 (0.2748+/-0.0037	2686 0.2686	2815 0.2815)	[385]	89.62	90.00
103	3301+/-6 (0.3301+/-0.0006	3290 0.3290	3310 0.3310)	[75]	89.80	90.00
104	2748+/-37 (0.2748+/-0.0037	2686 0.2686	2815 0.2815)	[385]	89.95	90.00
105	2918+/-6 (0.2918+/-0.0006	2907 0.2907	2927 0.2927)	[75]	89.80	90.00
106	2313+/-36 (0.2313+/-0.0036	2248 0.2248	2357 0.2357)	[72]	89.54	90.00
107	2918+/-6 (0.2918+/-0.0006	2907 0.2907	2927 0.2927)	[75]	89.80	90.00
108	2313+/-36 (0.2313+/-0.0036	2248 0.2248	2357 0.2357)	[72]	89.89	90.00
109	4474+/-10 (0.4474+/-0.0010	4456 0.4456	4491 0.4491)	[75]	89.80	90.00
110	1290+/-21 (0.1290+/-0.0021	1251 0.1251	1318 0.1318)	[72]	89.64	90.00
111	4474+/-10 (0.4474+/-0.0010	4456 0.4456	4491 0.4491)	[75]	89.80	90.00
112	1290+/-21 (0.1290+/-0.0021	1251 0.1251	1318 0.1318)	[72]	89.77	90.00
113	3741+/-8 (0.3741+/-0.0008	3727 0.3727	3756 0.3756)	[75]	89.80	90.00
114	1773+/-28 (0.1773+/-0.0028	1721 0.1721	1809 0.1809)	[72]	89.12	90.00
115	3741+/-8 (0.3741+/-0.0008	3727 0.3727	3756 0.3756)	[75]	89.80	90.00
116	1773+/-28 (0.1773+/-0.0028	1721 0.1721	1809 0.1809)	[72]	89.82	90.00

Measurement Accuracy: +/- 6 Oersted
Measurement Accuracy: +/- 0.01 Degrees



NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125/
4. ALL FILLETS R.010 MAX. NOTE EXCEPTIONS
5. BREAK ALL EDGES .005 TO .015 R. NOTE SHARP EDGES ON CRITICAL EDGES

REVISIONS		
REV	DESCRIPTION	DATE
A	ADDED POINTS Z AND W	NOV 5 93
B	ADDED SURFACE FINISH ORIENTATION DETAL	JUL 94

.080	X936134-01
"D"±.001	PART NUMBER

AL 7075-T6 OR T651 OR 6061-T6 OR T651
MATERIAL / SPECIFICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS ± DECIMALS .XX ±03 .XXX ±005 .XXXX ±.0010 ANGLES ±0°15'	ENG GERZESKI, R 14 DEC 93 DR. BUTERA SEP 20 93	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA. TITLE TENSILE TEST SPECIMEN RUBBER CASTING MOLD DRAWING NO. X936134

Figure 8: Tensile Test Specimen: Rubber Casting Mold

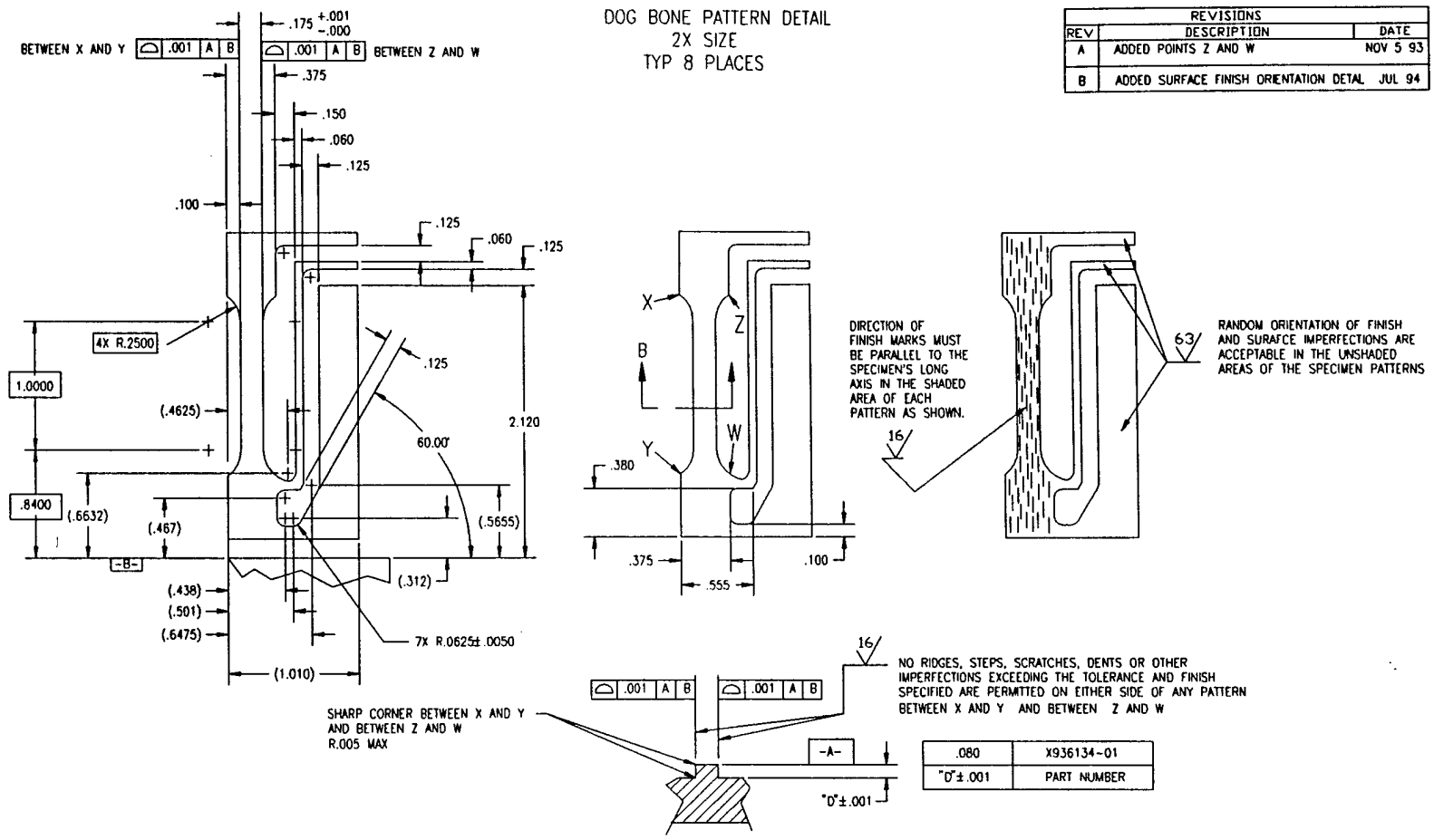


Figure 8: Tensile Test Specimen: Rubber Casting Mold: Detail; Continued

that at least three or more mechanically testable exposed and another three or more mechanically testable control specimens were created. Also, one additional exposed and one additional control specimen were required for thermal analysis.

Table 7: Specimens Generated

RUN	Exposed	Control	RUN	Exposed	Control
65	8	8	66	8	8
67	8	8	68	8	8
69	8	8	70	8	8
71	8	8	72	8	8
73	8	8	74	8	8
75	8	8	76	8	8
77	8	8	78	8	8
81	8	8	87	8	8
90	8	8	91	8	8
94	8	8	95	8	8
97	8	8	99	10	10
101	8	8	103	10	10
104	8	8	105	10	10
106	8	8	107	10	10
108	8	8	109	10	10
110	8	8	111	10	10
112	8	8	113	10	10
114	8	8	115	10	10
116	8	8			

Based upon the results of the PI's 1986 and early 1990's efforts, all specimens generated while exposed to the various magnetic fields were oriented with their tensile load axis perpendicular to the magnetic field's major overall vector. Figure 9 depicts this major overall vector and Figure 10 depicts the perpendicular orientation of the specimens to it. Actual specimen orientations for each experimental run are listed in Table 6. The worst deviation from perpendicular (90.00 degrees) was 86.61 degrees in run 69. The average deviation using Type I ovens and mold clamps was 89.37+/-0.71 degrees for the 29 runs using them. The worst case deviation for the remaining eight runs using Type II ovens and clamps was 89.80 degrees.

All specimens were generated by being cast, from a liquid mix of the base epoxy resin and a curing agent, into RTV-664 silicone rubber mold cavities. These molds were created by pouring the freshly mixed silicone rubber

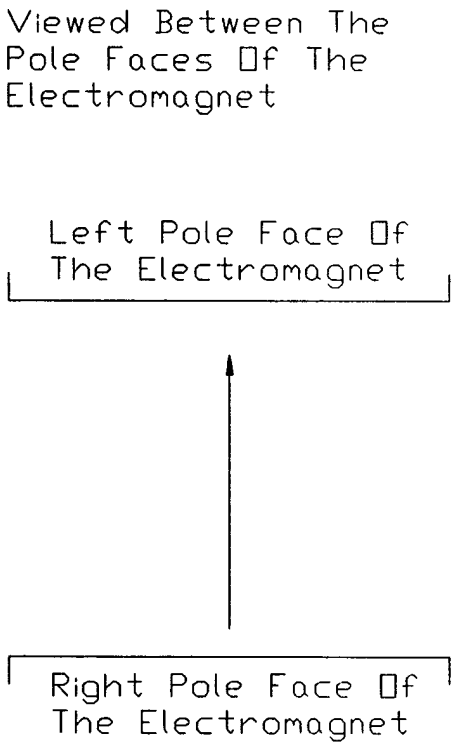


Figure 9: Major Magnetic Field Vector

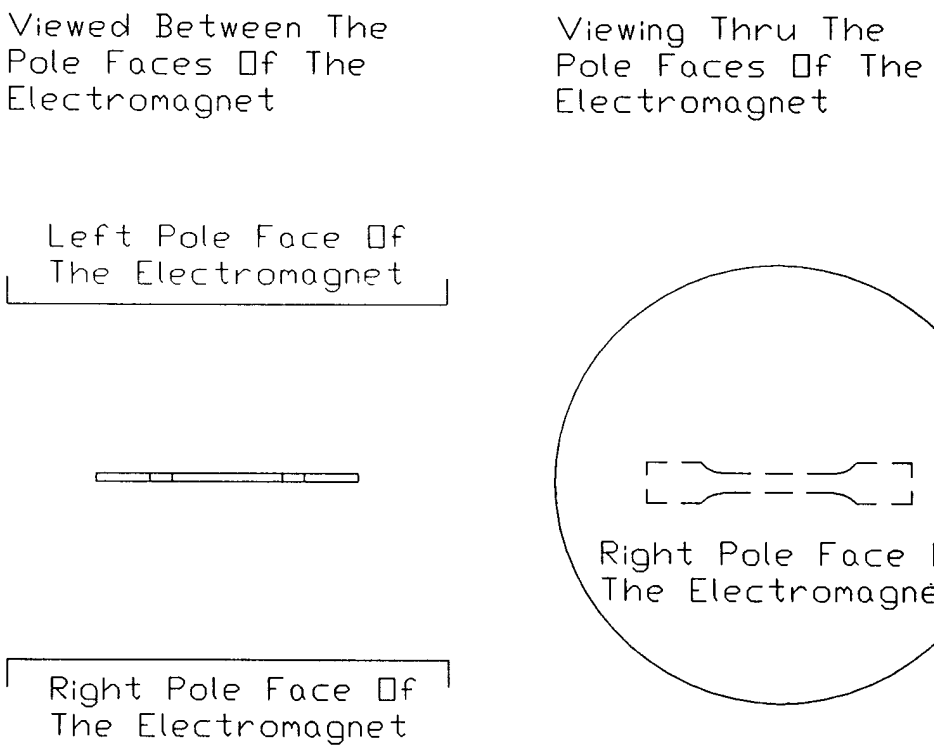


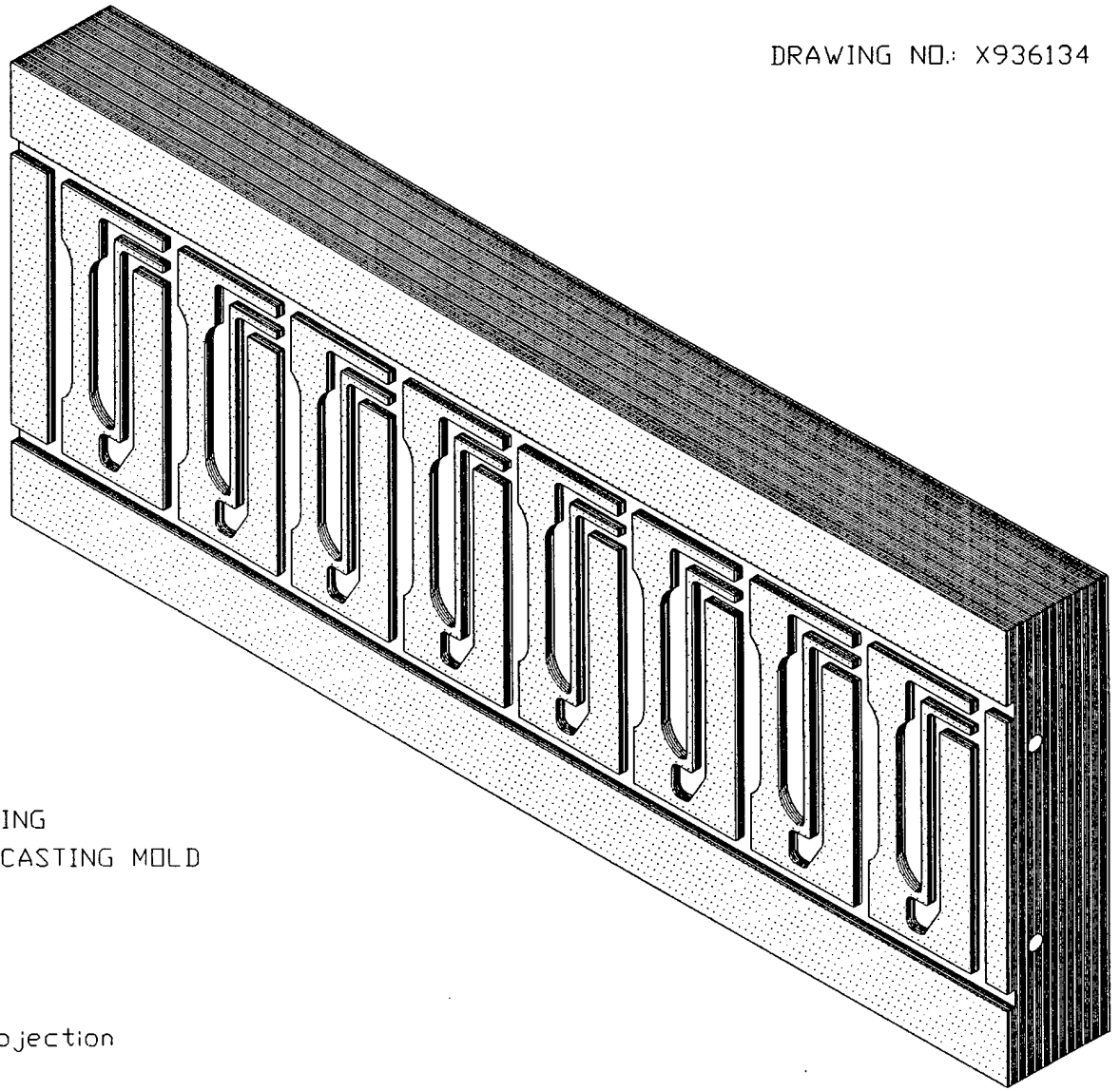
Figure 10: Perpendicular Specimen Orientation: Within Magnetic Field

system over the aluminum mold negative drafted in Figure 8 and isometrically depicted in Figure 11. The rubber was allowed to addition crosslink into a solid rubber sheet that, when pealed away from the aluminum negative, looked like the sheet shown in the lower right of Figure 12. This sheet was then trimmed and cut up into individual casting cavities and these cavities where then stacked together as depicted in the lower left of Figure 12. These silicone rubber mold stacks were then clamped together and placed onto ovens. The various epoxy resin systems used in this experimental effort where then cast into these molds and cured. The cured resultant was then removed from the molds by pealing the RTV-664 mold away. The specimens were then extracted from the cured mass by trimming away the flash and excess left in the sprues as depicted in the upper center of Figure 12.

A few problems were encountered early on in the experimental effort, with the RTV-664 rubber molds. The first problem encountered was the propensity of freshly mixed, cast, and curing molds to attract dust particles to their exposed surfaces. This resulted in those surfaces being severely pock marked. The second problem concerned the generation of bubbles in the cast and cured epoxy resin specimens. This resulted in rendering those specimens untestable.

For the early experimental runs in this effort, rubber negative casting cavities left over from the early 1990's efforts, namely Runs 40 through 59, were used. After two or three high temperature cyclings they soon became brittle and wore out. New rubber casting cavities were needed. They were generated from the RTV-664 rubber casting compound lots delineated in Table 3. These new molds immediately exhibited a significant flaw: they attracted dust particles to themselves which left substantial pock marks on their outer surfaces. This problem resulted from an unannounced change in the Trade Secret formulation of GE's RTV-664 to meet VOC emissions standards enacted by the State Of California in 1989. This pock marking was very deleterious, as the outer surface of one mold cavity formed part of the inner specimen casting cavity wall of another mold as depicted in Figure 12. These pock marks were between 5 and 15 mils deep and would result in the generation of 5 to 15 mil high burrs through the thickness of the cast epoxy specimens. These burrs would cause substantial unwarranted variations in the thickness measurements of specimens that were nominally only 80 mils thick. These thickness variations would then result in a commensurately large scatter in the measured strengths of

DRAWING NO.: X936134



TENSILE SPECIMEN CASTING
RTV RUBBER NEGATIVE CASTING MOLD
DRAFTSMAN: BOCOCK, B

Figure 11: Isometric Projection

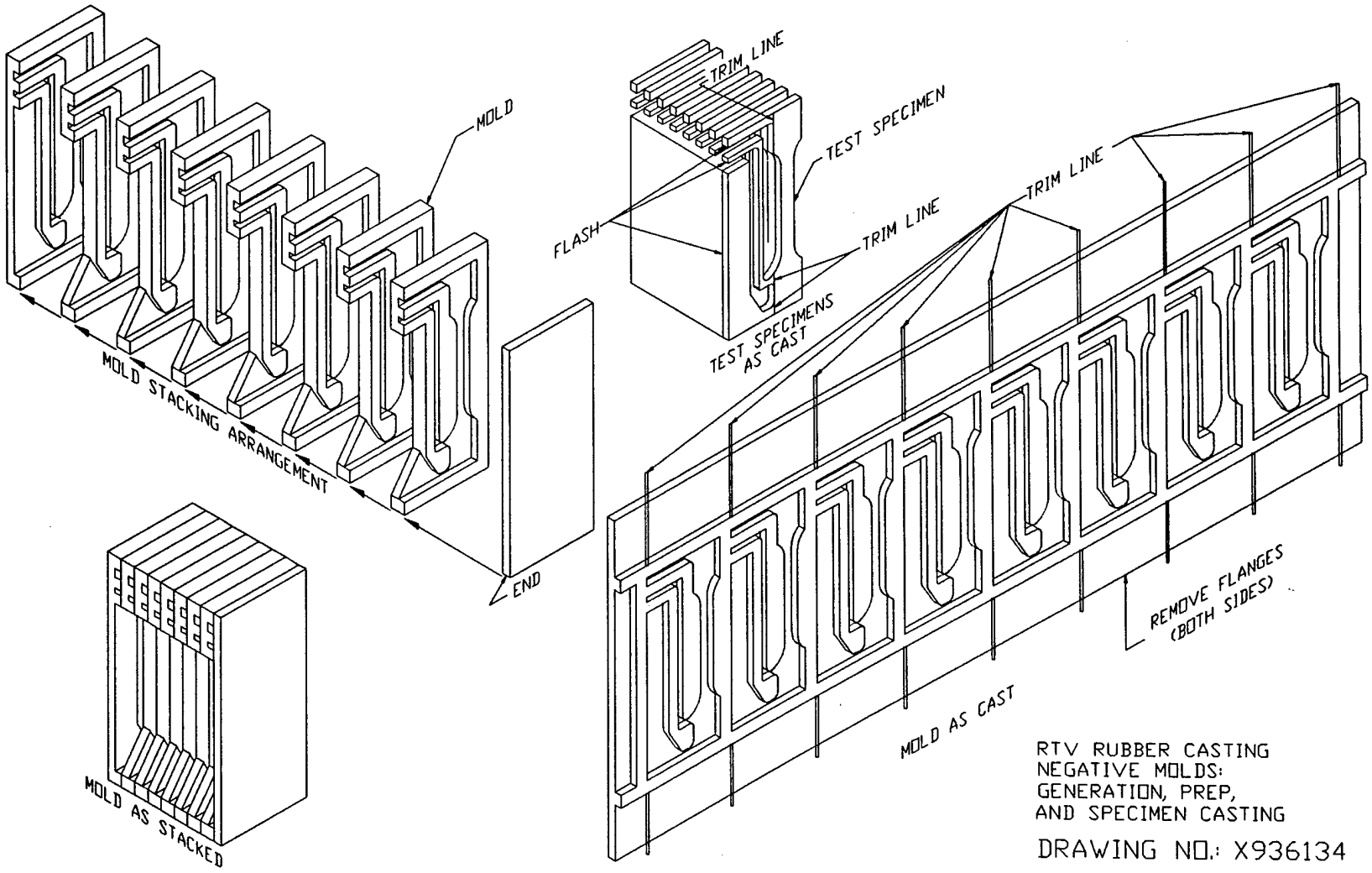


Figure 12: Rubber Molds: Preparation And Stacking

the specimens. The burrs would also become initiation points of failure, due to their modification of the stress fields in the material, and so cause an even greater scatter in the measured strength data. This was unacceptable, as testing neat resins is intrinsically very difficult without this complication. To overcome this problem the PI designed and built an overpressure vault out of plexiglas. Its specifics are described in Table 3. This overpressure vault was placed over the freshly cast rubber, completely encasing it. Bone dry nitrogen, delineated in Table 3, was blown into the vault and deflected uniformly throughout the volume of the vault by strategically positioned baffles. It was allowed to escape from the vault along the crack line where the vault's bottom surface met the support structure's surface. By regulating the volumetric flow of the nitrogen up to a substantial amount, the generation of and resulting number of pock marks was adequately suppressed; though never totally eliminated. The identification, evaluation, solution determination, and final recovery from this problem required seven work months to achieve and delayed the overall effort commensurately.

Beginning with Run 79 and continuing on through most of the ensuing runs up to Run 102, large numbers of individual specimens were rendered mechanically untestable because of the presence of numerous bubbles in their gage lengths and neck downs. For the fifteen runs not listed in any of the data tables in this report, so many specimens were rendered untestable that those runs were completely unusable. These runs show up as gaps in the run numbering. This problem also resulted from the previously mentioned unannounced change in the Trade Secret formulation of GE's RTV-664 to meet VOC emissions standards enacted by the State Of California in 1989. The physical manifestation of this change took many forms. First the cast sheets of the rubber, which previously had an almost mirror surface, had a series of blotches that resembled the marks left behind by a slowly drying up solvent. This indicated that a formulation change had been made to substitute a substantially less volatile solvent for a highly volatile solvent. Also the as cast rubber sheets were substantially less rigid than the previously generated sheets. This loss of rigidity is usually the result of the incorporation of plasticizers or a substantial skewing of the polymer's molecular weight distribution towards the lighter molecular weight species. Either action would result in the evolution of gas from the molds during the epoxy resin system's elevated temperature cure. This gas would result in the creation of bubbles in the cured resin. To overcome this the plasticizer or light ends were driven out of the

rubber molds by boiling them for 16 hours in double distilled water and then baking them at 395°F (202°C) for 96 hrs. This resulted in a temporary solution to the bubbles problem. A sufficient number of specimens cast in just such prepared molds were created during the first use of these molds to allow for that run to be usable. Unfortunately the second usage of these molds did not generate a sufficient number of testable specimens and further runs were even worse. The bubbles in these sequential runs had to be derived from gas that was either more intensely dissolved in the so processed rubber or that had simply collected in pockets left in the rubber from the evolution of the plasticizer or light ends. To overcome this the PI heated each set of molds to 400°F (205°C) and cooled them down under a vacuum just prior to their being used to cast specimens. This worked: a sufficient number of specimens were generated in every subsequent run after Run 102. The identification, evaluation, solution determination, and final recovery from this problem required eleven work months to achieve and delayed the overall effort commensurately.

Elevated Temperature Curing

Ovens and Mold Clamps

The resin systems used in this effort required exposure to elevated temperatures for many hours in order to be fully (ie 99+ percent of theoretical maximum) cured. To accomplish this, elevated temperature curing equipment needed to be fabricated that allowed this to take place between the poles of the electromagnets. This equipment needed to be designed and built so that it would not thermally modify the temperature sensitive electromagnets. If it did, then the strengths of the magnetic fields they generated would be shifted. It also needed to be designed and built so that it would not directly modify the strengths of the magnetic fields that the cast epoxy resin system's specimens experienced. To meet the above requirements various pieces of equipment such as oven like structures, rubber mold stack gripping apparatus, heat generation devices, and means to transport that heat to the epoxy resin system to cure it were needed.

Two generations of matched ovens and gripping assemblies were designed, assembled, and used by the PI for this effort. The first generation was designated Type 1; the second Type 2. Both ovens and gripping assemblies were

fabricated from very low magnetic susceptibility materials that did not measurably modify the strength of the magnetic fields that the curing specimens experienced. The ovens required insulation on their sides and bottoms so as to render them safer to work with, easier to control, and less taxing on the heat generation devices. On the sides of the ovens was a 0.25 in thick layer of fiber glass felt. This glass insulator on the vertical sides of the ovens is effectively a zero magnetic susceptibility material and it does not modify the strength of a magnetic field experienced by the curing specimens.

The ovens were also thermally isolated from the electromagnets by a series of insulators. This was done so as not to heat up the electromagnets beyond their ability to compensate for that heat and subsequently skew the strength of the magnetic fields that they were generating. The fiber glass felt insulation on the outsides of the ovens reduced their surface temperature down to roughly $140^{o}F+/-25^{o}F$. Completely surrounding the ovens in all areas, except those zones immediately parallel to the pole faces on the electromagnets, was a gap of air that also served as a thermal insulator. The ovens were bolted to the stands upon which the magnets were anchored. This forced their position and subsequently the position of the specimens cast within them to be repeatably set relative to the entire magnetic field generation and mapping system. It also conducted any heat from the oven's bottom and feet, through the anchoring bolts, and shunted it primarily into the stands and not into the electromagnets. As a result of these precautions the outer surfaces of the electromagnets experienced a temperature rise from the radiated heat of the ovens of no more than $15^{o}F$ and the coolant leaving the electromagnet registered a barely measurable rise of no more than $5^{o}F$. The constant current power supplies of the electromagnets were more than capable of compensating for the resistivity increase in the electromagnet's coils resulting from this temperature rise and maintain current and magnetic field strengths constant.

The mold stacks require an external gripping assembly to achieve a series of necessary end results. This gripping assembly consists of two plates, connecting rods, spacers on the rods between the plates, a series of fasteners, and compression springs. The prime function of the gripping assembly is to compress the individual rubber casting cavities together so as to seal the mold pieces together without distorting the shape of the dogbone casting cavities. For this experimental effort the second function of the gripping assembly was to accurately locate and

maintain the location of the dogbone casting cavities through out an experimental run. This was required to exactly determine the zone in the magnetic field that the specimens were cast in for that field's later measurement and mapping. The third function of the griping assembly was to compensate for thermally induced dimensional changes in the rubber molds while simultaneously accomplishing all of its other functions. The gripping assembly needed to be able to expand and contract as the rubber molds did in a predictable fashion so as to not induce a twist or deformation into the cast specimen's shape and to keep the zone of magnetic field mapping down to a minimum.

The the mold pack is the result of the incorporation of the mold stack into the gripping assembly. Figure 13 depicts a fully assembled Type 2 mold pack and an exploded drawing of the same. Both Type 1 and Type 2 gripping assemblies (clamps) used the same connecting rods, spacers on the rods between the plates, a series of fasteners, and compression springs. Table 3 delineates the specifics of these subcomponents. Figure 14 depicts the dimensions and configuration of the compression springs. These were wave type compression springs and they were designed to provide a gentile compression force on the mold pack over a large range of travel in a small space. Figure 15 depicts the dimensions and configuration of the spacer. All of these subcomponents were fabricated out of the effectively zero magnetic susceptibility materials delineated in Table 3. Therefore their presence near the mold stack would not measurably distort the strength of the magnetic field that the curing resin system would be exposed to.

The Type 1 oven and the Type 1 clamp were used in those twenty-nine runs in which eight exposed and eight control specimens were generated. Table 3 delineates the specifics associated with them. Figure 16 is a drafting of the oven. It was made from 304 stainless steel. 300 series stainless steels do, over time take on a slight ferromagnetic set, but since the zone of the magnetic field of experimental interest was inside the oven and could be mapped with the oven in place this set was tolerated. Figure 17 is a drafting of the clamp plates used in a Type 1 mold pack. It was made from 6-6-2 Titanium, which at the use conditions is effectively a zero susceptibility material.

There were a series of problems with the Type 1 combination's use. First it was very difficult to match and stabilize the temperature of the exposed Type 1 oven with a Type 1 mold pack inside it to that of a companion

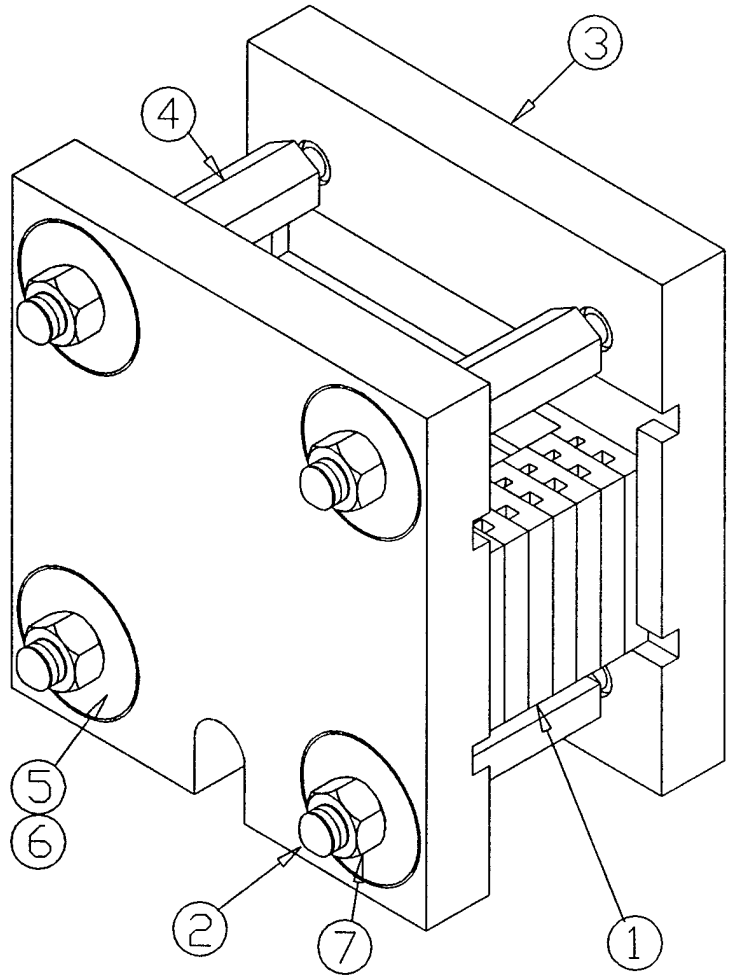


Figure 13: Mold Pack: Assembly

PARTS LIST:
1. Mold Pack X936134
2. Four 1/4-20 UNC By 3.000" Long Brass All Thread Rods
3. Two Type 2 Mold Clamp Plates X936159
4. Four Brass Spacers
5. Sixteen Spirawave, Gap Type, Wave Springs
6. Sixteen Brass Flat Washers ID 0.395" By OD 0.875" By 0.050" Thick
7. Eight 1/4-20 UNC Full Brass Nuts

TITLE: MOLD PACK ASSEMBLY

DRAWING NO.: X936158

DRAFTSMAN: BOCOCK, B DATE: 5 NOV 93

ENGINEER: GERZESKI, R DATE: 21 JAN 94

TOLERANCES: .XX"+/-0.03"
.XXX"+/-0.010"

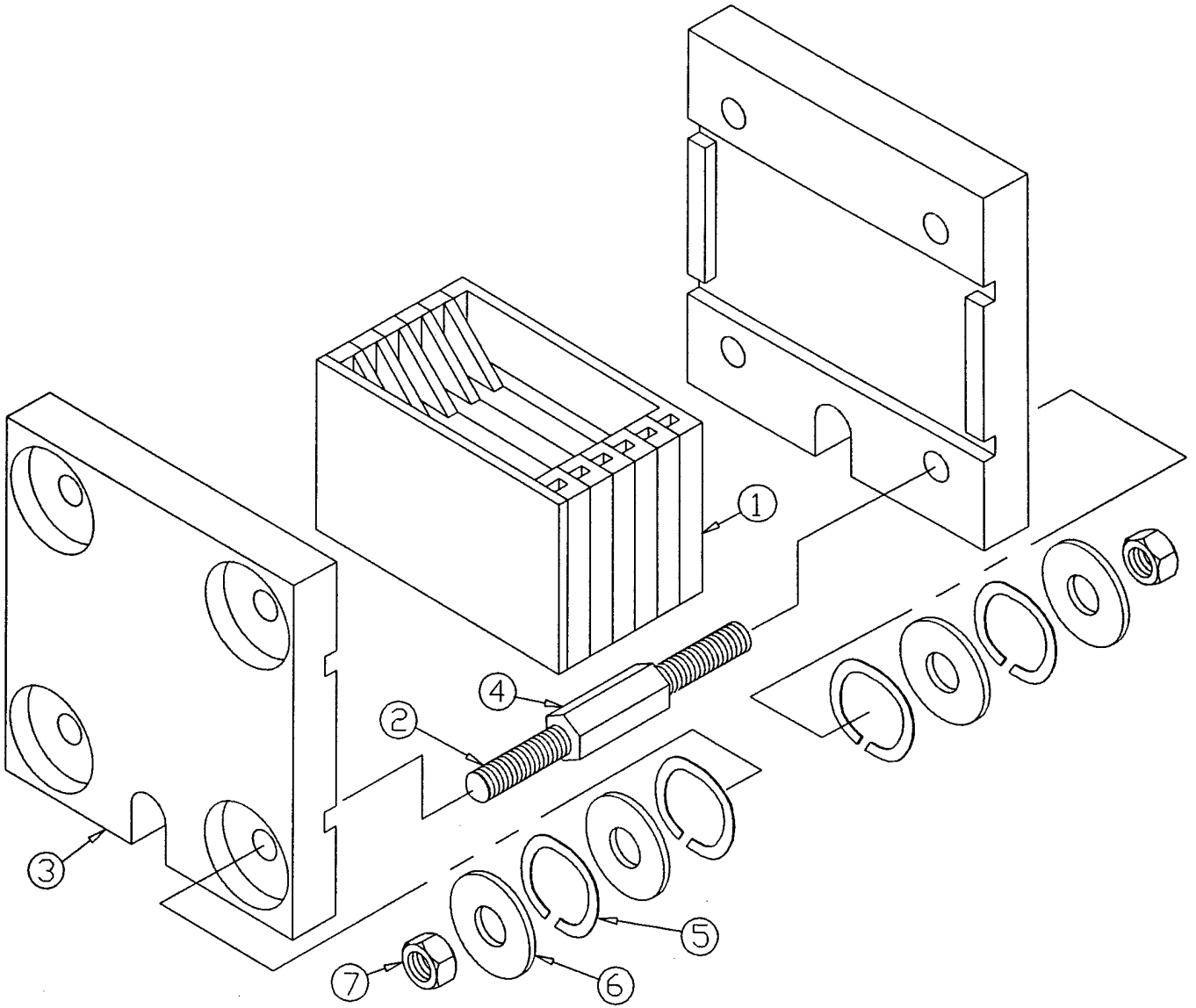
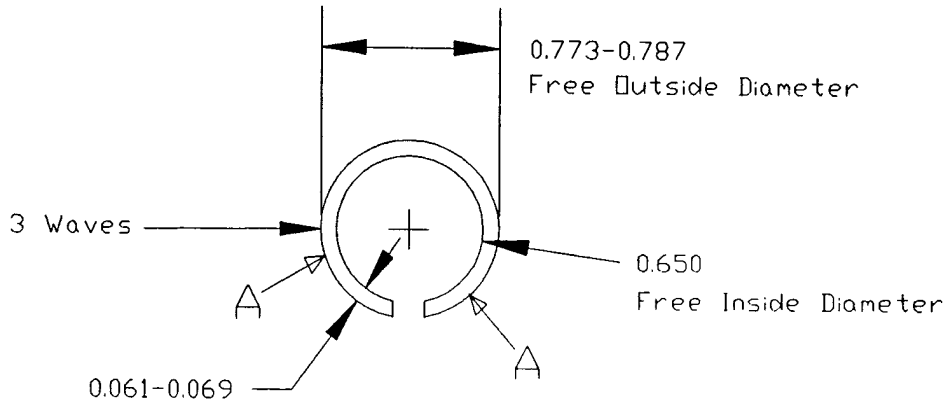
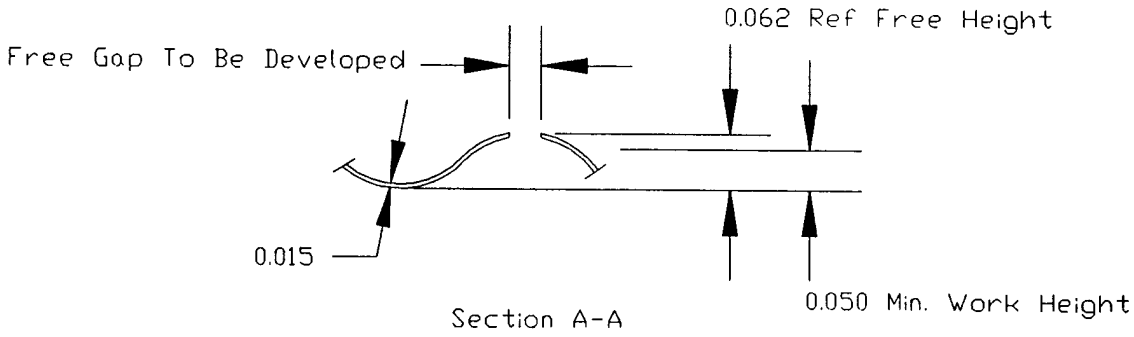


Figure 13: Mold Pack: Assembly: Exploded View; Continued



Approving Engineer:
Roger H. Gerzeski
Approval Date:
23/03/92

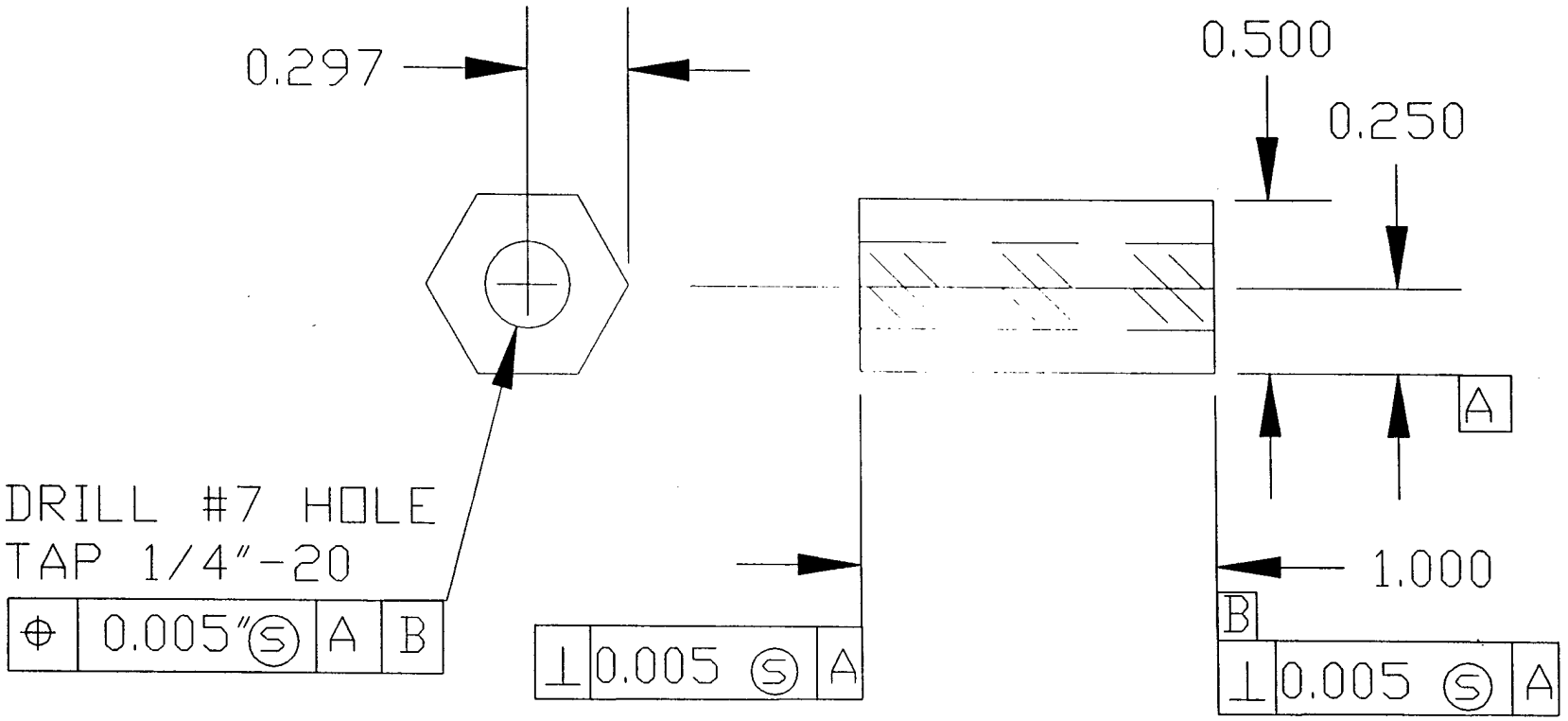


Notes:

1. Material Of Construction: Spring Temper Inconel X-750
2. Prep: 4 Hours In Oven Air At 1200 F
3. Clean: Vapor Degrease & Ultrasonic Clean

Drafting Date: 3-18-92

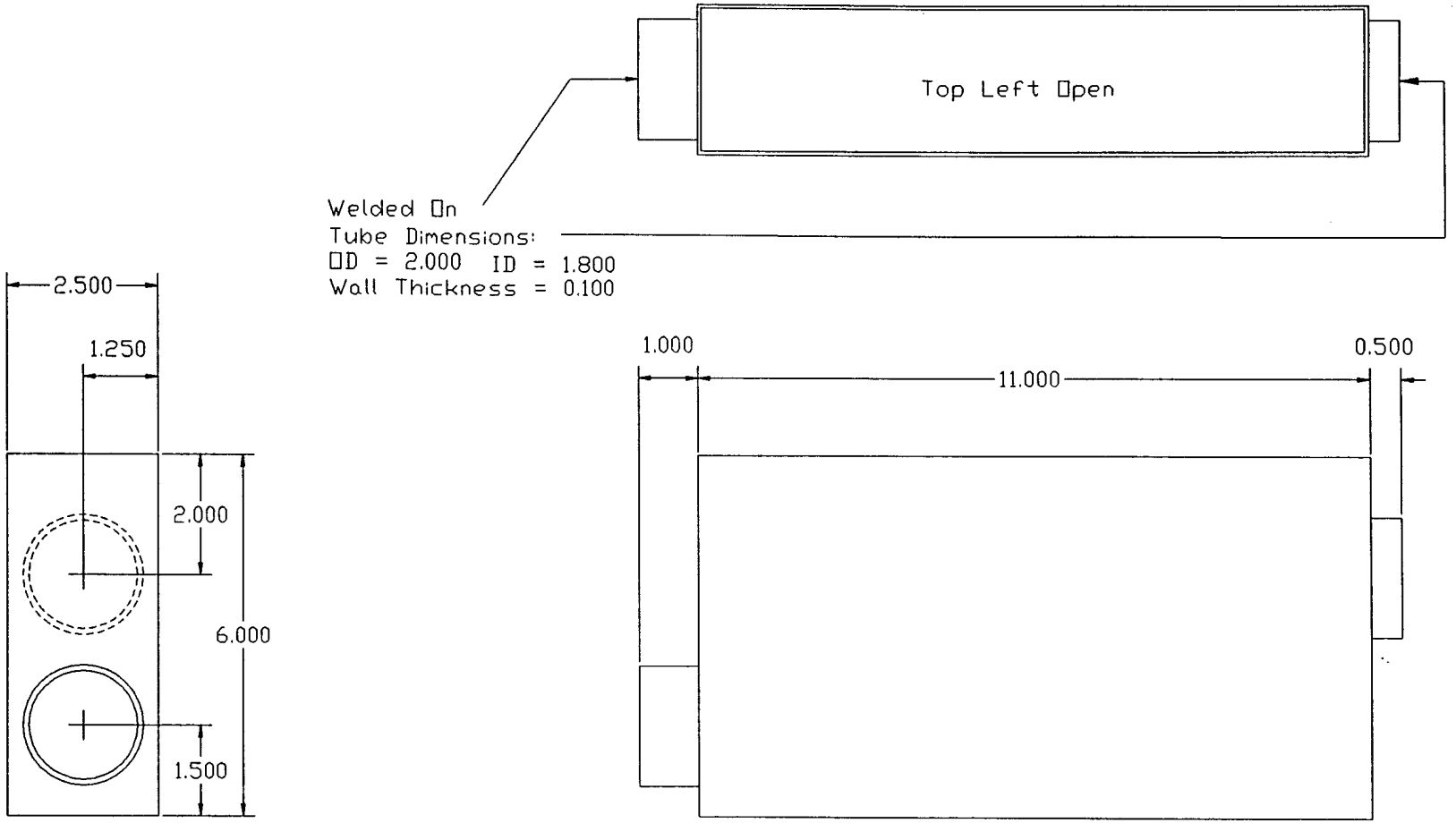
Figure 14: Mold Pack: Compression Spring: Spirawave, Gap Type



Material Of Construction:
1/2 Inch Brass Hex Stock

Tolerances: X.XXX" +/- 0.010
Engr/Draftsman: Roger H. Gerzeski
Date: 4 Feb 91

Figure 15: Mold Pack: Spacer



Notes:

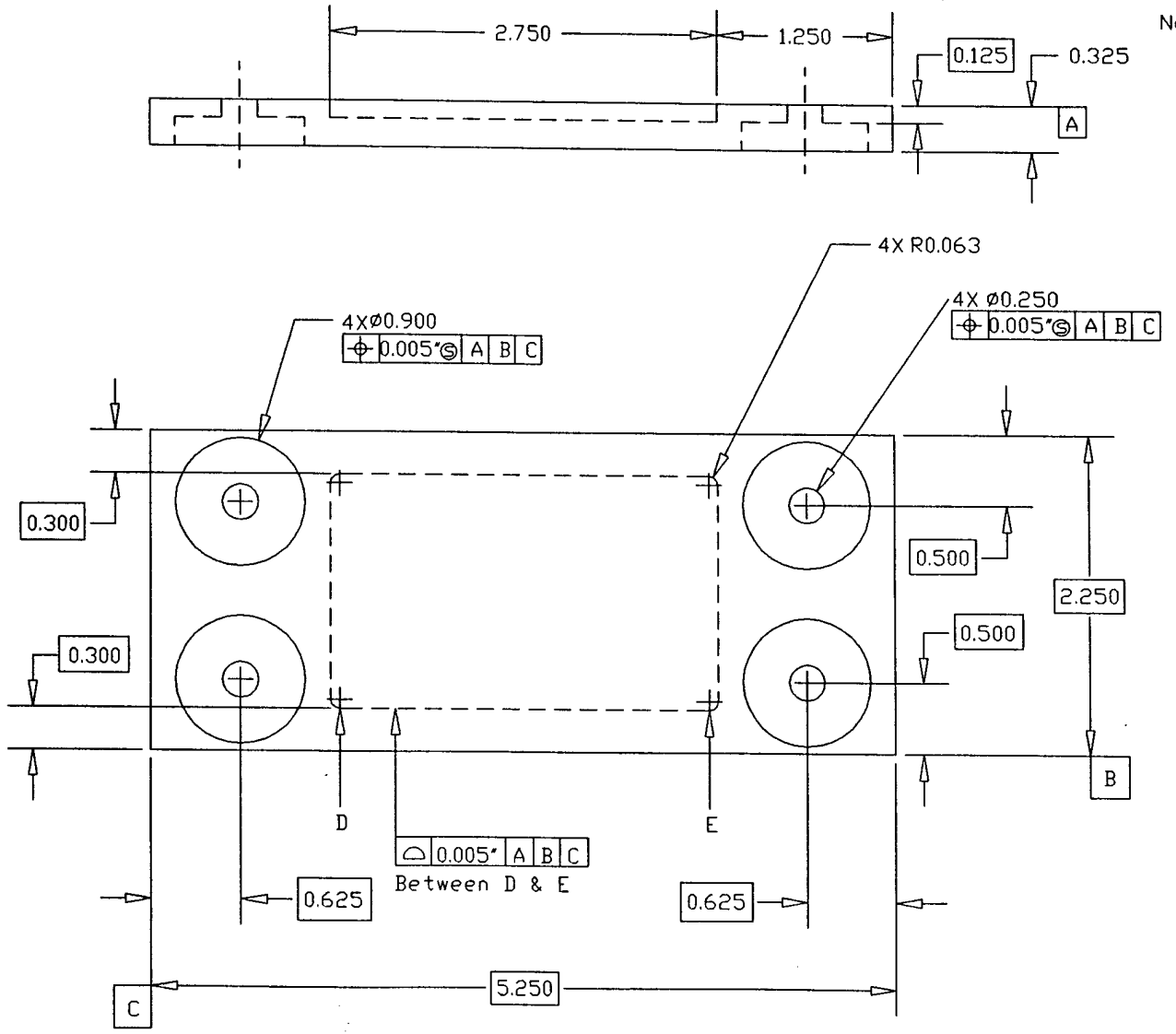
1. Continuous Air Tight Weld the Two 6.000" By 11.000" Sides To The Two 2.500" By 6.000" Sides And All Four Of These Sides To The 2.500" By 11.000" Bottom Plate.
2. The Top Of These Boxes Are To Be Left Open.
3. Continuous Air Tight Weld The 1" and 1/2" Long By 2" OD Tubes To Their Respective 2.500" By 6.000" Sides.

Material Of Construction: 0.063" Thick Stainless Steel Plate
Stainless Steel Tube

Designer/Draftsman: Ernie Butler
Tolerances: X.XXX +/- .0.010"

Date: Feb 1992

Figure 16: Type 1 Oven



Note: Interpret Drwg Per:
ANSI Y14.5M-1982

Material Of Construction:
Ti 6-6-2
Tolerances:
X.XXX" +/- 0.025"
Engineer/Draftsman:
Roger H. Gerzeski
Date:
26 Apr 92

Figure 17: Mold Pack: Type 1 Mold Clamp Plates

identical control Type 1 oven with a Type 1 mold pack in it. It would often require a full day and occasionally up to four days of continuous effort to get the two Type 1 ovens to hold the same temperature over a time span approaching that of an experimental run. Second during an experimental run, the temperatures of the mold packs within the paired ovens had to be continuously monitored and adjusted by tweaking the bone dry nitrogen flow rates and or the power settings on the two gas heaters, as the two tended to steadily drift off in two directions at two different rates. Third the Type 1 mold pack rode on an inverted U pedestal and over the duration of the experimental run it would, from contractions and expansions in the rubber that it contained, shift its position randomly in the oven by up to 0.25 in. This resulted in the necessity of substantially expanding the zone of the magnetic field that required mapping and reducing the accuracy of the reportable magnetic field strength under which the run was generated. Along with this random walk, no provision was made in the design and or fabrication of these Type 1 ovens and clamps to accurately and repeatably position the Type 1 mold pack in the Type 1 oven. This resulted in an additional inaccuracy and a subsequent expansion of the zone requiring mapping.

To resolve the problems associated with the Type 1 ovens and their companion Type 1 clamps the Type 2 ovens and companion Type 2 clamps were designed. Table 3 delineates the specifics associated with them. Figure 18 is a drafting of the oven with a Type 2 mold pack in it. All of the subcomponents to the Type 2 oven were made from effectively zero magnetic susceptibility materials. It was primarily made out of aluminum with brass fasteners, and Inconel X-750 main side walls. Figure 19 is a drafting of the clamp plates used in a Type 2 mold pack. It was made from 6-4 Titanium, which at the use conditions is effectively a zero susceptibility material. The Type 2 ovens and the Type 2 clamps were used in those eight runs in which ten exposed and ten control specimens were generated.

The Type 2 style oven and clamp set up resolved all of the thermal problems exhibited by the Type 1 set up. This was accomplished by primarily directing the flow of the gas heating medium directly into the bottom of the mold stack in the mold pack instead of splitting the flow around, above, and below it and even shunting some of it completely away from it as was done in the Type 1 set up. Also the Type 2 set up did not require the intense temperature control oversight during an experimental run that the Type

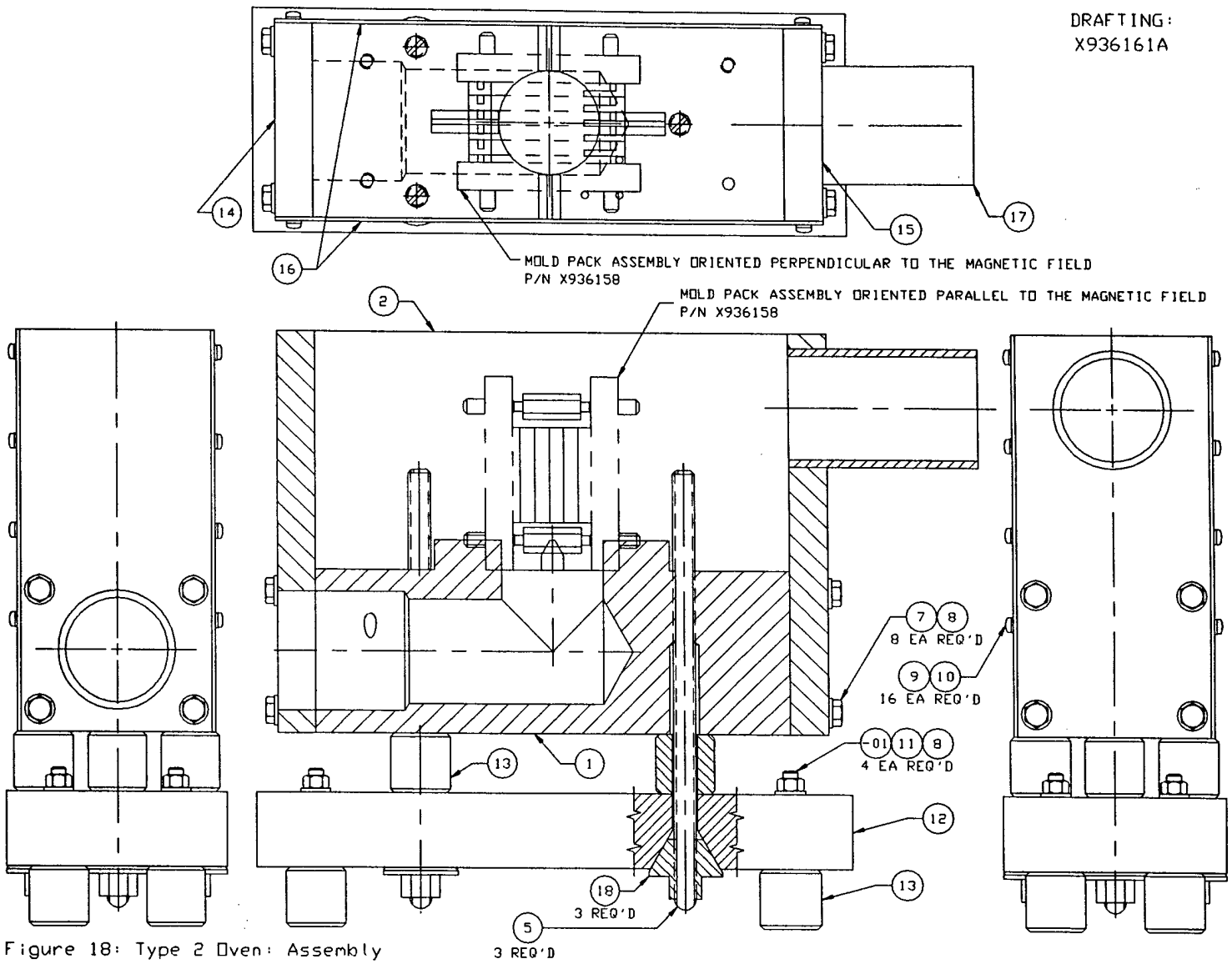


Figure 18: Type 2 Oven: Assembly

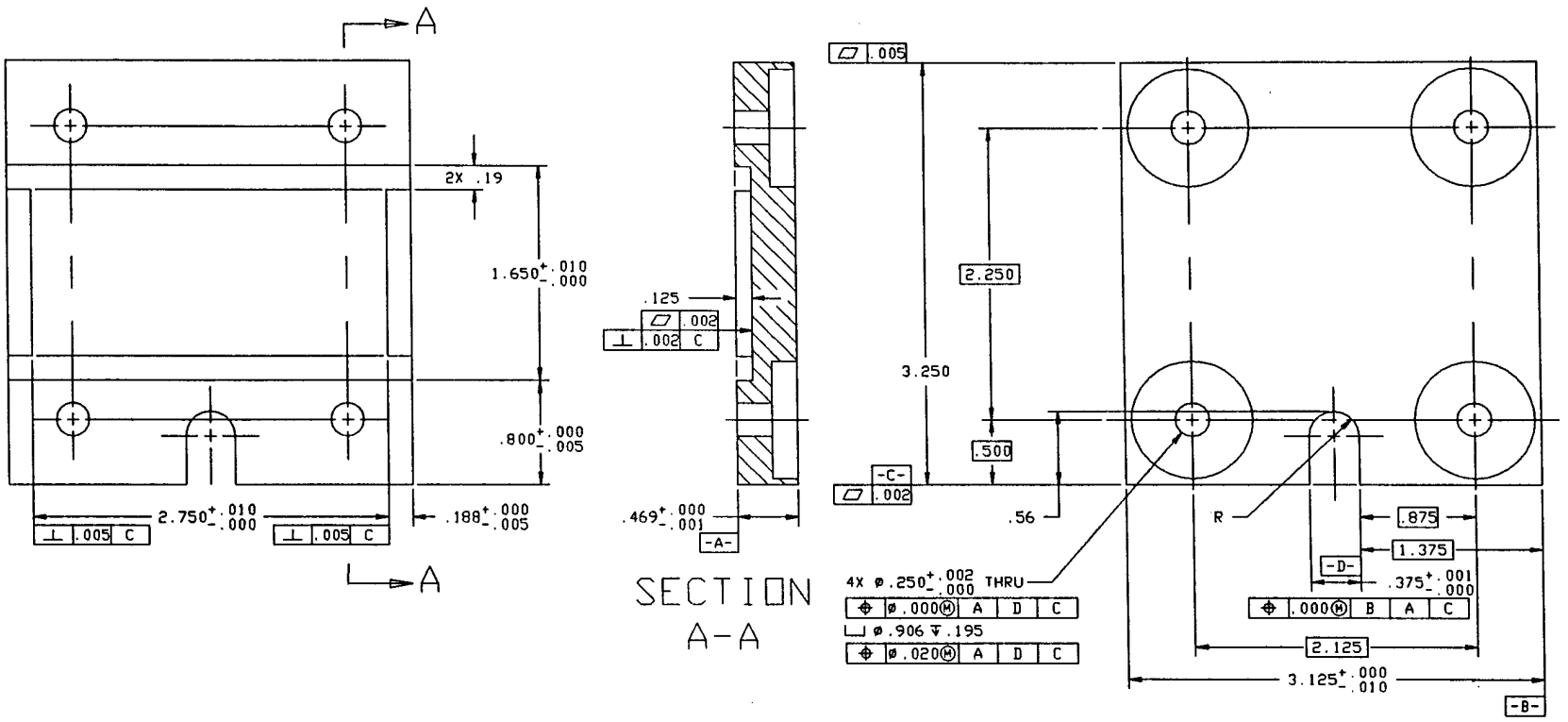
REVISIONS		
REV	DESCRIPTION	DATE
A	-10 CONFIG. ADDED	12MAY94

3		NUT, TAPERED	X947154		18
1		TUBE, OUTLET	X947135		17
2		SIDE PLATE, OVEN	X947134		16
1		END R.H., OVEN	X947133-03		15
1		END L.H., OVEN	X947133-01		14
A/R		SPACER	X947132		13
1		PLATE, SUPPORT	X947131		12
4		NUT	MS51970-1	.250-28 UNF	11
16		SCREW, PAN HD	MS35214-42	.164-32 UNC X .50 BRASS	10
16		WASHER, FLAT	NAS1149 B N832	#8 BRASS	9
	8	WASHER, FLAT	NAS1149 B 0463	.250 BRASS	8
8		SCREW, CAP-HEX	MS35309-308	.250-20 UNC X 1.00 BRASS	7
	4	SCREW, CAP-HEX	MS35309-303	.250-20 UNC X .50 BRASS	6
3		JACKSCREW	X936166		5
	1	SUPPORT, R.H.	X936165		4
	1	SUPPORT, L.H.	X936164		3
	1	SIDE, OVEN	X936163		2
1		BLOCK, OVEN	X936162		1
4		STUD	-01		
1		ASSEMBLY	-30		
	1	ASSEMBLY	-10		
-30	-10	NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION	FIND NO.

QUANITY REQUIRED — PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 .XXX±.010 ±0°15'	ENG GERZESKI, R 1 JUN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR. BOCOCK, B 10DEC93	TITLE OVEN, CURING ASSEMBLY
	H5	DRAWING NO. X936161 A

Figure 18: Type 2 Oven: Assembly: Notes, Continued



NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

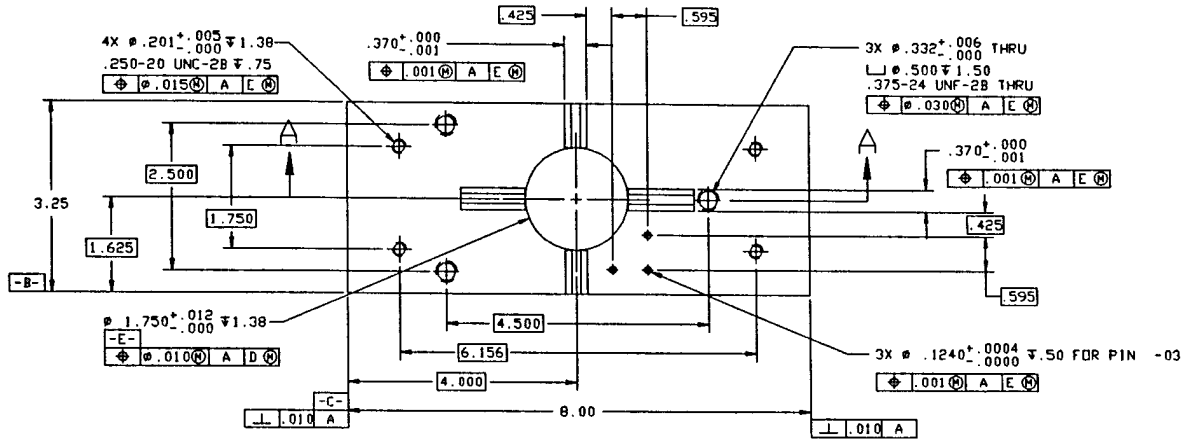
2	SIDE PLATE	TI 6-4 TITANIUM .50 PLATE
QTY REQD	NOMENCLATURE	MATERIAL / SPECIFICATION
	PARTS LIST	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG GERZESKI, R 9 JAN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 22OCT93	TITLE CLAMP PLATE MOLD PACK
	H5	DRAWING NO. X936159

Figure 19: Mold Pack: Type 2 Mold Clamp Plates

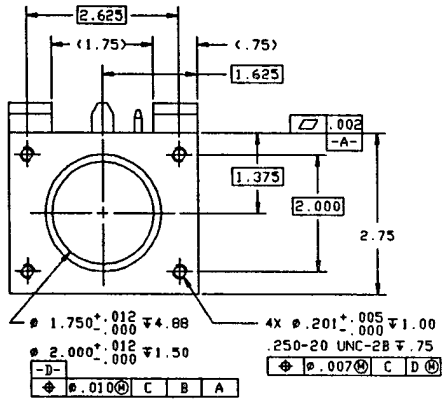
1 set up did. This was due to the larger amount of material comprising the Type 2 oven. This larger mass of material made changes in the oven's and the mold pack's temperatures far more gradual and so easier to control.

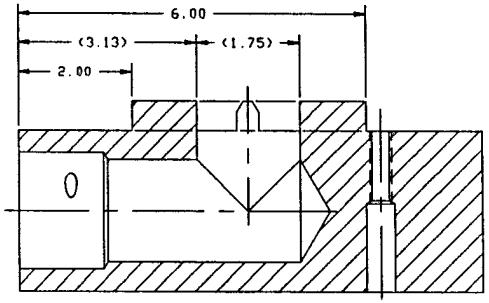
The Type 2 ovens and mold packs were specially designed to exactingly control the initial position and direct the mold stack induced expansion and contraction travel of the mold pack. This was accomplished by machining alinement slides and press fitting alinement pins into the main base block of the oven and cutting slide notches into the clamp plates. Figure 20 is a drafting of the ovens main base block and clearly delineates these machined slides and pins. Figure 19 clearly describes the cut notches in the clamps. By mating the cut notches of the mold clamps to the machined slides on the oven blocks and by placing the mold clamp plate between the press fit alinement pins and over the machined slides as depicted in Figure 18 the initial position and movement of a mold pack could be controlled. The alinement slide, cut grove, and pins rigidly held one of the mold pack's clamping plates in one initial position as seen in Figure 18. While this plate was being anchored the other plate of the mold pack was free to slide along the machined ridges in the oven block to compensate for the mold stacks expansion and contraction. Overall this arrangement anchored one plate to within a small and repeatable position, certainly less than +/- 5 mils, and rigidly constrained the range which the remainder of the pack moved to within a measurable discrepancy of +/- 5 mils along the specimen axis and +/- 25 mils along the mold pack's compression/expansion axis.

Both oven types required lids to seal off their tops, which as Figures 16 and 18 show were not designed and or built with metal lids. These lids needed to meet certain requirements. First, they needed to withstand the thermal cycling of the ovens. Second, they needed to be able to redirect the naturally rising heating fluid medium to its designated exit port. Third, they needed to be handy to manipulate so as to be easily placed on and or removed from the ovens. Fourth they needed to be made of a material which would not, even from its rather removed location to the mold packs, modify the strength of the magnetic fields that the curing specimens experienced. Lastly it needed to be transparent so as to be capable of providing visual access to the oven throughout its operation. Pyrex plate was used as the lid material for all of the ovens. Its specifics are listed in Table 3. It met all of the above requirements. To meet the handiness and flow redirection

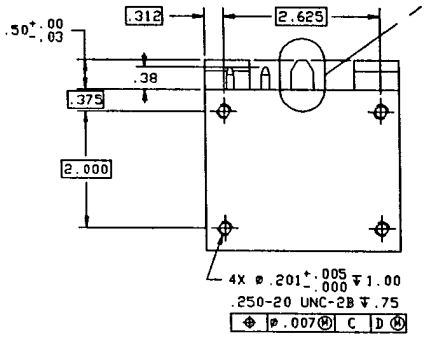


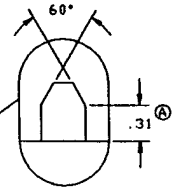
REVISIONS		
REV	DESCRIPTION	DATE
A	DIM VAS .25	25JAN94



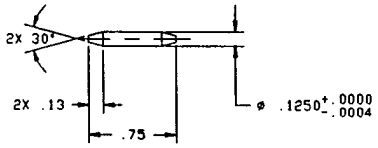


SECTION A-A





DETAIL
4 PLACES
SCALE 2:1



-03 PIN DETAIL
SCALE 2X

NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
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4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

QUANITY REQUIRED	NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION
3	PIN	-03	QQ-S-763 304 STN STL
1	BLOCK	-01	QQ-A-200/8 6061-T651 AL
	ASSEMBLY	-10	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG GERZESKI, R 10 APR 94	U.S. AIR FORCE PHILLIPS LAB. / ERWARDS AFB, CA.
	DR BOCOCK, B 10DEC93	TITLE OVEN BLOCK CURING OVEN
	H5	DRAWING NO. X936162 A

Figure 20: Type 2 Oven, Block

requirement a cork like bevel was ground on the bottom edges of the plate allowing it to seat into the mouth of an oven naturally.

Heaters And Heat Transfer

To fully cure a resin system it needs to be heated to an elevated temperature for many hours. Unfortunately many of the standard techniques used to heat ovens and their contents where not usable in this experimental context. A common technique used to heat ovens is resistive heating. This technique is completely unusable in a magnetic field. The current flowing through the resistive heating coils would be very forcefully acted upon by the magnetic field during its start up sequence. Due to a combination of Lenz's Law and Faraday's Law, the resistive heating coils would be both electrically burned out by the extremely large current pulse flowing through them and the oven itself would probably be ejected from the space between the poles. Another technique consists of burning a combustible fluid to directly heat the gas in the oven. This was rejected for safety reasons. Another technique involved the usage of a heat transfer fluid. With this technique a fluid would be heated outside of the influence of the magnetic field and transported into the ovens to subsequently heat the mold packs and thermally cure the resins cast within them. This technique was used in all of the experimental runs of this effort.

The heat transfer fluid used was bone dry nitrogen gas. The specifics associated with it are listed in Table 3. The bone dry nitrogen gas was used to assure that the cured resins would not be contaminated with any foreign matter, particularly water, borne into the ovens by the heat transfer fluid. It also provided a medium that would absorb any dissolved gases or compounds that were initially in or generated by the curing resin system and transport them away from the curing resin.

A one pass system was used in which the nitrogen heat transfer fluid would be heated, then transported to the ovens, where it would heat up the mold packs and the resins within them, and then be dumped into the surrounding atmosphere. This one pass system was selected because it provided the simplest system to fabricate, operate, and control. It also facilitated the removal of undesirable substances from the curing resin by constantly using clean heat transfer fluid and not a fluid that was steadily

becoming more concentrated with contaminants with each new pass. Its one drawback was that it used a substantial quantity of nitrogen gas during each run.

Leister-Hotwind <<S>> gas heaters were used to heat the nitrogen heat transfer fluid. Their specifics are listed in Table 3. A single feed of bone dry nitrogen gas was expanded and had its pressure reduced from the supply pressure to roughly atmospheric. It was fed to the heater and heated. The heated gas was then transported via flexible 2 in ID stainless steel tubing and specially designed couplers from the heater to the exposed and control ovens. One heater was used in early runs and the heated gas was split into two streams one going to the exposed and one to the control oven. This approach was abandoned when it became apparent that with each subsequent run the volume of gas being delivered to each oven was steadily and uncontrollably drifting away from being roughly equal. To resolve this an independent heater and gas delivery system was built for each oven: both exposed and control. A single feed of nitrogen gas was still used to provide the heat transfer fluid for both ovens but this feed was split into two streams by a manifold with pressure regulators before it was fed to the two independent heaters. With these two heat transfer fluid heating and transport systems it was possible to both regulate the volume and temperature of the gas delivered to each oven. This control made it far simpler to regulate both the oven's and the mold pack's temperatures during an experimental run and to stabilize and equalize the exposed set to its companion control set before a run.

Cure Profile

Each resin system used in the various experimental runs was cured according to a particular temperature profile. These desired profiles are described in Table 8. The extreme effort invested in the design, fabrication, and operation of the ovens, mold packs, heaters, and fluid heat transfer systems made possible the degree of temperature control needed to bring about these cure profiles. In general the cure profiles used in all of the experimental runs started out with the resin system being cast into both exposed and control molds at roughly room temperature. Bone dry nitrogen gas was already flowing through the transport piping system and through the ovens as the resin was cast. The heaters were then turned on to a pre-determined setting. The resin mold pack temperatures, the temperature of the heated nitrogen gas feed to the oven,

TABLE 8: CURE PROFILE

RUN	Cure Profile
65	300°F (149°C) for 4 Hrs, Heated From Initial Temp*
66	300°F (149°C) for 4 Hrs, Heated From Initial Temp
67	250°F (121°C) for 5 Hrs, Heated From Initial Temp
68	250°F (121°C) for 5 Hrs, Heated From Initial Temp
69	250°F (121°C) for 5 Hrs, Heated From Initial Temp
70	250°F (121°C) for 5 Hrs, Heated From Initial Temp
71	250°F (121°C) for 5 Hrs, Heated From Initial Temp
72	250°F (121°C) for 5 Hrs, Heated From Initial Temp
73	250°F (121°C) for 5 Hrs, Heated From Initial Temp
74	250°F (121°C) for 5 Hrs, Heated From Initial Temp
75	250°F (121°C) for 5 Hrs, Heated From Initial Temp
76	250°F (121°C) for 5 Hrs, Heated From Initial Temp
77	210°F (99°C) for 20 Hrs, Heated From Initial Temp
78	210°F (99°C) for 20 Hrs, Heated From Initial Temp
81	250°F (121°C) for 5 Hrs, Heated From Initial Temp
87	250°F (121°C) for 5 Hrs, Heated From Initial Temp
90	250°F (121°C) for 5 Hrs, Heated From Initial Temp
91	250°F (121°C) for 5 Hrs, Heated From Initial Temp
94	250°F (121°C) for 5 Hrs, Heated From Initial Temp
95	250°F (121°C) for 5 Hrs, Heated From Initial Temp
97	250°F (121°C) for 5 Hrs, Heated From Initial Temp
99	250°F (121°C) for 5 Hrs, Heated From Initial Temp
101	250°F (121°C) for 5 Hrs, Heated From Initial Temp
103	250°F (121°C) for 5 Hrs, Heated From Initial Temp
104	250°F (121°C) for 5 Hrs, Heated From Initial Temp
105	250°F (121°C) for 5 Hrs, Heated From Initial Temp
106	250°F (121°C) for 5 Hrs, Heated From Initial Temp
107	250°F (121°C) for 5 Hrs, Heated From Initial Temp
108	250°F (121°C) for 5 Hrs, Heated From Initial Temp
109	250°F (121°C) for 5 Hrs, Heated From Initial Temp
110	250°F (121°C) for 5 Hrs, Heated From Initial Temp
111	250°F (121°C) for 5 Hrs, Heated From Initial Temp
112	250°F (121°C) for 5 Hrs, Heated From Initial Temp
113	250°F (121°C) for 5 Hrs, Heated From Initial Temp
114	250°F (121°C) for 5 Hrs, Heated From Initial Temp
115	250°F (121°C) for 5 Hrs, Heated From Initial Temp
116	250°F (121°C) for 5 Hrs, Heated From Initial Temp

* The phrase "Heated From Initial Temp" means that the resin was "Heated Up From An Initial Temperature Corresponding To The Minimum Overall Cure Temperature Recorded For This Run".

and the temperature of the gas as it passed over the mold were all measured using type E thermocouples and recorded on an Esterline-Angus data recorder. The specifics associated with these pieces of equipment are listed in Table 3. The temperature of the mold packs was then allowed to naturally rise to a selected operational temperature. Type 1 ovens and mold packs usually required about 30 minutes to heat up to roughly 250^{o}F; Type 2 ovens and mold packs usually required about 40 minutes to do the same. The mold packs were then attempted to be maintained within +/- 10^{o}F of the predetermined curing temperature and the temperature of the exposed and control mold packs associated with any particular run were also maintained within +/- 10^{o}F of each other. To achieve this temperature control the power settings on the gas heaters were tweaked and the gas flow rate was tweaked through out the experiment. At the end of the pre-determined elevated temperature cure profile the heaters were powered down and the unheated nitrogen gas was allowed to flow over the mold packs to cool them. This cooling usually required 45 minutes.

Through out the entire forced heating sequence of the cure section in each of this effort's experimental runs, temperature measurements using type E thermocouple wires were made at the bottom of the feed trough in the exposed and the control mold stacks for each run. This temperature sampling point was arbitrarily decided by the author to be the temperature of all of the curing resin at any particular sampling time. These temperatures were sampled and stored on an Esterline-Angus data recorder, as were all of the other temperatures taken in this effort, every 10 minutes, at the start of an experimental run (ie just after the resin was cast), at the powering down of the heaters during an experimental run, and when ever the PI arbitrarily determined the need for a temperature reading to make a decision. The maximum and the minimum temperature experienced by a thermocouple were also recorded by the Esterline-Angus. Statistics were generated with all of these temperature readings for the curing resins in the exposed and the control for each experimental run in this effort. Their averages, their standards of deviation (STDS), and their extremes are tabulated in Table 9.

In addition to specific cure temperature statistics, a measure of exactly how well the temperature of the exposed mold pack for any particular run was maintained relative to the temperature of its corresponding control mold pack was determined. For each run at each temperature sampling

time the difference between the exposed mold pack's temperature and the control mold pack's temperature was determined. This was defined by the PI to be the "delta". The average, the stds, and the extremes associated with these delta for each experimental run were also determined. They are also tabulated in Table 9.

All of the statistics associated with the exposed, control, and their relative deltas were determined and tabulated for two different ranges of the cure profile. One set was tabulated for the entire forced heating duration associated with the curing of each experimental run's resin system. These statistics for the actual cure temperature profile experienced by the resin systems cast in each experimental run is tabulated in Table 9 under the column "Overall Cure". Another set was tabulated for the temperatures of the resin's cure profile after that cast resin had attained the pre-selected cure temperature and through to the end of the forced heating section of their cures. These statistics for the actual cure temperature profile of the various experimental run's resins is tabulated in Table 9 under the column "Post Heat-Up To Cure".

An examination of the cure temperature profile statistics associated with each experimental run and tabulated in Table 9 reveals the following. First, all specimens cast in each run, whether exposed or control, experienced a transient temperature spike of up to 65^{O}F higher than the average temperature at which they were intended to be cured. This was due to a partial run away of the curing reaction. It usually occurred just after the resin's temperature had reached the desired overall cure temperature. Nothing could be done with the equipment available to this effort to correct for this transient temperature spike. The resin's temperature usually dropped quickly back to the desired cure temperature and roughly remained there. Second, the vast majority of the curing profile experienced by the resin systems in each experimental run is represented in the column "Post Heat-Up To Cure" in Table 9. As can be seen from those results the average temperature for each mold pack in each experimental run was routinely kept to within +/- 10^{O}F of the desired cure temperature. Also the delta between the exposed and control mold packs for each run through out their entire elevated temperature cure profile were usually within +/- 10^{O}F of each other. Overall the cure temperature profile statistics tabulated in Table 9 decisively indicated that the resin systems cast in the corresponding exposed and control mold packs associated with the various

TABLE 9: CURE TEMPERATURES

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
65 EXPOSED	281+/-60	74	312	[19]	304+/-2	301	312	[16]
	(138+/-33	23	156)		(151+/-1	149	156)	
65 DELTA	4+/-6	-1	+17	[19]	3+/-4	0	+15	[16]
	(2+/-3	-1	+9)		(2+/-2	0	+8)	
65 CONTROL	277+/-62	75	303	[19]	301+/-2	297	303	[16]
	(136+/-34	24	151)		(149+/-1	147	151)	
66 EXPOSED	277+/-58	74	303	[20]	296+/-22	211	303	[17]
	(136+/-32	23	151)		(147+/-12	99	151)	
66 DELTA	-1+/-6	-20	+12	[20]	-3+/-5	-20	+1	[17]
	(-1+/-3	-11	+7)		(-2+/-3	-11	+1)	
66 CONTROL	279+/-59	75	311	[20]	299+/-18	231	311	[17]
	(137+/-33	24	155)		(148+/-10	111	155)	
67 EXPOSED	235+/-44	86	268	[34]	252+/-4	249	268	[28]
	(113+/-24	30	131)		(122+/-2	121	131)	
67 DELTA	-2+/-6	-8	+17	[34]	-4+/-2	-8	+3	[28]
	(-1+/-3	-4	+9)		(-2+/-1	-4	+2)	
67 CONTROL	237+/-49	80	271	[34]	256+/-4	253	271	[28]
	(114+/-27	27	133)		(124+/-2	123	133)	
68 EXPOSED	239+/-46	71	269	[34]	257+/-3	253	269	[28]
	(115+/-26	22	132)		(125+/-2	123	132)	
68 DELTA	1+/-7	-8	+21	[34]	-2+/-3	-8	+2	[28]
	(1+/-4	-4	+12)		(-1+/-2	-4	+1)	
68 CONTROL	238+/-50	70	270	[34]	258+/-4	253	270	[28]
	(114+/-28	21	132)		(126+/-2	123	132)	
69 EXPOSED	246+/-28	116	264	[30]	254+/-3	250	264	[26]
	(119+/-16	47	129)		(123+/-2	121	129)	
69 DELTA	-1+/-8	-13	+26	[29]	-4+/-2	-13	-3	[25]
	(-1+/-4	-7	+14)		(-2+/-1	-7	-2)	
69 CONTROL	247+/-35	100	277	[30]	258+/-5	254	277	[26]
	(119+/-19	37	136)		(126+/-3	123	136)	
70 EXPOSED	238+/-38	68	263	[31]	250+/-3	247	263	[26]
	(114+/-21	20	128)		(121+/-2	119	128)	
70 DELTA	1+/-5	-3	+20	[30]	-1+/-1	-3	+1	[25]
	(1+/-3	-2	+11)		(-1+/-1	-2	+1)	
70 CONTROL	237+/-41	64	266	[31]	251+/-3	248	266	[26]
	(114+/-23	18	130)		(122+/-2	120	130)	

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
71 EXPOSED	243+/-40	70	262	[31]	256+/-3	249	262	[27]
	(117+/-22	21	128)		(124+/-2	121	128)	
71 DELTA	0.4+/-8	-13	+26	[31]	-2+/-3	-13	-1	[27]
	(0.2+/-4	-7	+14)		(-1+/-2	-7	-1)	
71 CONTROL	243+/-45	68	278	[31]	258+/-5	255	278	[27]
	(117+/-25	20	137)		(126+/-3	124	137)	
72 EXPOSED	244+/-35	86	264	[31]	255+/-7	243	264	[27]
	(118+/-19	30	129)		(124+/-4	117	129)	
72 DELTA	1+/-5	-3	+18	[31]	-0.2+/-1	-3	+2	[27]
	(1+/-3	-2	+10)		(-0.1+/-1	-2	+1)	
72 CONTROL	243+/-38	77	264	[31]	255+/-6	246	264	[27]
	(117+/-21	25	129)		(124+/-3	119	129)	
73 EXPOSED	252+/-25	147	291	[30]	259+/-9	244	291	[27]
	(122+/-14	64	144)		(126+/-5	118	144)	
73 DELTA	-0.1+/-7	-14	+24	[30]	-2+/-4	-14	+2	[27]
	(-0.1+/-4	-8	+13)		(-1+/-2	-8	+1)	
73 CONTROL	252+/-31	123	305	[30]	260+/-12	246	305	[27]
	(122+/-17	51	152)		(127+/-7	119	152)	
74 EXPOSED	248+/-27	130	267	[30]	255+/-8	237	267	[26]
	(120+/-15	54	131)		(124+/-4	114	131)	
74 DELTA	1+/-5	-6	+15	[30]	-1+/-2	-6	+1	[26]
	(1+/-3	-3	+8)		(-1+/-1	-3	+1)	
74 CONTROL	247+/-31	118	273	[30]	256+/-8	240	273	[26]
	(119+/-17	48	134)		(124+/-4	116	134)	
75 EXPOSED	230+/-50	70	265	[31]	252+/-4	248	265	[25]
	(110+/-28	21	129)		(122+/-2	120	129)	
75 DELTA	-4+/-6	-21	+1	[31]	-2+/-3	-8	0	[25]
	(-2+/-3	-12	+1)		(-1+/-2	-4	0)	
75 CONTROL	235+/-48	69	267	[31]	254+/-6	248	267	[25]
	(113+/-27	21	131)		(123+/-3	120	131)	
76 EXPOSED	253+/-25	148	292	[30]	259+/-9	245	292	[27]
	(123+/-14	64	144)		(126+/-5	118	144)	
76 DELTA	-0.2+/-7	-14	+23	[30]	-2+/-4	-14	+2	[27]
	(-0.1+/-4	-8	+13)		(-1+/-2	-8	+1)	
76 CONTROL	253+/-31	125	306	[30]	261+/-12	247	306	[27]
	(123+/-17	52	152)		(127+/-7	119	152)	

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max [DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max [DP]
77 EXPOSED	220+/-22	62	237[126]	223+/-5	198	237[121]
	(104+/-12	17	114)	(106+/-3	92	114)
77 DELTA	2+/-4	-1	+37[126]	2+/-3	0	+4[121]
	(1+/-2	-1	+21)	(1+/-2	0	+2)
77 CONTROL	218+/-23	63	227[126]	222+/-5	197	227[121]
	(103+/-13	17	108)	(106+/-3	92	108)
78 EXPOSED	213+/-17	67	227[126]	215+/-3	212	227[122]
	(101+/-9	19	108)	(102+/-2	100	108)
78 DELTA	-1+/-3	-2	+17[126]	-1+/-1	-2	+3[122]
	(-1+/-2	-1	+9)	(-1+/-1	-1	+2)
78 CONTROL	213+/-18	68	224[126]	216+/-2	213	224[122]
	(101+/-10	20	107)	(102+/-1	101	107)
81 EXPOSED	236+/-41	62	253 [38]	251+/-1	249	253 [30]
	(113+/-23	17	123)	(122+/-1	121	123)
81 DELTA	1+/-5	-17	+17 [38]	2+/-2	-7	+3 [30]
	(1+/-3	-9	+9)	(1+/-1	-4	+2)
81 CONTROL	235+/-43	57	257 [38]	249+/-3	246	257 [30]
	(113+/-24	14	125)	(121+/-2	119	125)
87 EXPOSED	245+/-42	73	298 [31]	258+/-11	252	298 [27]
	(118+/-23	23	148)	(126+/-6	122	148)
87 DELTA	-1+/-4	-16	+8 [31]	0.4+/-2	-1	+8 [27]
	(-1+/-2	-9	+4)	(0.2+/-1	-1	+4)
87 CONTROL	246+/-39	74	290 [31]	257+/-9	251	290 [27]
	(119+/-22	23	143)	(125+/-5	122	143)
90 EXPOSED	235+/-50	79	294 [33]	255+/-9	245	294 [27]
	(113+/-28	26	146)	(124+/-5	118	146)
90 DELTA	0.2+/-4	-4	+18 [33]	-0.04+/-4	-3	+18 [27]
	(0.1+/-2	-2	+10)	(-0.02+/-2	-2	+10)
90 CONTROL	235+/-49	78	276 [33]	255+/-6	248	276 [27]
	(113+/-27	26	136)	(124+/-3	120	136)
91 EXPOSED	241+/-44	67	275 [33]	256+/-9	248	275 [28]
	(116+/-24	19	135)	(124+/-5	120	135)
91 DELTA	-0.3+/-2	-2	+7 [33]	-0.3+/-2	-2	+7 [28]
	(-0.2+/-1	-1	+4)	(-0.2+/-1	-1	+4)
91 CONTROL	241+/-44	68	273 [33]	257+/-8	249	273 [28]
	(116+/-24	20	134)	(125+/-4	121	134)

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
94 EXPOSED	238+/-46	70	278	[35]	254+/-6	246	278	[30]
	(114+/-26	21	137)		(123+/-3	119	137)	
94 DELTA	-0.1+/-3	-7	+9	[35]	-1+/-4	-5	+9	[30]
	(-0.1+/-2	-4	+5)		(-1+/-2	-3	+5)	
94 CONTROL	238+/-45	74	278	[35]	254+/-6	249	278	[30]
	(114+/-25	23	137)		(123+/-3	121	137)	
95 EXPOSED	239+/-43	71	266	[36]	253+/-5	246	266	[32]
	(115+/-24	22	130)		(123+/-3	119	130)	
95 DELTA	-1+/-3	-7	+14	[36]	0.1+/-3	-2	+14	[32]
	(-1+/-2	-4	+8)		(0.1+/-2	-1	+8)	
95 CONTROL	240+/-42	74	266	[36]	253+/-5	243	266	[32]
	(116+/-23	23	130)		(123+/-3	117	130)	
97 EXPOSED	247+/-31	90	260	[38]	255+/-3	251	260	[32]
	(119+/-17	32	127)		(124+/-2	122	127)	
97 DELTA	2+/-7	-6	+25	[38]	1+/-7	-6	+25	[32]
	(1+/-4	-3	+14)		(1+/-4	-3	+14)	
97 CONTROL	239+/-51	90	264	[38]	246+/-46	227	264	[32]
	(115+/-28	32	129)		(119+/-26	108	129)	
99 EXPOSED	234+/-49	68	258	[33]	252+/-2	250	258	[28]
	(112+/-27	20	126)		(122+/-1	121	126)	
99 DELTA	2+/-8	-29	+13	[33]	5+/-3	+2	+13	[28]
	(1+/-4	-16	+7)		(3+/-2	+2	+7)	
99 CONTROL	232+/-44	73	250	[33]	247+/-2	243	250	[28]
	(111+/-24	23	121)		(119+/-1	117	121)	
101 EXPOSED	256+/-18	NA	319	[33]	260+/-12	256	319	[29]
	(124+/-10	NA	159)		(127+/-7	124	159)	
101 DELTA	5+/-7	-3	+42	[33]	5+/-7	+1	+42	[29]
	(3+/-4	-2	+23)		(3+/-4	+1	+23)	
101 CONTROL	240+/-40	77	277	[36]	255+/-6	250	277	[29]
	(116+/-22	25	136)		(124+/-3	121	136)	
103 EXPOSED	242+/-37	73	259	[32]	252+/-5	246	259	[26]
	(117+/-21	23	126)		(122+/-3	119	126)	
103 DELTA	-0.2+/-8	-14	+10	[31]	-1+/-8	-14	+10	[25]
	(-0.1+/-4	-8	+6)		(-1+/-4	-8	+6)	
103 CONTROL	242+/-37	75	265	[32]	253+/-6	244	265	[26]
	(117+/-21	24	129)		(123+/-3	118	129)	

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
104 EXPOSED	242+/-37	75	262	[32]	252+/-2	247	262	[29]
	(117+/-21	24	128)		(122+/-1	119	128)	
104 DELTA	-3+/-6	-26	+5	[32]	-3+/-5	-13	+5	[29]
	(-2+/-3	-14	+3)		(-2+/-3	-7	+3)	
104 CONTROL	245+/-38	78	275	[32]	254+/-6	246	275	[29]
	(118+/-21	26	135)		(123+/-3	119	135)	
105 EXPOSED	239+/-51	60	256	[31]	255+/-1	253	256	[28]
	(115+/-28	16	124)		(124+/-1	123	124)	
105 DELTA	2+/-7	-19	+7	[29]	3+/-7	-19	+7	[26]
	(1+/-4	-11	+4)		(2+/-4	-11	+4)	
105 CONTROL	237+/-49	67	274	[31]	253+/-8	248	274	[28]
	(114+/-27	19	134)		(123+/-4	120	134)	
106 EXPOSED	238+/-49	63	258	[31]	254+/-1	252	258	[28]
	(114+/-27	17	126)		(123+/-1	122	126)	
106 DELTA	-1+/-6	-13	+7	[29]	-1+/-6	-13	+6	[26]
	(-1+/-3	-7	+4)		(-1+/-3	-7	+3)	
106 CONTROL	239+/-51	65	271	[31]	255+/-7	248	271	[28]
	(115+/-28	18	133)		(124+/-4	120	133)	
107 EXPOSED	242+/-47	72	259	[33]	257+/-1	254	259	[26]
	(117+/-26	22	126)		(125+/-1	123	126)	
107 DELTA	3+/-4	-10	+6	[32]	5+/-1	+3	+6	[25]
	(2+/-2	-6	+3)		(3+/-1	+2	+3)	
107 CONTROL	239+/-44	76	254	[33]	253+/-1	250	254	[26]
	(115+/-24	24	123)		(123+/-1	121	123)	
108 EXPOSED	240+/-46	74	259	[33]	254+/-1	251	259	[29]
	(116+/-26	23	126)		(123+/-1	122	126)	
108 DELTA	0.4+/-7	-32	+20	[32]	1+/-2	-5	+5	[28]
	(0.2+/-4	-18	+11)		(1+/-1	-3	+3)	
108 CONTROL	240+/-45	70	256	[33]	253+/-2	250	256	[29]
	(116+/-25	21	124)		(123+/-1	121	124)	
109 EXPOSED	234+/-44	70	259	[24]	252+/-4	242	259	[19]
	(112+/-24	21	126)		(122+/-2	117	126)	
109 DELTA	-12+/-18	-54	+7	[24]	-12+/-20	-54	+7	[19]
	(-7+/-10	-30	+4)		(-7+/-11	-30	+4)	
109 CONTROL	246+/-48	72	299	[24]	264+/-17	246	299	[19]
	(119+/-27	22	148)		(129+/-9	119	148)	

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
110 EXPOSED	239+/-46	72	287	[24]	251+/-1	250	253	[14]
	(115+/-26	22	142)		(122+/-1	121	123)	
110 DELTA	10+/-21	-14	+73	[24]	-1+/-7	-14	+6	[14]
	(6+/-12	-8	+41)		(-1+/-4	-8	+3)	
110 CONTROL	229+/-43	72	265	[24]	252+/-7	246	265	[14]
	(109+/-24	22	129)		(122+/-4	119	129)	
111 EXPOSED	240+/-40	69	266	[32]	256+/-3	253	266	[23]
	(116+/-22	21	130)		(124+/-2	123	130)	
111 DELTA	-4+/-7	-19	+11	[31]	-0.1+/-3	-3	+11	[22]
	(-2+/-4	-11	+6)		(-0.1+/-2	-2	+6)	
111 CONTROL	244+/-37	74	258	[32]	256+/-2	253	258	[23]
	(118+/-21	23	126)		(124+/-1	123	126)	
112 EXPOSED	242+/-36	77	254	[32]	253+/-1	250	254	[24]
	(117+/-20	25	123)		(123+/-1	121	123)	
112 DELTA	-1+/-5	-9	+14	[31]	-3+/-3	-9	+6	[23]
	(-1+/-3	-5	+8)		(-2+/-2	-5	+3)	
112 CONTROL	243+/-37	72	261	[32]	255+/-4	246	261	[24]
	(117+/-21	22	127)		(124+/-2	119	127)	
113 EXPOSED	246+/-42	67	285	[32]	259+/-8	255	285	[28]
	(119+/-23	19	141)		(126+/-4	124	141)	
113 DELTA	2+/-5	-16	+14	[32]	4+/-3	+2	+14	[28]
	(1+/-3	-9	+8)		(2+/-2	+1	+8)	
113 CONTROL	244+/-38	71	271	[32]	255+/-5	252	271	[28]
	(118+/-21	22	133)		(124+/-3	122	133)	
114 EXPOSED	245+/-43	67	305	[32]	258+/-13	252	305	[28]
	(118+/-24	19	152)		(126+/-7	122	152)	
114 DELTA	-1+/-5	-13	+7	[31]	0.4+/-3	-7	+7	[27]
	(-1+/-3	-7	+4)		(0.2+/-2	-4	+4)	
114 CONTROL	246+/-41	71	298	[32]	258+/-12	250	298	[28]
	(119+/-23	22	148)		(126+/-7	121	148)	
115 EXPOSED	232+/-48	73	255	[18]	254+/-1	253	255	[9]
	(111+/-27	23	124)		(123+/-1	123	124)	
115 DELTA	63+/-81	+2	+196	[17]	3+/-1	+2	+4	[8]
	(35+/-45	+1	+109)		(2+/-1	+1	+2)	
115 CONTROL	172+/-95	68	252	[18]	251+/-1	250	252	[9]
	(78+/-53	20	122)		(122+/-1	121	122)	

TABLE 9: CURE TEMPERATURES Continued

RUN	Overall Cure °F (°C) Mean+/-Std	Min	Max	[DP]	Post Heat-up To Cure °F (°C) Mean+/-Std	Min	Max	[DP]
116 EXPOSED	234+/-48	75	269	[19]	251+/-5	248	269	[16]
	(112+/-27	24	132)		(122+/-3	120	132)	
116 DELTA	3+/-12	-9	+42	[17]	1+/-6	-4	+14	[14]
	(2+/-7	-5	+23)		(1+/-3	-2	+8)	
116 CONTROL	231+/-47	77	253	[19]	248+/-5	240	253	[16]
	(111+/-26	25	123)		(120+/-3	116	123)	

Measurement Accuracy: +/- 1.8°F (1°C)

experimental runs of this effort experienced effectively the same cure temperature profile. Also the cure temperature profile actually experienced by the resin systems in this effort was for all intents and purposes the desired cure profile listed in Table 8.

Experimentation Sequence

Each experimental run, inorder to be considered a useful run in this effort, required 46 steps to be successfully completed. For the most part, each of these steps needed to be completed in sequence as they usually built upon one another. These individual steps and the time that each step required are described in the following paragraphs.

In Step 1 an electromagnet and its supporting equipment are turned on and allowed to stabilize for at least 12 hours (hrs) at a preselected amperage and pole face air gap. This step required 2 work hrs to complete over 2 calendar days.

For Step 2 the Control and Magnetic Field exposed Ovens are loaded with dummy mold packs. Both ovens are then heated up to the generally desired operating temperature. Once near this desired temperature, both ovens are stabilized for long duration continuous operation within 5°F of each other and to within 5°F of the desired operating temperature. This step required 1 to 4 work days to complete.

With Step 3 the resin casting mold packs, desired to be used in an experimental run, are assembled from cleaned and waxed mold clamps and cleaned and dry RTV 664 Silicone rubber mold cavity negatives. This step required 2 to 4 work hrs to complete. In Step 4 the resultant packs are then heated in air to the desired curing temperature plus 50°F for 1/2 to 1 hour. The heated mold packs are then placed in a vacuum desiccator, the desiccator is pumped down, and the mold packs are allowed to cool to room temperature while being vacuum degassed overnight. This step required 4 work hrs to complete over 1 calendar day. Following Step 4, for Step 5 the cooled and degassed mold packs are removed from their vacuum degas chambers and then precisely placed into the control and magnetic field exposed ovens. This step required 1 work hr.

For Step 6 a lab notebook is prepared to guide the PI and record the experimentally relevant measurements taken throughout the specimen casting phase of this experimental run sequence. This step required 2 work hrs to complete.

In Step 7 the Hall Probe adapter extension is rezeroed to extend straight down by alining its edges with a line and plumb bob. This step required 1 work hr over 1 to 2 calendar days. With Step 8 the three axis positioner, with the rezeroed adapter extension, is moved over a stabilized and running electromagnet and associated magnetic field exposed oven. It is then locked into a set, repeatable position relative to the support scaffold, electromagnets, and ovens. This step required 1 work hr. Immediately following Step 8, in Step 9 the three axis positioner is then turned on and zeroed. This alines and zeros the Hall Probe adapter extension over a specific and repeatable point in the magnetic field within the oven. This step required 1 work hr. In Step 10 the mold pack's coordinates, which define its initial position in the magnetic field, are mapped with this positioning equipment and recorded in a lab notebook. This step required 2 work hrs.

As a first step in the actual mixing of an epoxy resin system, in Step 11 the mobile balance isolation bench is moved to and set up near a functioning hood. The balances are leveled, turned on, and allowed to stabilize. In Step 12 the desired epoxy resin and curing agent are moved to the hood, taken out of the desiccated and dry nitrogen atmosphere environments in which they are stored, and added to cleaned flasks to be heated. For Step 13 all balances are electronically calibrated and all time keeping and or

timed data recording devices are synchronized and logged in a lab notebook. Continuing the resin mix prep with Step 14, the desired epoxy resin and the selected curing agent are heated up to a fluidic low viscosity condition. Combined, steps 11 through 14 required 3 work hrs to complete. In Step 15, a predetermined amount of heated epoxy resin is added to a clean Pyrex beaker and recorded in a lab notebook. The temperature of the epoxy resin at its addition to this beaker is listed in Table 10. Next in Step 16, a stoichiometric amount of preheated curing agent is then added to the resin in the beaker and also recorded in a lab notebook. The temperature of the curing agent added to the beaker is also listed in Table 10 for each particular run. For Step 17, The resin and curing agent are vigorously mixed for approximately one minute. The resultant resin system is then in Step 18 immersed into an ice water cooling vat until the mix's temperature is reduced to the desired casting temperature.

Step 19 is the initial step in the process of actually casting the mixed resin system into the tensile specimen generating molds. In this step, the cooled resin system is placed into a vacuum desiccator and the resin system is degassed for 15 minutes. For Step 20, the resin system is removed from the vacuum desiccator and cast first into the magnetic field exposed mold pack and then within one minute into the associated control mold pack. Combined, steps 15 through 20 required 2 to 4 work hrs to complete.

Elevated temperature curing of the cast resin system begins with Step 21. For this step and within one minute of casting the control mold pack, heated bone dry nitrogen gas is set flowing through the ovens surrounding the magnetic field exposed mold pack and its associated control mold pack. In addition and as Step 22, the temperature data recorder device is initiated and a recording of the casting's temperatures is logged within one minute after the heated gas is set flowing. For Step 23, the mold packs are allowed to naturally heat up to the desired curing temperature. Once near or at that temperature they are manually maintained within $10^{o}F$ of that temperature and to within $10^{o}F$ of each other for the desired duration. For Step 24, and one minute prior to the end of the desired curing duration, a final resin cure temperature is logged and the peak and valley temperatures which have been measured and retained in the data recorder's memory are logged. After the desired curing duration has elapsed and representing Step 25, the heaters are shut down and cold, bone dry nitrogen gas is allowed to flow over the mold packs until they have cooled down to room temperature.

TABLE 10: RESIN AND CURING AGENT TEMP AT ADDITION

RUN	Resin Addition Temp Begin °F (°C)	Resin Addition Temp End °F (°C)	Curing Agent Addition Temp Begin °F (°C)	Curing Agent Addition Temp End °F (°C)	
65	RT	RT	257	NA	99+% MDA
	(RT)	(RT)	(125)	(NA)	
66	RT	RT	275	NA	99+% MDA
	(RT)	(RT)	(135)	(NA)	
67	RT	RT	239	NA	99+% MDA
	(RT)	(RT)	(115)	(NA)	
68	RT	RT	275	NA	99+% MDA
	(RT)	(RT)	(135)	(NA)	
69	RT	RT	257	NA	99+% MDA
	(RT)	(RT)	(125)	(NA)	
70	RT	RT	248	NA	99+% MDA
	(RT)	(RT)	(120)	(NA)	
71	RT	RT	174	NA	99+% MPDA
	(RT)	(RT)	(79)	(NA)	
72	RT	RT	147	NA	99+% MPDA
	(RT)	(RT)	(61)	(NA)	
73	RT	RT	RT	RT	Tonox 60/40
	(RT)	(RT)	(RT)	(RT)	
	RT	RT	RT	RT	Epi Rez 5022
	(RT)	(RT)	(RT)	(RT)	
74	RT	RT	RT	RT	Tonox 60/40
	(RT)	(RT)	(RT)	(RT)	
	RT	RT	RT	RT	Epi Rez 5022
	(RT)	(RT)	(RT)	(RT)	
75	RT	RT	RT	RT	97+% PACM-20
	(RT)	(RT)	(RT)	(RT)	
76	RT	RT	RT	RT	97+% PACM-20
	(RT)	(RT)	(RT)	(RT)	
77	RT	RT	RT	RT	97+% PACM-20
	(RT)	(RT)	(RT)	(RT)	
78	RT	RT	RT	RT	97+% PACM-20
	(RT)	(RT)	(RT)	(RT)	
81	RT	RT	246	225	99+% MDA
	(RT)	(RT)	(119)	(107)	
87	RT	RT	282	239	99+% MDA
	(RT)	(RT)	(139)	(115)	
90	RT	RT	266	280	99+% MDA
	(RT)	(RT)	(130)	(138)	
91	RT	RT	151	133	99+% MPDA
	(RT)	(RT)	(66)	(56)	
94	RT	RT	151	126	99+% MPDA
	(RT)	(RT)	(66)	(52)	
95	RT	RT	138	158	97+% PACM-20
	(RT)	(RT)	(59)	(70)	

TABLE 10: RESIN AND CURING AGENT TEMP AT ADDITION
Continued

RUN	Resin Addition Temp Begin °F (°C)	End °F (°C)	Curing Agent Addition Temp Begin °F (°C)	End °F (°C)	
97	RT (RT)	RT (RT)	140 (60)	174 (79)	97+% PACM-20
99	199 (93)	NA (NA)	230 (110)	266 (130)	99+% MDA
101	212 (100)	NA (NA)	248 (120)	262 (128)	99+% MDA
103	178 (81)	NA (NA)	198 (92)	140 (60)	97+% PACM-20
104	178 (81)	NA (NA)	198 (92)	140 (60)	97+% PACM-20
105	203 (95)	187 (86)	234 (112)	252 (122)	99+% MDA
106	203 (95)	187 (86)	234 (112)	252 (122)	99+% MDA
107	188 (86.5)	NA (NA)	185 (85)	239 (115)	97+% PACM-20
108	188 (86.5)	NA (NA)	185 (85)	239 (115)	97+% PACM-20
109	207 (97)	199 (93)	262 (128)	243 (117)	99+% MDA
110	207 (97)	199 (93)	262 (128)	243 (117)	99+% MDA
111	189 (87)	187 (86)	184 (84.5)	237 (114)	97+% PACM-20
112	189 (87)	187 (86)	184 (84.5)	237 (114)	97+% PACM-20
113	203 (95)	199 (93)	266 (130)	248 (120)	99+% MDA
114	203 (95)	199 (93)	266 (130)	248 (120)	99+% MDA
115	145 (63)	139 (59.5)	81 (27)	80 (26.5)	97+% PACM-20
116	145 (63)	139 (59.5)	81 (27)	80 (26.5)	97+% PACM-20

Measurement Accuracy: +/- 0.5 °C

Combined, steps 21 through 25 required 6 to 21 work hrs to complete over 1 to 2 continuous calendar days.

As Step 26, the logged casting and curing temperatures are recorded in a lab notebook. This work required 2 to 4 hours to complete.

The three axis positioner is again turned on and rezeroed. This comprises Step 27. The mold pack's final coordinates, which define its final position in the magnetic field, are mapped out in Step 28. In Step 29 the mold packs are removed from their respective ovens and placed into polyethylene ziplock storage bags along with packs of indicating drierite desiccant. Combined, steps 27 through 29 required 2 to 4 work hrs to complete over 2 continuous calendar days.

For Step 30 the mold packs are removed from their Ziplock bags and the exact position of the rubber mold cavity negatives is determined relative to their position in the mold pack. The rubber mold cavities are removed from the mold clamps in Step 31 and the individual cast resin system specimens are them stripped from their individual rubber negative mold casting cavities. In Step 32 each of these individual specimens is then trimmed to remove any casting sprue spikes. The specimens are then inspected under a 10X magnifying device for defects, such as any entrained bubbles and or other flaws which would negate their usefulness as a test specimen. They are then sorted out as mechanically testable, thermally testable, or untestable. The individual specimens are then placed in individual polyethylene Ziplock bags along with packs of indicating Drierite desiccant. All of these bags, for each casting condition, are then put into larger Ziplock bags with more indicating Drierite desiccant. And finally all of the specimens bags, for each condition relative to each run, are placed into a final, larger Ziplock bag with more indicating Drierite desiccant and stored until they can be mensurated and tested. Combined, steps 30 through 32 required 4 work hrs to complete. The Drierite's specifics are listed in Table 3.

From the initial and final positions of the mold pack in the ovens and from the position of the rubber mold cavity negatives in the mold packs a three dimensional worst case zone of magnetic field exposure is determined and recorded in a lab notebook. This zone encases the maximum volume in which the cast specimens could possibly have been positioned at any time while they were within the magnetic field. This step, Step 33, required 1 work day.

For Step 34 the Hall Probe and Gaussmeter magnetic field strength measuring system is turned on and first zeroed and then checked for stability by being run overnight. As Step 35 the zeroed and stabilized Hall Probe is attached to the Hall Probe adapter extension clamp. The three axis positioner is once again turned on and for Step 36

rezeroed. Combined, steps 34 through 36 required 4 work hrs to complete over 2 continuous calendar days. The three dimensional zone of the magnetic field in which the resin specimens were cured is then mapped out by measuring the magnetic field at between 72 and 385 points within and at the edge of that zone and recorded in a lab notebook. This step, Step 37, required 4 to 10 continuous work hrs.

For Step 38 cast specimens determined suitable for mechanical testing are removed from their desiccated storage bags and mensurated for testing. This step required 2 work hrs. In Step 39 the Sintech mechanical testing machine is turned on, allowed to warm up, and then calibrated for a continuous session of neat resin specimen tensile testing. This step required 1 work hr over a 2 hr continuous period to complete. Measured specimens are mechanically tested in this step, Step 40, and the results from those specimens not failing in an unacceptable location or on a previously undetected flaw are graphed and recorded in a lab notebook. This step required 4 to 6 work hrs.

In Step 41 cast specimens determined suitable for thermal analysis are removed from their desiccated storage bags, cut, and trimmed to suitable sizes and returned to their bags. This step required 2 to 3 work hrs.

The thermal analysis specimens from Step 41 are next taken out of their desiccated storage bags. In Step 42 they are then weighted and encapsulated in hermetically sealed analysis cans. This step required 2 to 3 work hrs. For Step 43 the Du Pont DSC described in Table 3 is calibrated for a continuous session of neat resin specimen thermal analysis. This step required 4 to 8 continuous work hrs. In Step 44, DSC runs were made on the hermetically sealed specimens and the results are graphed and recorded in a lab notebook. This step required 2 work hrs.

As clean up from one experimental run and prep for the next, in Step 45 the rubber mold cavity negatives are soaked in double distilled water, scrubbed clean of all cast resin residue, checked for suitable flexibility, and then blown dry with bone dry nitrogen gas. This step required 1 work day. For Step 46 the mold clamps are scrubbed clean of all cast resin residue, blown dry with dry nitrogen gas, and waxed with boot polish. This step required 1/2 work day.

Due to the intricacy of this experimental sequence and the intense need for detail data acquisition the PI (Mr Roger H. Gerzeski) conducted all of the activities outlined in each of the above steps for all of the 57 experimental runs associated with this effort. Each successful experimental run required the PI to expend at least 11 working days of effort to complete and could take as long as 18 working days. The PI was able to shorten these time spans to 9 and 13.5 working days by conducting some of the same fore-mentioned steps for two different experimental runs simultaneously. The 37 successful runs associated with this effort required the PI to expend at least 333 working days and as much as 500 working days. Also interspersed in the successful runs were 20 other failed runs. Each of these failed runs took a minimum of 8 working days and a maximum of 12 working days of the PI's effort to progress far enough through the experimental sequence to determine that the run was unusable. The PI's simultaneous working through of similar steps for two different experimental runs reduced these failed run times to 6.5 and 8 working days respectively. These 20 failed runs required the PI to expend at least another 130 working days and as much as another 160 working days. Tallied together the PI invested at least 463 working days into the experimental portion of this effort which occurred between early 1992 and mid-early 1995.

Characterization

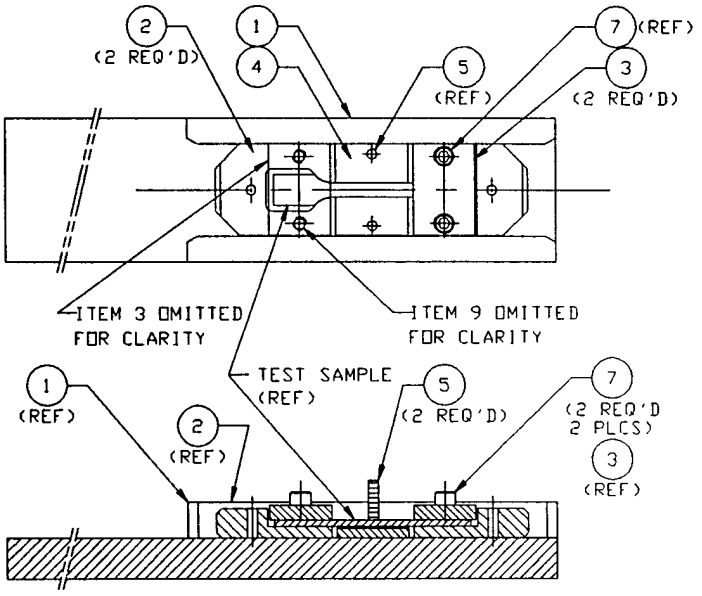
All experimental runs associated with this effort were mechanically and thermally characterized. All reasonably relevant tensile mechanical properties were determined from the specimens generated in each run. Also for each run the glass transition temperature (Tg) and a qualitative measure of the degree of cure of the epoxy resin systems cured in each run was determined.

Tensile Mechanical Characterization

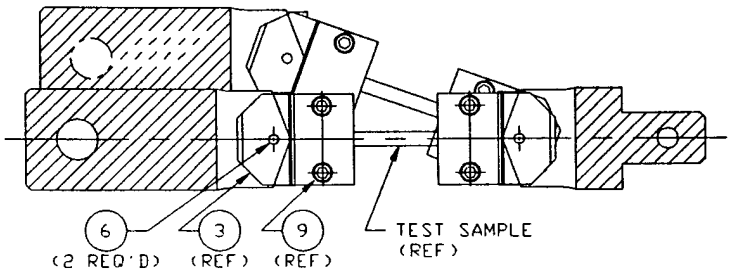
A standard uniaxial tension test was conducted on the cast miniature dogbone specimens generated in each condition of each run in this experimental effort. The mechanical testing system used was a Sintech 1 uniaxial tension-compression machine under both computer control and data acquisition/recording. The Sintech 1 system also used the two versions of the TESTWORKS data manipulation software package listed in Table 3 to determine relevant mechanical data from any tensile tested specimen's

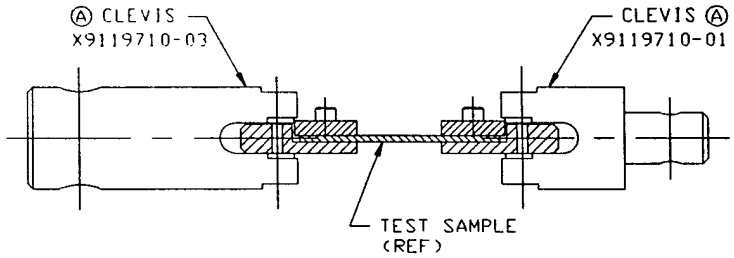
recorded stress versus strain curve. The specifics associated with this mechanical testing system are described in Table 3. Each specimen was tested using a constant extension rate type of tension test. The extension rate used in each mechanical test was 0.02 inch per min. All of the strain data acquired throughout this entire effort was measured with the same MTS extensometer. It's specifics are delineated in Table 3. From the stress versus strain curve data, generated from each successfully tension tested specimen, tensile stress and tensile strain at yield were determined for each specimen if that specimen had a yield point. Also for each successfully tested specimen the ultimate tensile stress and strain were determined at failure. The initial Youngs Modulus was also determined for each successfully tested specimen. And finally the gage cross-sectional area normalized energy to failure toughness of each successfully tested specimen was determined.

Specially designed, extremely tight toleranced jigs, fixtures, and clevis were required for this effort. These subcomponents were fabricated to enable the attachment of the miniature dogbone cast resin specimens to the Sintech testing machine. Results from the PI's early 90's efforts to tensile test similar dogbone specimens generated in runs 40 through 59 revealed the absolute necessity of using only the highest quality and tightest toleranced jigs, fixtures, and clevis to attach specimens to a testing machine. The shoddily machined and inadequately toleranced jigs, fixtures, and clevis fabricated for that previous effort resulted in two out of every three tested specimens failing in the neck-down and or tab portion of the dogbones. According to ASTM standards, failures in these regions of the specimen require the rejection of that test from any final reported results(158-60). To eliminate any potential for this type of failure rate to occur in this effort the PI designed the extremely tight toleranced jigs, fixtures, and clevis depicted in the assembly drafting Figure 21. The particulars associated with the subcomponents shown in Figure 21 are delineated in Table 3 and in the appendix. All of these jigs, fixtures, and clevis were routinely designed and fabricated to tolerances of 1 mil with a few exceptions to 2 mils and a very few exceptions to 3 mils. As a result of the this meticulous attention to detail, there were only 2 definite rejected failures that could be attributed to this equipment in the over 400 plus tested specimens associated with this effort.



PREP





TEST

QTY REQD	NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION	FIND NO.
4	SCREW, SKT HD CAP	MS16995-25	#8-32UNC X .375 LONG	7
2	PIN ALIGNMENT	X9119712-03		6
2	PIN ALIGNMENT	X9119712-01		5
1	SPACER	X9119709-01		4
2	GRIP, UPPER	X9119708-01		3
2	GRIP, LOWER	X9119707-01		2
1	ALIGNMENT BLOCK	X9119706-01		1
1	ASSEMBLY	-10		

PARTS LIST

REVISIONS		
REV	DESCRIPTION	DATE
A	CLEVIS ADDED TO ASSY	01JUN92

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES + .xx± .03 + - .xxx± .010 -

ENG GERZESKI, R 16 FEB 92

DR BOCOCK, B 04NOV91

H5

U.S. AIR FORCE
PHILLIPS LAB EDWARDS AFB CA

TITLE FIXTURE, TENSILE TEST ASSEMBLY COMPOSITES LAB

DRAWING NO. X9119705 A

Figure 21: Tensile Test Fixture Assembly

Thermal Characterization

Standard DSC scans were conducted on three to five specimens cut out of one of the cast miniature dogbone specimens generated in each condition of each run in this experimental effort. These DSC scans were conducted to derive the glass transition temperature (Tg) and the degree of cure for each specimen generated in each run of this effort. A DuPont Thermal Analyst 2000 DSC was used to conduct these scans. Its specifics are described in Table 3. Each DSC scan used the same profile. Except for the first scan in any days continuous effort, which started at room temperature, the scan was begun at a sample temperature of between 50 and 100°C, it was then ramped up in temperature at a rate of 10°C per minute, and the run was terminated when the specimen reached 200°C. All specimens were air sealed in hermetic aluminum pans and heated under a nitrogen flow of 50 ml/min.

From the heat flow versus temperature curve data acquired from a DSC scan, the Tg of the specimens were determined. Tg was taken to be the temperature found at the absolute bottom of the heat flow spike associated with the heat flow change generated by a second order transition in an almost but not completely cured thermoset material.

An estimate of the residual heat of reaction H_{res} of the material was hand calculated from selected Heat Flow versus Temperature curves that appeared to be extreme cases for each different type epoxy resin system used. The area under the heat flow versus temperature curve was measured from the Tg point on the curve up until the curve stopped climbing and linearized out. From this area and the previously weighted mass of the DSCed specimen the H_{res} could be determined.

Throughout the entire experimental effort only eight distinct combinations of cure temperature profiles, amine curing agent types, and concentrations of those agents were used. Table 11 delineates these experimental cure style combinations. To determine a measure of the degree to which the specimens generated in each of the experimental runs of this effort was cured, the Heat Of Reaction (H_{rxn}) of the cure style at the cure temperature for that epoxy resin system used in any particular experimental run was calculated based upon the works of S. Sourour and K. Horie for amine cured epoxies.(161-2) A surprising resultant of their work was that small increases in the concentration

of the curing agent above stoichiometric had little if no accurately measurable effect on the base epoxy resin system's H_{rxn}. Based upon their work and the experimental findings of the PI in his late eighties and early nineties efforts, there were in fact only six H_{rxn}s relevant to the various cure styles used in this experimental effort. Table 12 lists those calculated H_{rxn}s for the six more simplified cure styles used in this effort.

Table 11: Experimental Cure Styles

Curing Agent	Concentration PHR	Thermal Cure Profile
97+% PACM-20 (ii,v)	28.0	250°F (121°C) 5 Hrs
97+% PACM-20 (ii)	28.0	210°F (99°C) 20 Hrs
Tonox 60/40 (vi)	29.9	250°F (121°C) 5 Hrs
Epi Rez 5022 (vii)	24.9	
99+% MPDA (i)	14.0	250°F (121°C) 5 Hrs
99+% MDA (iii)	25.5	250°F (121°C) 5 Hrs
99+% MDA (iii)	26.0	250°F (121°C) 5 Hrs
99+% MDA (iii)	27.0	300°F (149°C) 4 Hrs
99+% MDA (iii)	28.0	300°F (149°C) 4 Hrs

i. 1,3 Phenylenediamine
ii. 4,4'Methylene bis (Cyclohexylamine), Lot #: 00807KX
iii. 4,4'-Methylene Dianaline
iv. EPON 830
v. 4,4'Methylene bis (Cyclohexylamine), Lot #: 01314DT
vi. Tonox 60/40
vii. Epi Rez 5022

Table 12: Heat Of Reaction, H_{RXN}, At Cure Temperature

CURING AGENT	CURE TEMPERATURE °F	(°C)	H_{RXN} Cal/gm	(J/gm)
MDA	250	(121)	100	(417)
MDA	300	(149)	110	(460)
mPDA	250	(121)	110	(460)
TONOX 60/40	250	(121)	150	(628)
PACM-20	250	(121)	99	(414)
PACM-20	210	(99)	92	(384)

NOTE: These Heats Of Reaction Are derived from the works of S. Sourour (161) and K. Horie (162).

Worst case degrees of cure for the different cure styles used in this effort were determined from a percentage ratio of the H_{res} to the H_{rxn} calculated for that specific cure style. Based upon the techniques used to obtain the various cure style's H_{rxn} and and the various experimental run's H_{res} the PI believed that anything more would be unfounded by the available data.

RESULTS AND DISCUSSION

Characterization Results

Mechanical Studies Results

Table 13 lists the Tensile Stress At Yield (TSY) and the Ultimate Tensile Stress (UTS) of the magnetic field exposed and corresponding control specimens in those experimental runs that generated mechanically testable specimens. As can be seen from the results listed in Table 13, there is, with only one exception out of 37 measured averages, no discernable difference in either the peak stress, also TSY, between those specimens generated under any magnetic field strength exposure and their cogenerated controls. Also as can be seen from other results listed in Table 13, there is, with only one exception out of 37 measured averages, no discernable difference in either the break stress, also UTS, between those specimens generated under any magnetic field strength exposure and their cogenerated controls.

Run 94 is the only run in this experimental effort to exhibit a minutely discernable difference in the TSY and UTS results between magnetic field exposed specimens and their control specimens. The TSY and UTS average results for the control specimens are discernibly larger than the same results for the magnetic field exposed specimens. Also the range of these stress results for the control specimens is marginally larger than and does not overlap the range of the stress results for the exposed specimens. These differences in the control and exposed stresses are not significant. When the exposed stress average is added to its STD its sum is equal to the average of all of the control specimens generated in this effort. Also the difference between the largest stress value found in the magnetic field exposed specimens relative to the smallest value of the stress found in that run's corresponding control specimens is only 0.01 KSI. This difference is completely insignificant when compared to the overall

measurement accuracy of the test which was +/- 0.09 KSI. Additionally the TSY and UTS values for Run 94's control specimens are the largest measured in this experimental effort for the runs in which mPDA was used. This indicates that Run 94's values are statistically larger than expected. Based on these points, the difference between Run 94's exposed and control stress values is not significant and is a statistical anomaly.

Table 14 lists the Strain To Yield (STY) and the Strain To Failure (STF) of the magnetic field exposed and corresponding control specimens in those experimental runs that generated mechanically testable specimens. As can be seen from the results listed in Table 14, there is, with only two exceptions out of 37 measured averages, no discernable difference in either the peak strain, also STY, between those specimens generated under any magnetic field strength exposure and their cogenerated controls. Also as can be seen from other results listed in Table 14, there is, with only two exceptions out of 37 measured averages, no discernable difference in either the break strain, also STF, between those specimens generated under any magnetic field strength exposure and their cogenerated controls.

Runs 77 and 99 are the only runs in this experimental effort to exhibit a difference in the STY and STF results between their magnetic field exposed specimens and their control specimens. The STY and STF average results for the control specimens of these runs are larger than the same results for their corresponding magnetic field exposed specimens. Also the range of these strain results for the two control specimens are marginally larger than and do not overlap the range of the stress results for the two associated exposed specimens. These differences in the control and exposed strains for these two runs are not significant. The strain values for both runs are below the overall average strain values for the curing agents used. This indicates that the specimens, both control and exposed, generated from these batches of resins using these curing agents were marginal to begin with. Also the range of the exposed strain values for both runs are well with in the range of the overall average of the controls. And lastly when one takes into account the measurement accuracy of the extensometer used to measure these strains (see Table 3 for the extensometer's specifics) and adds that inaccuracy to the STDs of the exposed and control values the inaccuracy ranges overlap and the two values are not statistically different. Based on these, the difference between Runs 77's and 99's exposed and control strain values are not significant and represent statistical anomalies.

Table 13A: STRESS; MDA Cured Specimens

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]
65 CONTROL	11.14+/-0.28	10.79	11.49	[6]	11.09+/-0.24	10.79	11.37	[6]
	(76.8+/-1.9	74.4	79.2)		(76.4+/-1.6	74.4	78.4)	
65 EXPOSED	11.13+/-0.15	11.00	11.35	[4]	11.13+/-0.15	11.00	11.35	[4]
	(76.7+/-1.1	75.8	78.2)		(76.7+/-1.1	75.8	78.2)	
66 CONTROL	10.94+/-0.40	10.19	11.98	[6]	10.68+/-0.44	10.04	11.11	[6]
	(75.4+/-2.8	70.3	82.6)		(73.6+/-3.0	69.2	76.6)	
66 EXPOSED	11.33+/-0.62	10.92	12.25	[4]	11.11+/-0.63	10.56	11.98	[4]
	(78.1+/-4.2	75.3	84.5)		(76.6+/-4.2	72.8	82.6)	
67 CONTROL	11.50+/-0.24	11.20	11.76	[5]	11.47+/-0.23	11.20	11.67	[5]
	(79.3+/-1.6	77.2	81.1)		(79.1+/-1.6	77.2	80.5)	
67 EXPOSED	11.34+/-0.34	11.01	11.85	[5]	11.31+/-0.29	11.01	11.71	[5]
	(78.2+/-2.4	75.9	81.7)		(78.0+/-2.0	75.9	80.7)	
68 CONTROL	10.44+/-0.58	10.08	11.29	[4]	10.44+/-0.57	10.08	11.28	[4]
	(72.0+/-4.0	69.5	77.8)		(71.9+/-3.9	69.5	77.8)	
68 EXPOSED	11.31+/-0.50	10.94	12.03	[4]	11.30+/-0.50	10.94	12.02	[4]
	(78.0+/-3.5	75.4	83.0)		(77.9+/-3.4	75.4	82.9)	
69 CONTROL	11.54+/-0.65	10.48	12.24	[6]	11.53+/-0.65	10.48	12.24	[6]
	(79.6+/-4.5	72.3	84.4)		(79.5+/-4.5	72.3	84.4)	
69 EXPOSED	12.02+/-0.22	11.74	12.38	[6]	12.01+/-0.22	11.72	12.38	[6]
	(82.9+/-1.5	80.9	85.3)		(82.8+/-1.5	80.8	85.3)	
70 CONTROL	11.57+/-0.37	11.08	11.86	[4]	11.56+/-0.36	11.08	11.84	[4]
	(79.8+/-2.5	76.4	81.8)		(79.7+/-2.5	76.4	81.7)	
70 EXPOSED	11.61+/-0.49	11.26	11.96	[2]	11.61+/-0.49	11.26	11.96	[2]
	(80.1+/-3.4	77.7	82.5)		(80.1+/-3.4	77.7	82.5)	
81 CONTROL	11.87+/-0.33	11.61	12.24	[3]	11.87+/-0.33	11.61	12.24	[3]
	(81.8+/-2.3	80.0	84.4)		(81.8+/-2.3	80.0	84.4)	
81 EXPOSED	11.47+/-0.58	10.95	12.10	[3]	11.47+/-0.58	10.95	12.10	[3]
	(79.1+/-4.0	75.5	83.4)		(79.1+/-4.0	75.5	83.4)	
87 CONTROL	11.88+/-0.45	10.92	12.25	[7]	11.80+/-0.42	10.91	12.18	[7]
	(81.9+/-3.1	75.3	84.5)		(81.4+/-2.9	75.3	84.0)	
87 EXPOSED	11.92+/-0.28	11.57	12.24	[5]	11.87+/-0.26	11.57	12.24	[5]
	(82.2+/-1.9	79.8	84.4)		(81.8+/-1.8	79.8	84.4)	
90 CONTROL	12.22+/-0.17	11.91	12.38	[6]	11.89+/-0.20	11.69	12.13	[6]
	(84.2+/-1.2	82.1	85.4)		(82.0+/-1.3	80.6	83.6)	
90 EXPOSED	12.01+/-0.16	11.79	12.21	[6]	11.79+/-0.33	11.22	12.20	[6]
	(82.8+/-1.1	81.3	84.2)		(81.3+/-2.3	77.4	84.1)	

Table 13A: STRESS; MDA Cured Specimens Continued

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
99 CONTROL	12.42+/-0.03	12.41	12.44 [2]	12.42+/-0.03	12.41	12.44 [2]
	(85.7+/-0.2	85.5	85.8)	(85.7+/-0.2	85.5	85.8)
99 EXPOSED	11.83+/-0.37	11.41	12.10 [3]	11.83+/-0.37	11.41	12.10 [3]
	(81.6+/-2.6	78.7	83.5)	(81.6+/-2.6	78.7	83.5)
101 CONTROL	12.13+/-0.36	11.46	12.43 [6]	12.09+/-0.34	11.46	12.43 [6]
	(83.7+/-2.5	79.0	85.7)	(83.4+/-2.3	79.0	85.7)
101 EXPOSED	12.00+/-0.23	11.70	12.35 [6]	11.89+/-0.26	11.52	12.21 [6]
	(82.7+/-1.6	80.7	85.2)	(82.0+/-1.8	79.5	84.2)
105 CONTROL	11.68+/-0.41	11.04	12.14 [5]	11.66+/-0.41	11.04	12.14 [5]
	(80.5+/-2.8	76.1	83.7)	(80.4+/-2.8	76.1	83.7)
105 EXPOSED	12.14+/-0.16	11.86	12.26 [5]	12.14+/-0.16	11.86	12.26 [5]
	(83.7+/-1.1	81.8	84.6)	(83.7+/-1.1	81.8	84.5)
106 CONTROL	12.12+/-0.21	11.80	12.26 [4]	12.07+/-0.21	11.80	12.25 [4]
	(83.6+/-1.5	81.4	84.5)	(83.2+/-1.5	81.4	84.5)
106 EXPOSED	12.20+/-0.34	11.91	12.58 [4]	12.19+/-0.34	11.91	12.58 [4]
	(84.1+/-2.4	82.1	86.7)	(84.1+/-2.3	82.1	86.7)
109 CONTROL	12.04+/-0.09	11.99	12.14 [3]	12.03+/-0.08	11.99	12.12 [3]
	(83.0+/-0.6	82.6	83.7)	(83.0+/-0.5	82.6	83.6)
109 EXPOSED	11.95+/-0.57	11.26	12.55 [4]	11.81+/-0.49	11.26	12.46 [4]
	(82.4+/-3.9	77.7	86.5)	(81.4+/-3.4	77.7	85.9)
110 CONTROL	12.07+/-0.51	11.32	12.47 [4]	12.05+/-0.50	11.32	12.46 [4]
	(83.2+/-3.5	78.1	86.0)	(83.0+/-3.4	78.1	85.9)
110 EXPOSED	12.37+/-0.14	12.21	12.55 [4]	12.23+/-0.09	12.14	12.35 [4]
	(85.3+/-1.0	84.2	86.5)	(84.3+/-0.6	83.7	85.2)
113 CONTROL	11.84+/-1.03	10.30	12.46 [4]	11.83+/-1.02	10.30	12.46 [4]
	(81.6+/-7.1	71.0	85.9)	(81.6+/-7.1	71.0	85.9)
113 EXPOSED	11.78+/-0.61	11.08	12.20 [3]	11.78+/-0.61	11.08	12.20 [3]
	(81.2+/-4.2	76.4	84.1)	(81.2+/-4.2	76.4	84.1)
114 CONTROL	12.28+/-0.13	12.18	12.42 [3]	12.20+/-0.18	12.04	12.40 [3]
	(84.7+/-0.9	84.0	85.6)	(84.1+/-1.3	83.0	85.5)
114 EXPOSED	12.05+/-0.47	11.36	12.41 [4]	12.05+/-0.47	11.36	12.41 [4]
	(83.1+/-3.2	78.3	85.6)	(83.1+/-3.2	78.3	85.6)
AVG RUNS	69-70,81,87,90,99,101,105,106,109,110,113,114					
OV. CONTROL	11.97+/-0.27	10.30	12.47[57]	11.92+/-0.26	10.30	12.46[57]
	(82.6+/-1.9	71.0	86.0)	(82.2+/-1.8	71.0	85.9)

Table 13A: STRESS; MDA Cured Specimens Continued

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
AVG RUNS	67-70,81,87,90					
OV. CONTROL	**11.57**	**10.08**	**12.38**	**11.51**	**10.08**	**12.24**
	(79.8	69.5	85.4)	(79.3	69.5	84.4)

Measurement Accuracy: +/- 0.09 KSI

Table 13B: STRESS; PACM-20 Cured Specimens

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
75 CONTROL	**9.01+/-0.82**	7.76	**10.15** [8]	**9.01+/-0.82**	**7.76**	**10.15** [8]
	(62.1+/-5.6	53.5	70.0)	(62.1+/-5.6	53.5	70.0)
75 EXPOSED	**9.03+/-0.96**	7.63	**9.76** [4]	**9.03+/-0.96**	**7.63**	**9.76** [4]
	(62.2+/-6.6	52.6	67.3)	(62.2+/-6.6	52.6	67.3)
76 CONTROL	**9.92+/-0.83**	8.94	**10.87** [6]	**9.92+/-0.83**	**8.94**	**10.87** [6]
	(68.4+/-5.7	61.6	74.9)	(68.4+/-5.7	61.6	74.9)
76 EXPOSED	**9.77+/-0.68**	8.77	**10.55** [6]	**9.77+/-0.68**	**8.77**	**10.55** [6]
	(67.3+/-4.7	60.5	72.8)	(67.3+/-4.7	60.5	72.8)
77 CONTROL	**11.02+/-0.07**	**10.96**	**11.10** [3]	**11.02+/-0.07**	**10.96**	**11.10** [3]
	(76.0+/-0.5	75.6	76.5)	(76.0+/-0.5	75.6	76.5)
77 EXPOSED	**10.27+/-0.76**	**9.40**	**11.14** [5]	**10.27+/-0.76**	**9.40**	**11.14** [5]
	(70.8+/-5.2	64.8	76.8)	(70.8+/-5.2	64.8	76.8)
78 CONTROL	**10.89+/-0.59**	**10.03**	**11.31** [4]	**10.87+/-0.58**	**10.03**	**11.26** [4]
	(75.0+/-4.0	69.1	78.0)	(75.0+/-4.0	69.1	77.6)
78 EXPOSED	**10.96+/-0.23**	**10.69**	**11.12** [3]	**10.96+/-0.23**	**10.69**	**11.12** [3]
	(75.5+/-1.6	73.7	76.7)	(75.5+/-1.6	73.7	76.7)
95 CONTROL	**10.46+/-0.95**	**8.93**	**11.34** [5]	**10.46+/-0.95**	**8.93**	**11.34** [5]
	(72.1+/-6.6	61.5	78.2)	(72.1+/-6.6	61.5	78.2)
95 EXPOSED	**10.73+/-0.19**	**10.54**	**10.92** [3]	**10.73+/-0.19**	**10.54**	**10.92** [3]
	(74.0+/-1.3	72.7	75.3)	(74.0+/-1.3	72.7	75.3)
97 CONTROL	**10.98+/-0.21**	**10.74**	**11.11** [3]	**10.98+/-0.21**	**10.74**	**11.11** [3]
	(75.7+/-1.5	74.0	76.6)	(75.7+/-1.5	74.0	76.6)
97 EXPOSED	**10.67+/-0.95**	**9.57**	**11.24** [3]	**10.67+/-0.95**	**9.57**	**11.24** [3]
	(73.5+/-6.6	66.0	77.5)	(73.5+/-6.6	66.0	77.5)

Table 13B: STRESS; PACM-20 Cured Specimens Continued

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]
103 CONTROL	10.52+/-0.50	9.76	10.98	[5]	10.52+/-0.50	9.76	10.98	[5]
	(72.5+/-3.5	67.3	75.7)		(72.5+/-3.5	67.3	75.7)	
103 EXPOSED	10.99+/-0.25	10.72	11.28	[5]	10.98+/-0.26	10.71	11.28	[5]
	(75.8+/-1.7	73.9	77.8)		(75.7+/-1.8	73.8	77.8)	
104 CONTROL	10.90+/-0.40	10.34	11.24	[4]	10.90+/-0.40	10.34	11.24	[4]
	(75.1+/-2.8	71.3	77.5)		(75.1+/-2.8	71.3	77.5)	
104 EXPOSED	10.00+/-1.78	7.09	11.21	[5]	9.96+/-1.75	7.09	11.11	[5]
	(68.9+/-12.3	48.9	77.3)		(68.7+/-12.1	48.9	76.6)	
107 CONTROL	11.09+/-0.13	10.96	11.21	[3]	11.09+/-0.13	10.96	11.21	[3]
	(76.5+/-0.9	75.6	77.3)		(76.5+/-0.9	75.6	77.3)	
107 EXPOSED	11.10+/-0.14	10.89	11.22	[4]	11.10+/-0.14	10.89	11.22	[4]
	(76.5+/-1.0	75.1	77.4)		(76.5+/-1.0	75.1	77.4)	
108 CONTROL	11.40+/-0.13	11.22	11.51	[4]	11.39+/-0.12	11.22	11.47	[4]
	(78.6+/-0.9	77.4	79.4)		(78.5+/-0.8	77.4	79.1)	
108 EXPOSED	10.89+/-0.91	9.84	11.50	[3]	10.89+/-0.91	9.84	11.50	[3]
	(75.1+/-6.3	67.8	79.3)		(75.1+/-6.3	67.8	79.3)	
111 CONTROL	11.24+/-0.04	11.18	11.29	[4]	11.11+/-0.08	11.00	11.19	[4]
	(77.5+/-0.3	77.1	77.8)		(76.6+/-0.6	75.8	77.2)	
111 EXPOSED	11.21+/-0.16	10.98	11.33	[4]	11.18+/-0.15	10.98	11.31	[4]
	(77.3+/-1.1	75.7	78.1)		(77.1+/-1.1	75.7	77.9)	
112 CONTROL	11.47+/-0.02	11.44	11.49	[3]	11.34+/-0.22	11.09	11.49	[3]
	(79.1+/-0.2	78.9	79.2)		(78.2+/-1.5	76.4	79.2)	
112 EXPOSED	11.41+/-0.04	11.36	11.44	[3]	11.17+/-0.33	10.81	11.44	[3]
	(78.6+/-0.3	78.3	78.9)		(77.0+/-2.3	74.5	78.9)	
115 CONTROL	11.26+/-0.16	11.13	11.44	[3]	11.23+/-0.11	11.13	11.35	[3]
	(77.6+/-1.1	76.7	78.9)		(77.4+/-0.8	76.7	78.3)	
115 EXPOSED	11.22+/-0.28	10.80	11.38	[4]	11.22+/-0.28	10.80	11.38	[4]
	(77.3+/-1.9	74.5	78.5)		(77.3+/-1.9	74.5	78.5)	
116 CONTROL	11.10+/-0.24	10.83	11.26	[3]	10.90+/-0.28	10.66	11.21	[3]
	(76.5+/-1.6	74.6	77.6)		(75.1+/-1.9	73.5	77.3)	
116 EXPOSED	11.07+/-0.22	10.83	11.34	[4]	11.07+/-0.22	10.83	11.34	[4]
	(76.3+/-1.5	74.7	78.2)		(76.3+/-1.5	74.7	78.2)	
AVG RUNS	75,76,95,97,103,104,107,108,111,112,115,116							
OV. CONTROL	10.78+/-0.71	7.76	11.51	[51]	10.74+/-0.69	7.76	11.49	[51]
	(74.3+/-4.9	53.5	79.4)		(74.0+/-4.7	53.5	79.2)	

Table 13B: STRESS; PACM-20 Cured Specimens Continued

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
AVG RUNS	75,76,95,97					
OV. CONTROL	10.09	7.76	11.34	10.09	7.76	11.34
	(69.5	53.5	78.2)	(69.5	53.5	78.2)

Measurement Accuracy: +/- 0.09 KSI

Table 13C: STRESS; Tonox 60/40, EPI REZ 5022 Cured Specimens

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
73 CONTROL	10.98+/-0.81	9.98	11.67 [4]	10.98+/-0.81	9.98	11.67 [4]
	(75.7+/-5.6	68.8	80.4)	(75.7+/-5.6	68.8	80.4)
73 EXPOSED	10.67+/-0.06	10.63	10.73 [3]	10.67+/-0.06	10.63	10.73 [3]
	(73.5+/-0.4	73.3	74.0)	(73.5+/-0.4	73.3	74.0)
74 CONTROL	10.32+/-0.56	9.51	11.15 [6]	10.32+/-0.56	9.51	11.15 [6]
	(71.1+/-3.8	65.6	76.9)	(71.1+/-3.8	65.6	76.9)
74 EXPOSED	10.28+/-0.55	9.55	11.06 [6]	10.28+/-0.55	9.55	11.06 [6]
	(70.9+/-3.8	65.8	76.2)	(70.9+/-3.8	65.8	76.2)

Measurement Accuracy: +/- 0.09 KSI

Table 13D: STRESS; mPDA Cured Specimens

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max [DPs]
71 CONTROL	11.78+/-0.71	11.06	12.49 [4]	11.78+/-0.71	11.06	12.49 [4]
	(81.2+/-4.9	76.3	86.1)	(81.2+/-4.9	76.3	86.1)
71 EXPOSED	12.29+/-0.42	11.80	12.73 [4]	12.29+/-0.42	11.80	12.73 [4]
	(84.7+/-2.9	81.4	87.8)	(84.7+/-2.9	81.4	87.8)

Table 13D: STRESS; mPDA Cured Specimens Continued

RUN	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max	[DPs]
72 CONTROL	12.52+/-0.63	11.67	13.42	[6]	12.52+/-0.63	11.67	13.42	[6]
	(86.3+/-4.3	80.5	92.6)		(86.3+/-4.3	80.5	92.6)	
72 EXPOSED	12.42+/-0.29	12.00	12.74	[5]	12.42+/-0.29	12.00	12.74	[5]
	(85.6+/-2.0	82.8	87.9)		(85.6+/-2.0	82.8	87.9)	
91 CONTROL	11.67+/-0.46	11.14	11.95	[3]	11.67+/-0.46	11.14	11.95	[3]
	(80.4+/-3.1	76.8	82.4)		(80.4+/-3.1	76.8	82.4)	
91 EXPOSED	11.54+/-1.68	9.10	12.80	[4]	11.54+/-1.68	9.10	12.80	[4]
	(79.6+/-11.6	62.8	88.3)		(79.6+/-11.6	62.8	88.3)	
94 CONTROL	12.58+/-0.29	12.26	12.88	[4]	12.58+/-0.29	12.26	12.88	[4]
	(86.7+/-2.0	84.5	88.8)		(86.7+/-2.0	84.5	88.8)	
94 EXPOSED	10.86+/-1.38	9.49	12.25	[3]	10.86+/-1.38	9.49	12.25	[3]
	(74.9+/-9.5	65.4	84.4)		(74.9+/-9.5	65.4	84.4)	
AVG RUNS	71,72,91,94							
OV.CONTROL	12.14	11.06	13.42		12.14	11.06	13.42	
	(83.7	76.3	92.6)		(83.7	76.3	92.6)	

Measurement Accuracy: +/- 0.09 KSI

TABLE 14A: STRAIN; MDA Cured Specimens

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
65 CONTROL	9.3+/-1.2	7.7	10.6	[6]	10.1+/-2.2	7.7	13.1	[6]
65 EXPOSED	9.1+/-1.0	8.3	10.3	[4]	9.1+/-1.0	8.3	10.3	[4]
66 CONTROL	9.0+/-0.5	6.7	11.0	[6]	9.6+/-2.9	6.7	13.9	[6]
66 EXPOSED	9.5+/-0.2	9.2	9.5	[4]	11.2+/-1.2	10.2	12.9	[4]
67 CONTROL	7.6+/-0.9	6.1	8.6	[5]	7.9+/-1.3	6.1	9.7	[5]
67 EXPOSED	6.4+/-0.9	5.5	7.9	[5]	6.6+/-1.4	5.5	9.0	[5]
68 CONTROL	5.4+/-1.7	4.5	8.0	[4]	5.5+/-1.9	4.5	8.3	[4]
68 EXPOSED	6.8+/-1.1	5.6	8.3	[4]	6.8+/-1.1	5.6	8.3	[4]
69 CONTROL	6.8+/-1.6	5.1	8.5	[6]	6.9+/-1.7	5.1	8.5	[6]
69 EXPOSED	7.3+/-1.0	5.3	8.3	[6]	7.5+/-1.2	5.3	8.5	[6]

TABLE 14A: STRAIN; MDA Cured Specimens Continued

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
70 CONTROL	6.9+/-0.9	6.2	8.2	[4]	7.0+/-1.1	6.2	8.5	[4]
70 EXPOSED	7.1+/-1.2	6.3	7.9	[2]	7.1+/-1.2	6.3	7.9	[2]
81 CONTROL	6.7+/-1.4	5.8	8.3	[3]	6.7+/-1.4	5.8	8.3	[3]
81 EXPOSED	6.2+/-1.9	4.8	8.4	[3]	6.2+/-1.9	4.8	8.4	[3]
87 CONTROL	7.3+/-1.1	5.3	8.4	[7]	7.9+/-1.8	5.3	9.9	[7]
87 EXPOSED	7.2+/-0.4	6.5	7.7	[5]	7.5+/-0.6	6.5	8.0	[5]
90 CONTROL	8.0+/-0.5	7.0	8.5	[6]	9.5+/-1.2	7.4	11.0	[6]
90 EXPOSED	7.9+/-0.6	7.2	8.8	[6]	9.1+/-2.0	7.3	12.6	[6]
99 CONTROL	7.3+/-0.4	7.0	7.5	[2]	7.3+/-0.4	7.0	7.5	[2]
99 EXPOSED	5.9+/-0.4	5.5	6.2	[3]	5.9+/-0.4	5.5	6.2	[3]
101 CONTROL	7.7+/-1.0	5.8	8.7	[6]	8.4+/-1.5	5.8	10.1	[6]
101 EXPOSED	7.9+/-0.7	6.9	8.8	[6]	8.6+/-1.3	6.9	10.4	[6]
105 CONTROL	6.6+/-1.2	5.0	8.1	[5]	6.8+/-1.4	5.0	8.6	[5]
105 EXPOSED	6.8+/-0.7	5.7	7.4	[5]	6.8+/-0.7	5.7	7.4	[5]
106 CONTROL	7.3+/-0.8	6.4	8.3	[4]	7.6+/-0.9	6.4	8.5	[4]
106 EXPOSED	6.5+/-0.9	5.7	7.4	[4]	6.6+/-1.0	5.7	7.5	[4]
109 CONTROL	8.4+/-1.2	7.0	9.1	[3]	8.4+/-1.2	7.0	9.1	[3]
109 EXPOSED	7.1+/-1.7	5.3	9.0	[4]	8.0+/-2.7	5.3	10.5	[4]
110 CONTROL	8.0+/-1.6	5.6	8.9	[4]	8.5+/-1.9	5.6	9.7	[4]
110 EXPOSED	8.2+/-0.3	7.7	8.5	[4]	9.6+/-2.0	8.0	12.4	[4]
113 CONTROL	7.3+/-2.0	4.4	8.7	[4]	7.6+/-2.2	4.5	9.6	[4]
113 EXPOSED	7.3+/-1.7	5.4	8.8	[3]	7.3+/-1.8	5.4	9.0	[3]
114 CONTROL	8.3+/-0.4	8.0	8.7	[3]	8.9+/-0.5	8.5	9.4	[3]
114 EXPOSED	6.9+/-1.2	5.4	8.2	[4]	6.9+/-1.2	5.4	8.2	[4]
AVG RUNS	69,70,81,87,90,99,101,105,106,109,110,113,114							
OV. CONTROL	7.4+/-0.6	4.4	9.1	[57]	7.8+/-0.9	4.5	11.0	[57]
AVG RUNS	67-70,81,87,90							
OV. CONTROL	7.0	4.5	8.6		7.3	4.5	11.0	

Measurement Accuracy: +/- 0.5 %

TABLE 14B: STRAIN; PACM-20 Cured Specimens

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
75 CONTROL	4.8+/-0.8	3.6	5.9	[8]	4.8+/-0.8	3.6	5.9	[8]
75 EXPOSED	4.7+/-0.8	3.5	5.4	[4]	4.7+/-0.8	3.5	5.4	[4]
76 CONTROL	6.1+/-1.3	4.5	7.8	[6]	6.1+/-1.3	4.5	7.8	[6]
76 EXPOSED	5.7+/-0.9	4.5	6.8	[6]	5.7+/-0.9	4.5	6.8	[6]
77 CONTROL	6.3+/-0.4	5.9	6.6	[3]	6.3+/-0.4	5.9	6.6	[3]
77 EXPOSED	4.8+/-0.8	3.7	5.5	[5]	4.8+/-0.8	3.7	5.5	[5]
78 CONTROL	6.0+/-1.2	4.4	7.4	[4]	6.2+/-1.5	4.4	8.1	[4]
78 EXPOSED	5.7+/-0.4	5.2	6.1	[3]	5.7+/-0.4	5.2	6.1	[3]
95 CONTROL	7.0+/-2.1	4.3	10.1	[5]	7.0+/-2.1	4.3	10.1	[5]
95 EXPOSED	7.6+/-1.2	6.5	8.9	[3]	7.6+/-1.2	6.5	8.9	[3]
97 CONTROL	7.8+/-0.4	7.3	8.0	[3]	7.8+/-0.4	7.3	8.0	[3]
97 EXPOSED	7.9+/-2.7	4.8	9.7	[3]	7.9+/-2.7	4.8	9.7	[3]
103 CONTROL	6.7+/-1.2	5.1	7.9	[5]	6.7+/-1.2	5.1	7.9	[5]
103 EXPOSED	7.4+/-0.6	6.7	8.1	[5]	7.4+/-0.6	6.7	8.1	[5]
104 CONTROL	7.2+/-1.3	5.6	8.6	[4]	7.3+/-1.4	5.7	9.0	[4]
104 EXPOSED	6.3+/-2.6	2.7	8.9	[5]	6.6+/-3.0	2.7	9.6	[5]
107 CONTROL	8.4+/-1.1	7.3	9.5	[3]	8.5+/-1.3	7.3	9.9	[3]
107 EXPOSED	8.0+/-0.6	7.2	8.6	[4]	8.1+/-0.8	7.2	9.0	[4]
108 CONTROL	8.5+/-1.1	7.1	9.7	[4]	8.8+/-1.3	7.2	10.1	[4]
108 EXPOSED	7.4+/-2.2	4.9	8.7	[3]	7.4+/-2.2	4.9	8.7	[3]
111 CONTROL	8.7+/-0.6	8.1	9.3	[4]	9.9+/-1.2	8.6	11.5	[4]
111 EXPOSED	8.9+/-0.9	7.7	9.7	[4]	9.4+/-1.2	7.7	10.1	[4]
112 CONTROL	8.9+/-0.4	8.6	9.3	[3]	10.2+/-2.2	8.9	12.8	[3]
112 EXPOSED	8.6+/-0.3	8.2	8.9	[3]	9.9+/-1.4	8.2	10.8	[3]
115 CONTROL	8.0+/-0.9	7.4	9.0	[3]	8.4+/-1.6	7.3	10.2	[3]
115 EXPOSED	7.9+/-1.0	6.4	8.7	[4]	8.0+/-1.1	6.4	8.8	[4]
116 CONTROL	7.8+/-1.0	6.8	8.6	[3]	9.2+/-2.7	6.8	12.2	[3]
116 EXPOSED	7.5+/-0.4	7.2	8.1	[4]	7.7+/-0.5	7.2	8.2	[4]

TABLE 14B: STRAIN; PACM-20 Cured Specimens Continued

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
AVG RUNS 75,76,95,97,103,104,107,108,11,112,115,116								
OV. CONTROL	7.5+/-1.2	3.6	10.1	[51]	7.9+/-1.6	3.6	12.8	[51]

Measurement Accuracy: +/- 0.5 %

TABLE 14C: STRAIN; TONOX 60/40, EPI REZ 5022, Cured Specimens

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
73 CONTROL	5.2+/-1.4	3.7	6.5	[4]	5.2+/-1.4	3.7	6.5	[4]
73 EXPOSED	5.0+/-0.2	4.9	5.2	[3]	5.0+/-0.2	4.9	5.2	[3]
74 CONTROL	5.2+/-0.8	3.8	6.1	[6]	5.2+/-0.8	3.8	6.1	[6]
74 EXPOSED	4.5+/-0.6	4.0	5.6	[6]	4.5+/-0.6	4.0	5.6	[6]

Measurement Accuracy: +/- 0.5 %

TABLE 14D: STRAIN; mPDA, Cured Specimens

RUN	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	[DPs]	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max	[DPs]
71 CONTROL	5.9+/-1.7	4.5	8.1	[4]	5.9+/-1.7	4.5	8.1	[4]
71 EXPOSED	6.6+/-0.6	5.8	7.1	[4]	6.6+/-0.6	5.8	7.1	[4]
72 CONTROL	6.3+/-0.7	5.4	7.0	[6]	6.3+/-0.7	5.4	7.0	[6]
72 EXPOSED	5.7+/-0.8	4.6	6.5	[5]	5.7+/-0.8	4.6	6.5	[5]
91 CONTROL	4.6+/-0.7	3.9	5.3	[3]	4.6+/-0.7	3.9	5.3	[3]
91 EXPOSED	4.6+/-1.3	3.0	6.2	[4]	4.6+/-1.3	3.0	6.2	[4]
94 CONTROL	5.7+/-0.7	5.0	6.6	[4]	5.7+/-0.7	5.0	6.6	[4]
94 EXPOSED	4.0+/-1.0	3.1	5.1	[3]	4.0+/-1.0	3.1	5.1	[3]
AVG RUNS 71,72,91,94								
OV. CONTROL	5.6	3.9	8.1		5.6	3.9	8.1	

Measurement Accuracy: +/- 0.5 %

Table 15 lists the Initial Youngs Modulus (modulus) of the magnetic field exposed and corresponding control specimens that were generated in those experimental runs that were also mechanically testable. As can be seen from the results listed in Table 15, there is no effective difference in the modulus of those specimens generated under any magnetic field strength exposure relative to their cogenerated controls.

There were no discernable differences in the modulus measurements between those specimens generated under any magnetic field strength exposure and their cogenerated controls for any of the runs conducted in this effort.

TABLE 15A: MODULUS; MDA Cured Specimens

RUN	Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
65 CONTROL	340+/-18	317	356	[6]	(2.34+/-0.12	2.19	2.45)
65 EXPOSED	327+/-14	312	345	[4]	(2.25+/-0.10	2.15	2.38)
66 CONTROL	306+/-14	294	328	[6]	(2.11+/-0.10	2.03	2.26)
66 EXPOSED	313+/-21	296	342	[4]	(2.16+/-0.14	2.04	2.36)
67 CONTROL	376+/-9	362	384	[5]	(2.59+/-0.06	2.50	2.65)
67 EXPOSED	380+/-27	342	406	[5]	(2.62+/-0.19	2.36	2.80)
68 CONTROL	356+/-23	334	378	[4]	(2.45+/-0.16	2.30	2.61)
68 EXPOSED	366+/-23	349	399	[4]	(2.52+/-0.16	2.41	2.75)
69 CONTROL	367+/-20	347	404	[6]	(2.53+/-0.14	2.39	2.79)
69 EXPOSED	378+/-67	338	512	[6]	(2.61+/-0.46	2.33	3.53)
70 CONTROL	369+/-31	332	407	[4]	(2.54+/-0.21	2.29	2.81)
70 EXPOSED	401+/-59	359	443	[2]	(2.76+/-0.41	2.48	3.05)
81 CONTROL	371+/-20	349	389	[3]	(2.56+/-0.14	2.41	2.68)
81 EXPOSED	369+/-2	368	371	[3]	(2.54+/-0.01	2.54	2.56)
87 CONTROL	358+/-9	345	368	[7]	(2.47+/-0.06	2.38	2.54)
87 EXPOSED	353+/-13	334	366	[5]	(2.43+/-0.09	2.30	2.52)
90 CONTROL	355+/-19	332	379	[6]	(2.45+/-0.13	2.29	2.61)
90 EXPOSED	351+/-17	326	375	[6]	(2.42+/-0.12	2.25	2.59)
99 CONTROL	361+/-17	349	373	[2]	(2.49+/-0.12	2.41	2.57)
99 EXPOSED	362+/-16	344	373	[3]	(2.50+/-0.11	2.37	2.57)

TABLE 15A: MODULUS; MDA Cured Specimens Continued

RUN	Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
101 CONTROL	345+/-18	323	376	[6]	(2.38+/-0.12	2.23	2.59)
101 EXPOSED	332+/-18	316	363	[6]	(2.29+/-0.12	2.18	2.50)
105 CONTROL	372+/-11	361	387	[5]	(2.56+/-0.08	2.49	2.67)
105 EXPOSED	367+/-13	357	386	[5]	(2.53+/-0.09	2.46	2.66)
106 CONTROL	365+/-17	347	385	[4]	(2.52+/-0.12	2.39	2.65)
106 EXPOSED	380+/-6	375	386	[4]	(2.62+/-0.04	2.59	2.66)
109 CONTROL	335+/-20	319	357	[3]	(2.31+/-0.14	2.20	2.46)
109 EXPOSED	350+/-17	340	375	[4]	(2.41+/-0.12	2.34	2.59)
110 CONTROL	333+/-6	329	343	[4]	(2.30+/-0.04	2.27	2.36)
110 EXPOSED	337+/-10	323	347	[4]	(2.32+/-0.07	2.23	2.39)
113 CONTROL	342+/-17	329	367	[4]	(2.36+/-0.12	2.27	2.53)
113 EXPOSED	333+/-9	327	344	[3]	(2.30+/-0.06	2.25	2.37)
114 CONTROL	340+/-11	327	347	[3]	(2.34+/-0.08	2.25	2.39)
114 EXPOSED	343+/-15	323	354	[4]	(2.36+/-0.10	2.23	2.44)
AVG RUNS	69,70,81,87,90,99,101,105,106,109,110,113,114						
OV. CONTROL	355+/-14	319	407	[57]	(2.45+/-0.10	2.20	2.81)
AVG RUNS	67-70,81,87,90						
OV. CONTROL	365	332	407		(2.51	2.29	2.81)

TABLE 15B: MODULUS; PACM-20 Cured Specimens

RUN	Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
75 CONTROL	295+/-13	277	318	[8]	(2.03+/-0.09	1.91	2.19)
75 EXPOSED	301+/-8	290	308	[4]	(2.08+/-0.06	2.00	2.12)
76 CONTROL	311+/-19	290	334	[6]	(2.14+/-0.13	2.00	2.30)
76 EXPOSED	303+/-5	294	308	[6]	(2.09+/-0.03	2.03	2.12)
77 CONTROL	401+/-82	366	453	[3]	(2.76+/-0.57	2.52	3.12)
77 EXPOSED	414+/-64	371	488	[3]	(2.85+/-0.44	2.56	3.36)
78 CONTROL	348+/-8	338	354	[4]	(2.40+/-0.06	2.33	2.44)
78 EXPOSED	379+/-30	345	400	[3]	(2.61+/-0.21	2.38	2.76)

TABLE 15B: MODULUS; PACM-20 Cured Specimens Continued

RUN		Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
95	CONTROL	334+/-8	327	346	[5]	(2.30+/-0.06	2.25	2.39)
95	EXPOSED	349+/-12	335	359	[3]	(2.41+/-0.08	2.31	2.48)
97	CONTROL	312+/-10	302	322	[3]	(2.15+/-0.07	2.08	2.22)
97	EXPOSED	321+/-14	307	336	[3]	(2.21+/-0.10	2.12	2.32)
103	CONTROL	323+/-11	309	339	[5]	(2.23+/-0.08	2.13	2.34)
103	EXPOSED	332+/-8	321	343	[5]	(2.29+/-0.06	2.21	2.36)
104	CONTROL	337+/-12	319	347	[4]	(2.32+/-0.08	2.20	2.39)
104	EXPOSED	344+/-14	331	365	[5]	(2.37+/-0.10	2.28	2.52)
107	CONTROL	308+/-10	297	316	[3]	(2.12+/-0.07	2.05	2.18)
107	EXPOSED	324+/-6	321	333	[4]	(2.23+/-0.04	2.21	2.30)
108	CONTROL	327+/-12	318	343	[4]	(2.25+/-0.08	2.19	2.36)
108	EXPOSED	335+/-11	326	347	[3]	(2.31+/-0.08	2.25	2.39)
111	CONTROL	326+/-13	312	339	[4]	(2.25+/-0.09	2.15	2.34)
111	EXPOSED	316+/-8	307	327	[4]	(2.18+/-0.06	2.12	2.25)
112	CONTROL	333+/-13	321	347	[3]	(2.30+/-0.09	2.21	2.39)
112	EXPOSED	332+/-10	323	343	[3]	(2.29+/-0.07	2.23	2.36)
115	CONTROL	324+/-3	322	327	[3]	(2.23+/-0.02	2.22	2.25)
115	EXPOSED	320+/-10	310	334	[4]	(2.21+/-0.07	2.14	2.30)
116	CONTROL	331+/-4	326	335	[3]	(2.28+/-0.03	2.25	2.31)
116	EXPOSED	330+/-14	310	342	[4]	(2.28+/-0.10	2.14	2.36)
AVG	RUNS	75,76,95,97,103,104,107,108,111,112,115,116						
OV.	CONTROL	322+/-13	277	347	[51]	(2.22+/-0.09	1.91	2.39)
AVG	RUNS	75,76,95,97						
OV.	CONTROL	313	277	346		(2.16	1.91	2.39)

TABLE 15C: MODULUS; TONOX 60/40,EPIREZ 5022 Cured Specimens

RUN		Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
73	CONTROL	404+/-20	384	431	[4]	(2.79+/-0.14	2.65	2.97)
73	EXPOSED	380+/-9	374	390	[3]	(2.62+/-0.06	2.58	2.69)

TABLE 15C: MODULUS; TONOX 60/40,EPIREZ 5022 Cured Specimens

RUN	Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
74 CONTROL	380+/-15	362	404	[6]	(2.62+/-0.10	2.50	2.79)
74 EXPOSED	392+/-24	357	422	[6]	(2.70+/-0.17	2.46	2.91)

TABLE 15D: MODULUS; mPDA, Cured Specimens

RUN	Modulus KSI Mean+/-Std	Min	Max	[DPs]	(GPa) Mean+/-Std	Min	Max
71 CONTROL	379+/-37	330	419	[4]	(2.61+/-0.26	2.28	2.89)
71 EXPOSED	371+/-26	341	401	[4]	(2.56+/-0.18	2.35	2.77)
72 CONTROL	382+/-24	344	419	[6]	(2.63+/-0.17	2.37	2.89)
72 EXPOSED	406+/-32	371	454	[5]	(2.80+/-0.22	2.56	3.13)
91 CONTROL	411+/-32	376	443	[4]	(2.83+/-0.22	2.59	3.05)
91 EXPOSED	407+/-23	382	430	[4]	(2.81+/-0.16	2.63	2.97)
94 CONTROL	392+/-30	359	431	[4]	(2.70+/-0.21	2.48	2.97)
94 EXPOSED	419+/-29	386	441	[3]	(2.89+/-0.20	2.66	3.04)
AVG RUNS	71,72,91,94						
OV. CONTROL	391	330	443		(2.70	2.28	3.05)

Table 16 lists the Toughness, as measured from the areas under the stress versus strain curves, of the magnetic field exposed and corresponding control specimens that were generated in those experimental runs that were mechanically testable. As can be seen from the results listed in Table 16, there is, with only four exceptions out of 37 measured averages, no resolvable differences between the toughness exhibited by those specimens generated under any magnetic field strength exposure and their cogenerated controls.

Runs 77, 94, 99, and 114 are the only runs in this experimental effort to exhibit a difference in the toughness exhibited by magnetic field exposed specimens relative to their associated control specimens. The average toughness results for the control specimens are discernibly larger than the same results for the magnetic field exposed specimens. Also the range of these toughness results for the four control specimens are marginally larger than and do not overlap the range of the toughness

results for the four corresponding exposed specimens. These differences in the control and exposed toughness for these four runs are not significant. The toughness values for Runs 77 and 99 are less than the overall average toughness values for the curing agents used. This indicates that the specimens, both control and exposed, generated from the batches of resins using these curing agents were marginal to begin with. Also the range of the exposed toughness values for Runs 77, 99, and 114 are well within the range of the overall average of the controls. The range of Run 94's toughness values extends well into the range of it's like curing agent cured overall control's and its average is well within two stds of the overall same cured control's average. Run 114's control value and range values are high in comparison to it's like curing agent cured control average and range; where as, Run 114's exposed value and range are roughly equal to the overall control values and range. In Run 114's case it is the control value that is the anomalous statistical exception and not the exposed value. Based on these points, the difference between Runs 77, 94, 99, and 114 exposed and control toughness values are not significant and represent statistical anomalies.

TABLE 16A: TOUGHNESS; MDA Cured Specimens

RUN	Energy To Break / Area						
	$Ft\text{-}Lb_f/in^2$				(J/cm^2)		
	Mean+/-Std	Min	Max	[DPs]	Mean+/-Std	Min	Max
65 CONTROL	34.71+/-10.86	23.86	48.69	[6]	(165.1+/-51.7	113.8	231.7)
65 EXPOSED	29.84+/-4.60	25.92	35.49	[4]	(142.0+/-21.9	123.3	168.9)
66 CONTROL	31.88+/-13.75	18.19	52.69	[6]	(151.7+/-65.4	86.6	250.7)
66 EXPOSED	40.56+/-7.93	34.56	52.08	[4]	(193.0+/-37.7	164.5	247.8)
67 CONTROL	27.39+/-6.25	18.83	36.31	[5]	(130.3+/-29.7	89.6	172.8)
67 EXPOSED	21.44+/-6.82	16.09	33.35	[5]	(102.0+/-32.5	76.6	158.7)
68 CONTROL	15.64+/-8.05	11.32	27.70	[4]	(74.4+/-38.3	53.9	131.8)
68 EXPOSED	21.85+/-5.82	16.24	29.96	[4]	(104.0+/-27.7	77.3	142.6)
69 CONTROL	22.86+/-8.48	13.62	31.79	[6]	(108.8+/-40.4	64.8	151.3)
69 EXPOSED	26.14+/-5.19	16.70	31.15	[6]	(124.4+/-24.7	79.5	148.2)
70 CONTROL	23.01+/-5.47	18.94	30.74	[4]	(109.5+/-26.0	90.1	146.3)
70 EXPOSED	23.72+/-6.07	19.43	28.01	[2]	(112.9+/-28.9	92.5	133.3)
81 CONTROL	22.55+/-6.67	18.10	30.22	[3]	(107.3+/-31.7	86.1	143.8)
81 EXPOSED	20.10+/-9.10	13.39	30.46	[3]	(95.6+/-43.3	63.7	145.0)
87 CONTROL	28.26+/-8.95	14.93	37.76	[7]	(134.5+/-42.6	71.0	179.7)
87 EXPOSED	25.81+/-2.67	21.38	28.33	[5]	(122.8+/-12.7	101.7	134.8)

TABLE 16A: TOUGHNESS; MDA Cured Specimens Continued

RUN	Energy To Break / Area Ft-Lb_f/in^2 Mean+/-Std	Min	Max	[DPs]	(J/cm^2) Mean+/-Std	Min	Max
90 CONTROL	35.95+/-6.13	25.66	43.20	[6]	(171.1+/-29.2	122.1	205.6)
90 EXPOSED	33.53+/-9.28	25.09	50.19	[6]	(159.6+/-44.2	119.4	238.8)
99 CONTROL	25.36+/-1.70	24.15	26.56	[2]	(120.7+/-8.1	114.9	126.4)
99 EXPOSED	18.26+/-2.77	16.30	20.23	[3]	(86.9+/-13.2	77.6	96.3)
101 CONTROL	30.96+/-7.68	17.40	39.58	[6]	(147.3+/-36.5	82.8	188.3)
101 EXPOSED	31.17+/-6.72	22.48	40.91	[6]	(148.3+/-32.0	107.0	194.7)
105 CONTROL	22.75+/-6.61	14.31	32.13	[5]	(108.3+/-31.5	68.1	152.9)
105 EXPOSED	23.30+/-3.17	18.16	26.16	[5]	(110.9+/-15.1	86.4	124.5)
106 CONTROL	27.19+/-4.86	20.44	31.24	[4]	(129.4+/-23.1	97.3	148.7)
106 EXPOSED	22.97+/-5.45	18.12	27.91	[4]	(109.3+/-25.9	86.2	132.8)
109 CONTROL	29.28+/-5.06	23.44	32.39	[3]	(139.3+/-24.1	111.5	154.1)
109 EXPOSED	28.81+/-13.51	15.25	41.39	[4]	(137.1+/-64.3	72.6	197.0)
110 CONTROL	30.59+/-9.60	16.30	36.85	[4]	(145.6+/-45.7	77.6	175.4)
110 EXPOSED	36.82+/-10.67	28.78	51.65	[4]	(175.2+/-50.8	137.0	245.8)
113 CONTROL	26.52+/-10.91	11.17	36.34	[4]	(126.2+/-51.9	53.2	172.9)
113 EXPOSED	24.65+/-8.83	15.14	32.59	[3]	(117.3+/-42.0	72.0	155.1)
114 CONTROL	33.30+/-2.62	30.49	35.68	[3]	(158.5+/-12.5	145.1	169.8)
114 EXPOSED	23.46+/-5.82	16.02	29.55	[4]	(111.6+/-27.7	76.2	140.6)
AVG RUNS	69,70,81,87,90,99,101,105,106,109,110,113,114						
OV. CONTROL	27.58+/-4.33	11.17	43.20	[57]	(131.2+/-20.6	53.2	205.6)
AVG RUNS	67-70,81,87,90						
OV. CONTROL	25.09	11.32	43.20		(119.4	53.9	205.6)

TABLE 16B: TOUGHNESS; PACM-20 Cured Specimens

RUN	Energy To Break / Area Ft-Lb_f/in^2 Mean+/-Std	Min	Max	[DPs]	(J/cm^2) Mean+/-Std	Min	Max
75 CONTROL	10.82+/-3.02	6.69	15.45	[8]	(51.5+/-14.4	31.8	73.5)
75 EXPOSED	10.50+/-2.96	6.42	13.38	[4]	(50.0+/-14.1	30.6	63.7)
76 CONTROL	16.28+/-5.28	9.92	23.38	[6]	(77.5+/-25.1	47.2	111.3)
76 EXPOSED	14.39+/-3.78	9.55	19.30	[6]	(68.5+/-18.0	45.4	91.8)

TABLE 16B: TOUGHNESS; PACM-20 Cured Specimens Continued

RUN	Energy To Break / Area $Ft\text{-}lb_f/in^2$ Mean+/-Std	Min	Max	[DPs]	(J/cm^2) Mean+/-Std	Min	Max
77 CONTROL	19.61+/-1.66	17.69	20.64	[3]	(93.3+/-7.9	84.2	98.2)
77 EXPOSED	12.86+/-3.44	8.43	14.79	[5]	(61.2+/-16.4	40.1	70.4)
78 CONTROL	19.14+/-6.82	11.24	27.90	[4]	(91.1+/-32.5	53.5	132.8)
78 EXPOSED	17.27+/-2.34	14.70	19.29	[3]	(82.2+/-11.1	69.9	91.8)
95 CONTROL	21.29+/-9.63	9.78	35.82	[5]	(101.3+/-45.8	46.5	170.5)
95 EXPOSED	23.54+/-5.27	18.58	29.08	[3]	(112.0+/-25.1	88.4	138.4)
97 CONTROL	24.23+/-2.23	21.65	25.57	[3]	(115.3+/-10.6	103.0	121.7)
97 EXPOSED	25.19+/-11.76	11.71	33.32	[3]	(119.9+/-56.0	55.7	158.6)
103 CONTROL	19.51+/-5.39	12.72	25.07	[5]	(92.8+/-25.6	60.5	119.3)
103 EXPOSED	23.01+/-3.05	19.92	26.20	[5]	(109.5+/-14.5	94.8	124.7)
104 CONTROL	22.89+/-6.31	15.54	30.53	[4]	(108.9+/-30.0	74.0	145.3)
104 EXPOSED	20.40+/-12.62	4.50	33.96	[5]	(97.1+/-60.1	21.4	161.6)
107 CONTROL	27.74+/-5.84	22.60	34.09	[3]	(132.0+/-27.8	107.5	162.2)
107 EXPOSED	25.76+/-3.57	21.34	29.96	[4]	(122.6+/-17.0	101.6	142.6)
108 CONTROL	29.72+/-6.06	22.36	35.89	[4]	(141.4+/-28.8	106.4	170.8)
108 EXPOSED	23.45+/-9.92	11.99	29.29	[3]	(111.6+/-47.2	57.1	139.4)
111 CONTROL	34.84+/-5.24	28.86	41.56	[4]	(165.8+/-24.9	137.3	197.8)
111 EXPOSED	31.95+/-5.70	23.48	35.51	[4]	(152.0+/-27.1	111.7	169.0)
112 CONTROL	36.67+/-10.55	30.52	48.85	[3]	(174.5+/-50.2	145.2	232.5)
112 EXPOSED	34.92+/-6.63	27.32	39.54	[3]	(166.2+/-31.6	130.0	188.2)
115 CONTROL	27.94+/-7.73	22.65	36.81	[3]	(133.0+/-36.8	107.8	175.2)
115 EXPOSED	26.03+/-5.04	18.81	29.76	[4]	(123.9+/-24.0	89.5	141.6)
116 CONTROL	31.65+/-12.78	20.57	45.64	[3]	(150.6+/-60.8	97.9	217.2)
116 EXPOSED	24.98+/-2.55	21.80	27.08	[4]	(118.9+/-12.1	103.7	128.9)
AVG RUNS	75,76,95,97,103,104,107,108,111,112,115,116						
OV. CONTROL	25.29+/-7.63	6.69	48.85	[51]	(120.3+/-36.3	31.8	232.5)
AVG RUNS	75,76,95,97						
OV. CONTROL	18.16	6.69	35.82		(86.4	31.8	170.5)

TABLE 16C: TOUGHNESS; TONOX 60/40, EPI REZ 5022 Cured Specimens

RUN	Energy To Break / Area $Ft\text{-}lb_f/in^2$ Mean+/-Std	Min	Max	[DPs]	(J/cm^2) Mean+/-Std	Min	Max
73 CONTROL	16.20+/-6.65	9.33	22.52	[4]	(77.1+/-31.6	44.4	107.2)
73 EXPOSED	14.45+/-0.64	13.82	15.10	[3]	(68.8+/-3.0	65.8	71.9)
74 CONTROL	14.64+/-3.45	9.03	19.22	[6]	(69.7+/-16.4	43.0	91.5)
74 EXPOSED	12.24+/-2.88	9.55	17.46	[6]	(58.2+/-13.7	45.4	83.1)

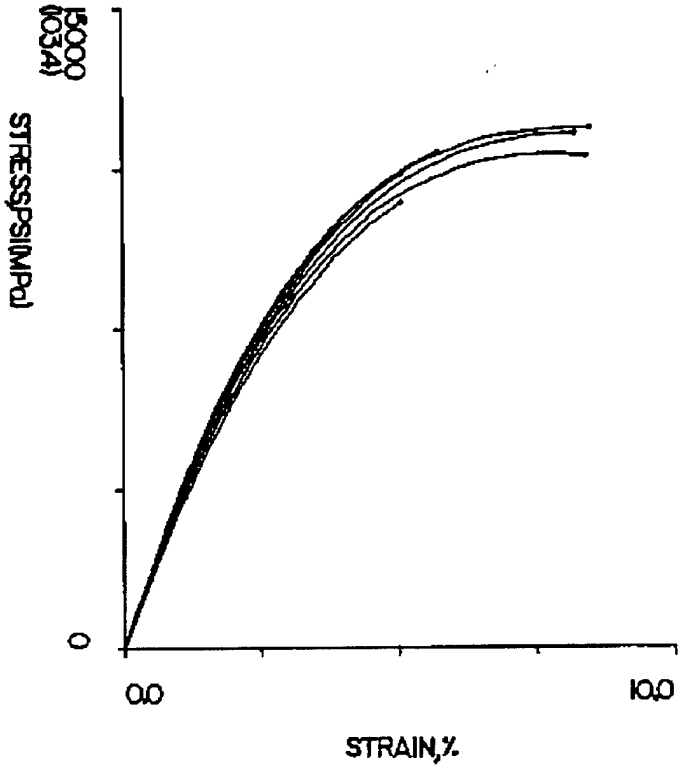
TABLE 16D: TOUGHNESS; mPDA, Cured Specimens

RUN	Energy To Break / Area $Ft\text{-}lb_f/in^2$ Mean+/-Std	Min	Max	[DPs]	(J/cm^2) Mean+/-Std	Min	Max
71 CONTROL	18.74+/-7.85	12.18	29.11	[4]	(89.2+/-37.4	58.0	138.5)
71 EXPOSED	22.08+/-2.90	18.29	25.18	[4]	(105.1+/-13.8	87.0	119.8)
72 CONTROL	21.46+/-4.11	16.92	26.63	[6]	(102.1+/-19.6	80.5	126.7)
72 EXPOSED	18.83+/-3.45	14.01	22.46	[5]	(89.6+/-16.4	66.7	106.9)
91 CONTROL	13.78+/-2.85	10.78	16.45	[3]	(65.6+/-13.6	51.3	78.3)
91 EXPOSED	13.94+/-6.16	6.29	21.31	[4]	(66.3+/-29.3	29.9	101.4)
94 CONTROL	19.30+/-3.38	16.12	23.87	[4]	(91.8+/-16.1	76.7	113.6)
94 EXPOSED	11.08+/-4.61	6.94	16.04	[3]	(52.7+/-21.9	33.0	76.3)
AVG RUNS	71,72,91,94						
OV. CONTROL	18.32	10.78	29.11		(87.2	51.3	138.5)

Figures 22 thru 28 are the stress versus strain curves of Runs 69, 72, 73, 78, 87, 97, and 111. These curves are representative of all of the stress versus strain curves resulting from the mechanical testing of specimens from all of the experimental runs and the curing styles used. As can be seen from these curves their is no discernable difference between those for specimens generated while exposed to a magnetic field relative to their simultaneously generated controls.

Overall the mechanical properties of resin systems that have been fully cured while simultaneously exposed to the magnetic field strengths and associated ranges as delineated in Table 5 are not enhanced by this exposure. While enhancements to the mechanical properties of these epoxy resin systems may exist when selected, very tightly controlled magnetic field strengths within this overall range are used, these enhancements are not apparent from this experimental effort's results and appear to not be viable for incorporation into actual production devices.

Run 69 CONTROL Stress Versus Strain Curves:



Run 69 EXPOSED Stress Versus Strain Curves:

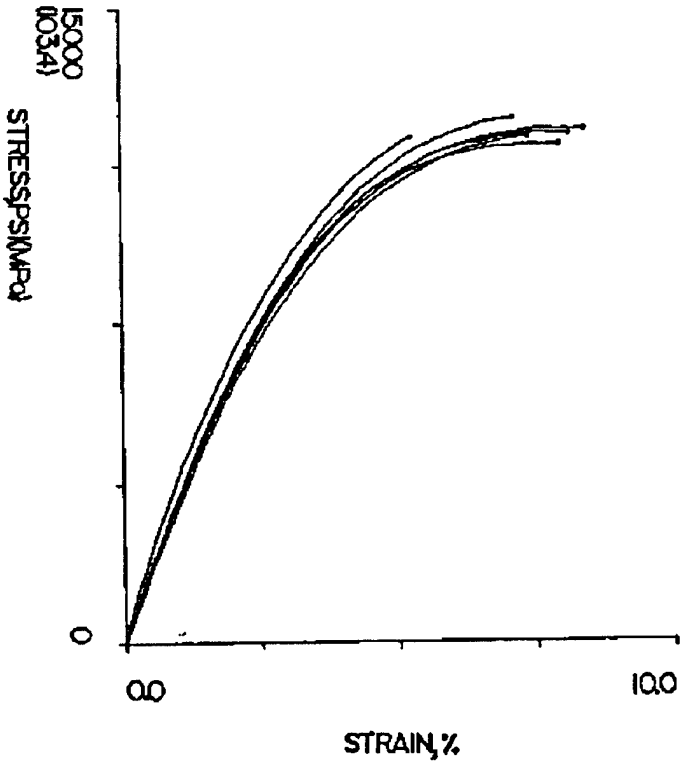
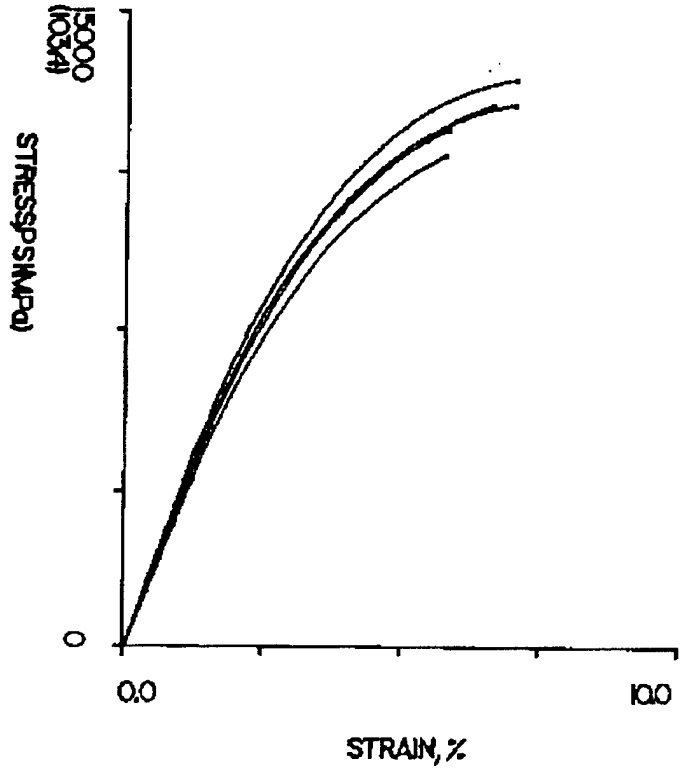


Figure 22: Run 69 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - MDA

Run 72 CONTROL Stress Versus Strain Curves:



Run 72 EXPOSED Stress Versus Strain Curves:

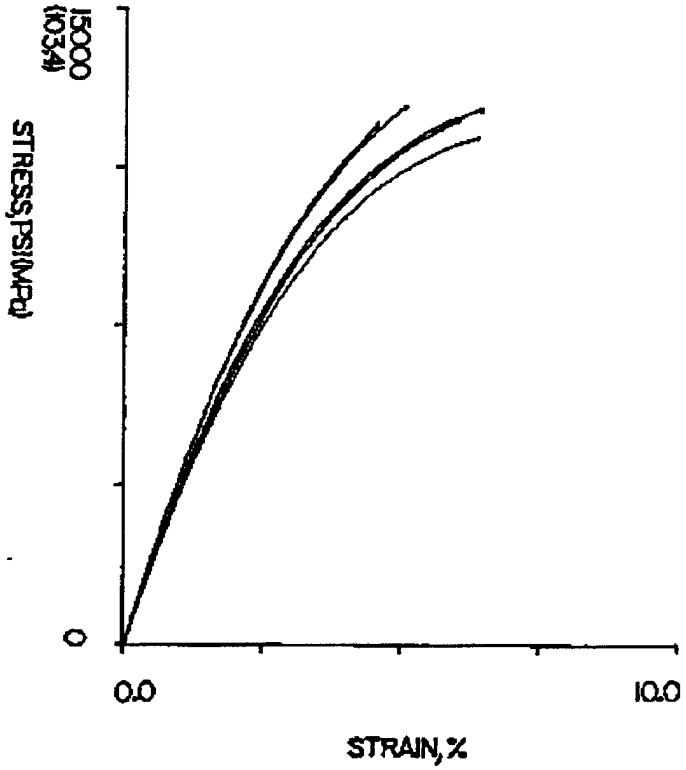
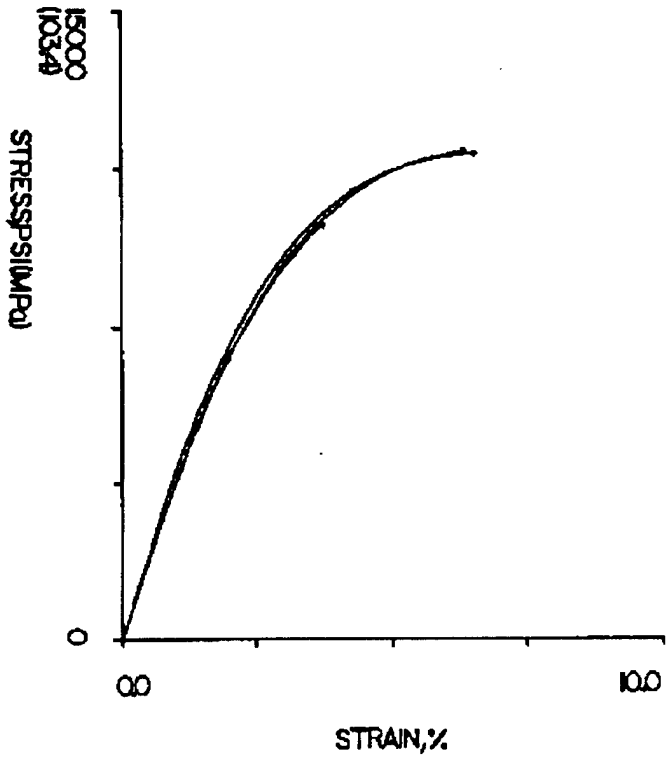


Figure 23: Run 72 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - mPDA

Run 73 CONTROL Stress Versus Strain Curves:



Run 73 EXPOSED Stress Versus Strain Curves:

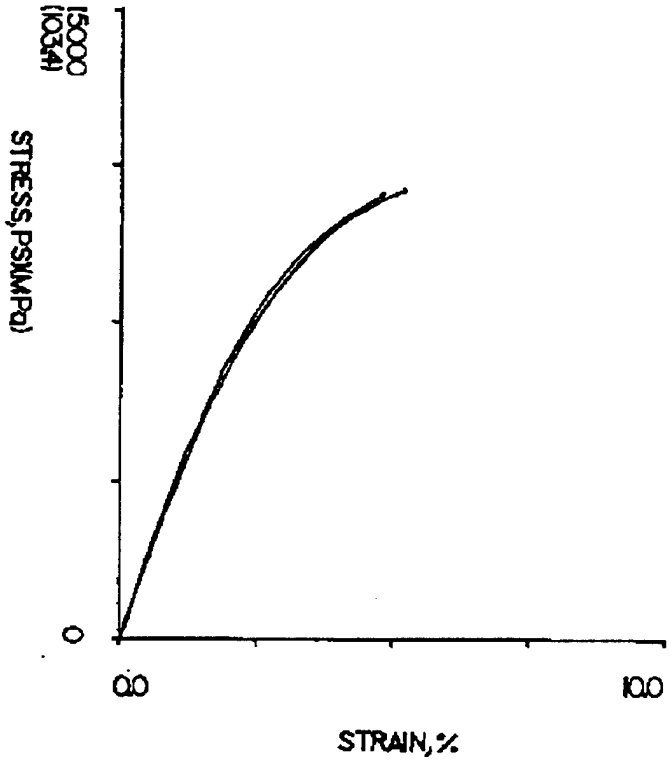
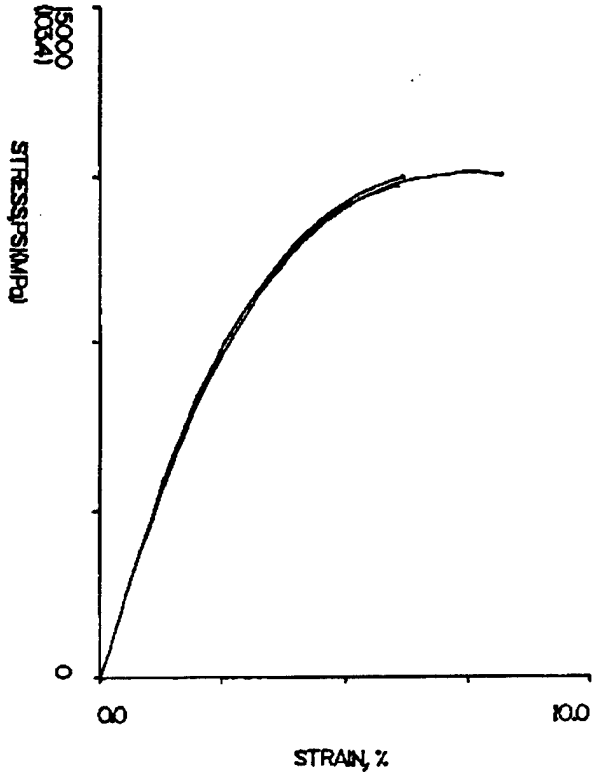


Figure 24: Run 73 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - TONOX 60/40 - EPI REZ 5022

Run 78 CONTROL Stress Versus Strain Curves:



Run 78 EXPOSED Stress Versus Strain Curves:

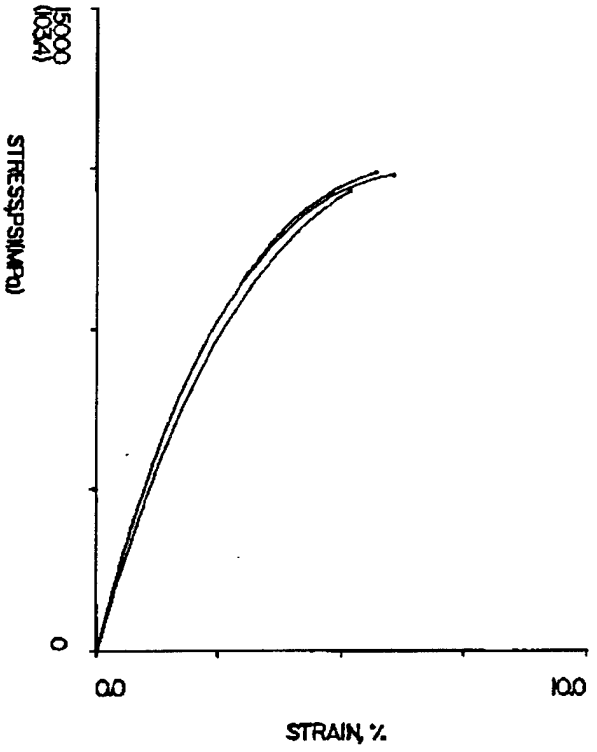
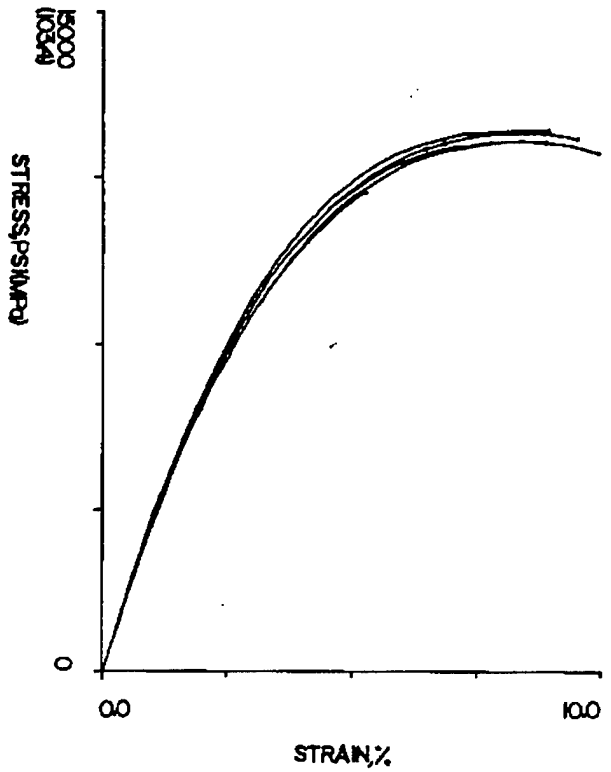


Figure 25: Run 78 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - PACM-20

Run 87 CONTROL Stress Versus Strain Curves:



Run 87 EXPOSED Stress Versus Strain Curves:

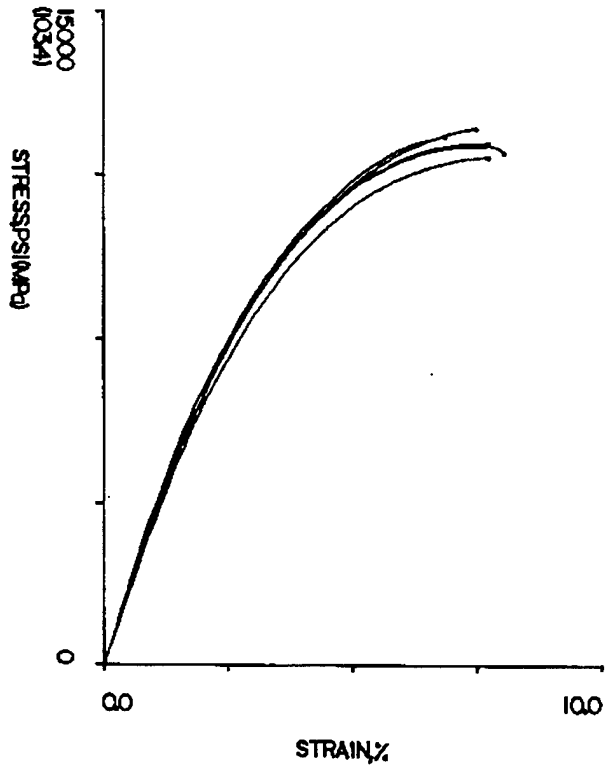
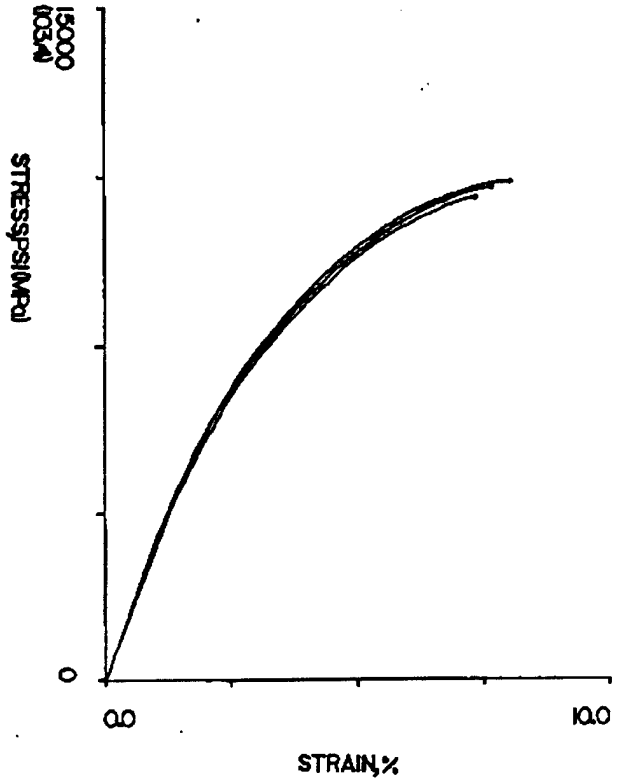


Figure 26: Run 87 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - MDA

Run 97 CONTROL Stress Versus Strain Curves:



Run 97 EXPOSED Stress Versus Strain Curves:

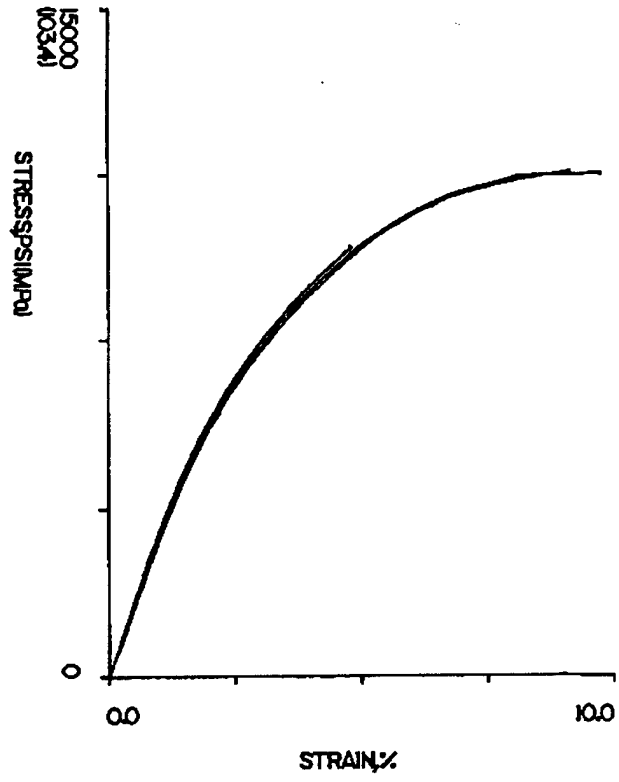
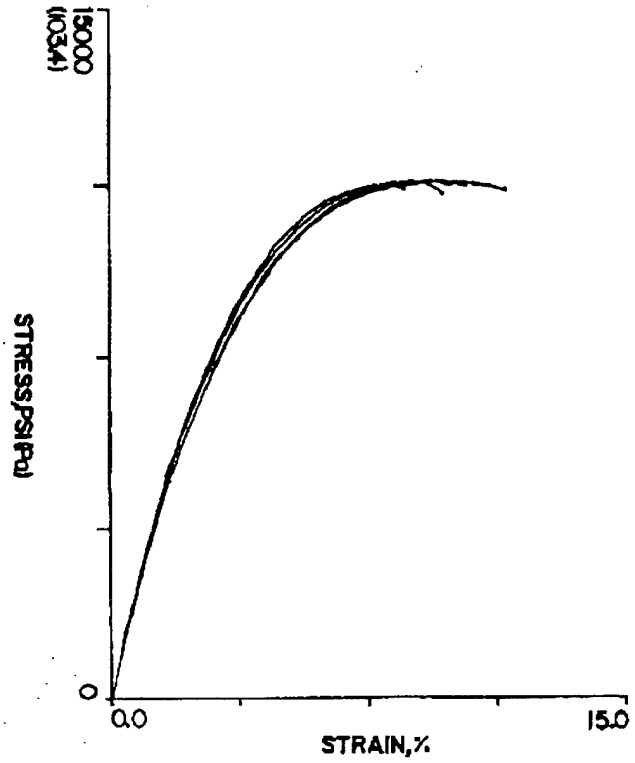


Figure 27: Run 97 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - PACM-20

Run 111 CONTROL Stress Versus Strain Curves:



Run 111 EXPOSED Stress Versus Strain Curves:

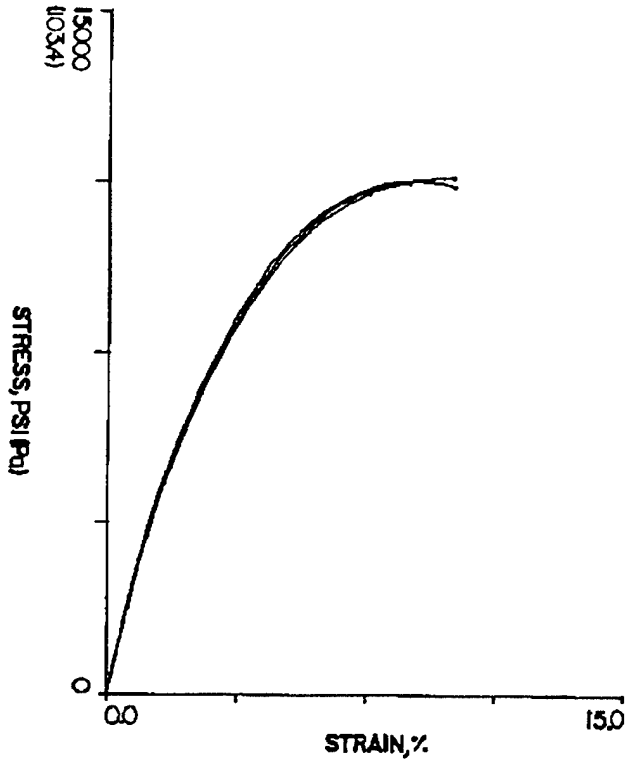


Figure 28: Run 111 Stress Versus Strain Curves
Note: Epoxy Resin System Used EPON 830 - PACM-20

These mechanical results do not support the extensive list of mechanical property enhancement results published by the S-R's.(21-155) They indicated that they were able to achieve numerous enhancements in the mechanical properties of similar resin systems cured in similar ways while simultaneously exposed to similar magnetic field strengths. These mechanical property results cast serious doubt on the validity of those S-R claims.

Thermal Studies Results

Glass Transition Temperature Results

Table 17 lists the Glass Transition Temperatures (Tg) of the magnetic field exposed and corresponding control specimens in those experimental runs that generated mechanically testable specimens. As can be seen from the results listed in Table 17 with only six exceptions out of 37 measured averages, there is no discernable difference in Tgs exhibited by those specimens generated under any magnetic field strength exposure relative to their cogenerated controls.

TABLE 17A: Tg; MDA Cured Specimens

RUN	Tg ^{o}F				(^{o}C)		
	Mean+/-Std	Min	Max	[DPs]	Mean+/-Std	Min	Max
65 EXPOSED	333+/-2	331	335	[4]	(167+/-1	166	169)
65 CONTROL	335+/-3	331	337	[4]	(168+/-1	166	169)
66 EXPOSED	335+/-1	334	335	[4]	(168+/-0.4	168	169)
66 CONTROL	335+/-0.2	335	335	[4]	(168+/-0.1	168	169)
67 EXPOSED	311+/-1	309	312	[4]	(155+/-1	154	156)
67 CONTROL	316+/-1	314	317	[4]	(158+/-1	157	158)
68 EXPOSED	309+/-6	300	313	[4]	(154+/-3	149	156)
68 CONTROL	313+/-3	310	317	[4]	(156+/-2	155	158)
69 EXPOSED	308+/-1	306	309	[3]	(153+/-1	152	154)
69 CONTROL	314+/-1	313	314	[3]	(156+/-0.4	156	157)
70 EXPOSED	305+/-1	303	306	[4]	(151+/-1	150	152)
70 CONTROL	309+/-1	308	310	[4]	(154+/-1	153	155)

TABLE 17A: Tg; MDA Cured Specimens Continued

RUN	Tg °F Mean+/-Std	Min	Max	[DPs]	(°C) Mean+/-Std	Min	Max
81 EXPOSED	302+/-2	300	304	[3]	(150+/-1	149	151)
81 CONTROL	304+/-0.5	303	304	[3]	(151+/-0.3	151	151)
87 EXPOSED	313+/-0.3	313	314	[3]	(156+/-0.2	156	157)
87 CONTROL	309+/-1	308	310	[3]	(154+/-0.4	154	154)
90 EXPOSED	301+/-1	300	302	[3]	(150+/-1	149	151)
90 CONTROL	295+/-1	294	295	[3]	(146+/-1	145	146)
99 EXPOSED	303+/-1	301	304	[3]	(150+/-1	150	151)
99 CONTROL	293+/-1	292	295	[3]	(145+/-1	144	146)
101 EXPOSED	306+/-1	305	307	[3]	(152+/-1	152	153)
101 CONTROL	293+/-3	291	296	[3]	(145+/-1	144	147)
105 EXPOSED	307+/-8	299	313	[3]	(153+/-4	148	156)
105 CONTROL	305+/-3	302	307	[3]	(152+/-2	150	153)
106 EXPOSED	298+/-5	295	304	[3]	(148+/-3	146	151)
106 CONTROL	309+/-1	308	311	[3]	(154+/-1	153	155)
109 EXPOSED	299+/-3	298	302	[3]	(148+/-1	148	150)
109 CONTROL	318+/-1	317	319	[3]	(159+/-1	158	160)
110 EXPOSED	295+/-2	293	297	[3]	(146+/-1	145	147)
110 CONTROL	309+/-1	309	310	[3]	(154+/-0.4	154	154)
113 EXPOSED	312+/-2	310	314	[3]	(156+/-1	155	157)
113 CONTROL	310+/-1	310	311	[3]	(155+/-1	154	155)
114 EXPOSED	307+/-1	305	307	[3]	(153+/-1	152	153)
114 CONTROL	309+/-4	306	313	[3]	(154+/-2	152	156)
AVG RUNS	69,70,81,87,90,99,101,105,106,109,110,113,114						
OV. CONTROL	306+/-8	291	319	[40]	(152+/-4	141	160)
AVG RUNS	67-70-81,87,90						
OV. CONTROL	309	294	317		(154	146	158)

Measurement Accuracy: +/- 1.1 °C

TABLE 17B: Tg; PACM-20 Cured Specimens

RUN	Tg °F Mean+/-Std	Min	Max	[DPs]	(°C) Mean+/-Std	Min	Max
75 EXPOSED	299+/-2	297	301	[4]	(148+/-1	147	149)
75 CONTROL	305+/-3	302	308	[4]	(152+/-1	150	153)
76 EXPOSED	308+/-1	307	309	[4]	(153+/-0.3	153	154)
76 CONTROL	314+/-2	312	315	[4]	(157+/-1	156	157)
77 EXPOSED	283+/-0.5	282	283	[4]	(139+/-0.3	139	140)
77 CONTROL	291+/-1	290	293	[4]	(144+/-1	143	145)
78 EXPOSED	285+/-1	284	285	[4]	(140+/-0.3	140	141)
78 CONTROL	286+/-1	284	287	[4]	(141+/-1	140	142)
95 EXPOSED	297+/-1	296	298	[3]	(147+/-1	146	148)
95 CONTROL	298+/-2	295	299	[3]	(148+/-1	146	149)
97 EXPOSED	300+/-2	298	302	[3]	(149+/-1	148	150)
97 CONTROL	297+/-1	296	298	[3]	(147+/-1	147	148)
103 EXPOSED	305+/-5	302	311	[3]	(152+/-3	150	155)
103 CONTROL	304+/-6	297	310	[4]	(151+/-3	147	155)
104 EXPOSED	296+/-3	293	299	[3]	(147+/-2	145	148)
104 CONTROL	295+/-2	293	296	[3]	(146+/-1	145	147)
107 EXPOSED	305+/-2	302	306	[3]	(151+/-1	150	152)
107 CONTROL	298+/-2	297	300	[3]	(148+/-1	147	149)
108 EXPOSED	297+/-1	296	298	[3]	(147+/-1	147	148)
108 CONTROL	292+/-1	291	293	[3]	(144+/-0.5	144	145)
111 EXPOSED	307+/-1	307	308	[3]	(153+/-0.4	153	153)
111 CONTROL	302+/-2	301	304	[3]	(150+/-1	149	151)
112 EXPOSED	296+/-5	292	302	[3]	(147+/-3	144	150)
112 CONTROL	296+/-4	294	300	[3]	(147+/-2	145	149)
115 EXPOSED	308+/-1	307	308	[3]	(153+/-0.4	153	153)
115 CONTROL	308+/-1	306	309	[3]	(153+/-1	152	154)
116 EXPOSED	297+/-1	296	297	[3]	(147+/-0.3	147	147)
116 CONTROL	297+/-1	295	298	[3]	(147+/-1	146	148)
AVG RUNS	75,76,95,97,103,104,107,108,111,112,115,116						
OV. CONTROL	301+/-6	291	315	[39]	(149+/-3	144	157)

TABLE 17B: Tg; PACM-20 Cured Specimens

RUN	Tg °F Mean+/-Std	Min	Max	[DPs]	(°C) Mean+/-Std	Min	Max
AVG RUNS	75,76,95,97						
OV. CONTROL	304+/-2	295	315		(151+/-1	146	157)

Measurement Accuracy: +/- 1.1 °C

TABLE 17C: Tg; TONOX 60/40, EPI REZ 5022 Cured Specimens

RUN	Tg °F Mean+/-Std	Min	Max	[DPs]	(°C) Mean+/-Std	Min	Max
73 EXPOSED	263+/-5	258	269	[4]	(128+/-3	126	131)
73 CONTROL	262+/-6	258	271	[4]	(128+/-3	125	133)
74 EXPOSED	262+/-3	260	266	[4]	(128+/-1	127	130)
74 CONTROL	262+/-3	259	266	[4]	(128+/-2	126	130)

Measurement Accuracy: +/- 1.1 °C

TABLE 17D: Tg; mPDA Cured Specimens

RUN	Tg °F Mean+/-Std	Min	Max	[DPs]	(°C) Mean+/-Std	Min	Max
71 EXPOSED	307+/-1	306	308	[3]	(153+/-1	152	154)
71 CONTROL	319+/-1	318	320	[3]	(160+/-1	159	160)
72 EXPOSED	299+/-6	291	305	[4]	(148+/-3	144	151)
72 CONTROL	308+/-2	306	310	[4]	(153+/-1	152	154)
91 EXPOSED	310+/-4	307	314	[3]	(155+/-2	153	157)
91 CONTROL	299+/-0.1	299	299	[3]	(148+/-0.1	148	148)
94 EXPOSED	300+/-1	299	301	[3]	(149+/-0.5	148	149)
94 CONTROL	304+/-2	302	307	[3]	(151+/-1	150	153)
AVG RUNS	71,72,91,94						
OV. CONTROL	308+/-8	299	320		(153+/-4.5	148	160)

Measurement Accuracy: +/- 1.1 °C

Run 110 is the only run in the 17 experimental runs of this effort which used MDA as a curing agent to exhibit a minutely discernable difference in the Tg results between magnetic field exposed specimens and their control specimens. The Tg average results for the control specimens are larger than the same results for the magnetic field exposed specimens. Also the range of these Tg results for the control specimens is larger than and does not overlap the range of the Tg results for the exposed specimens. These differences in the control and exposed Tgs are not significant. Run 110's control average and range values are high in comparison to the overall control average and range. This indicates that its values are slightly anomalous. Where as, Run 110's exposed average and range are well within the overall control's range. Based on these points, the difference between Run 110's exposed and control Tg values is not significant and is a statistical anomaly.

Run 77 represents the only run in the 14 experimental runs of this effort to use PACM-20 as a curing agent to exhibit an irrefutable difference in the Tg results between magnetic field exposed specimens and their control specimens. It is also the only run throughout the entire effort to exhibit an irrefutable difference in any value measured from the control and exposed specimens generated in any experimental run. Run 77's control Tg value is $5^{o}C$ higher than its associated exposed value. Unfortunately due to the fact that Runs 77 and 78 are the only runs to use the $210^{o}F(99^{o}C)$ cure profile nothing more can be stated to refute or support this finding.

Runs 71, 72, 91, and 94 are the four experimental runs in this effort to use mPDA as their curing agent. They all exhibit minutely discernable differences in the Tg results between magnetic field exposed specimens and their control specimens. The Tg average results for the control specimens of Runs 71, 72, and 94 are larger than the same results for the magnetic field exposed specimens. Also the range of these Tg results for these control specimens are larger than and do not overlap the range of the Tg results for their corresponding exposed specimens. The exact reverse is the case for the results generated in Run 91. The differences in these control and exposed Tgs are not significant.

For Run 94 the Tg values for both runs are below the overall average Tg value for this curing agent. This indicates that the specimens, both control and exposed,

generated from this batch of resin were marginal to begin with. Also the range of the exposed Tg values for this run is well within the range of the overall control's average. Also when the Tg measurement accuracy of the DSC used to measure these Tgs is considered (see Table 3 for the DSC's specifics) and added to the inaccuracy represented by the STDs of the exposed and control averages the inaccuracy ranges overlap and the two values are not statistically different. Based on these points, the difference between Run 94's exposed and control Tg values is not significant and is a statistical anomaly.

The average Tg for the control of Run 91 is at the lowest end of the range of Tg values for the overall control's average and indicates that this run's control Tg is itself an anomaly. Additionally Run 91's exposed Tg average is almost identical to the overall control's average Tg. From these facts, the difference between Run 91's exposed and control Tg values is not significant and is a statistical anomaly.

When the Tg measurement accuracy of the DSC used to measure Run 72's Tgs is considered (see Table 3 for the DSC's specifics) and added to the inaccuracy represented by the STDs of the exposed and control Tg averages the inaccuracy ranges overlap and the two values are not statistically different. Also the range of Run 72's exposed Tg values extends well into the range of it's like curing agent cured overall control's and its exposed average is well within two stds of the overall same overall control's average. Considering these facts, the difference between Run 72's exposed and control Tg values is not significant and is a statistical anomaly.

Run 71's control average and range values are the largest measured in this effort for this curing agent and cure profile; where as, Run 71's exposed average Tg is equal to the overall control's value and its exposed range values are comfortably in the middle of the range values of the overall control. In Run 71's case it is the control average Tg value that is the anomalous statistical exception and not the exposed average Tg value. With this information, the difference between Run 71's exposed and control average Tg's is not significant and is a statistical anomaly.

Degree Of Cure Results

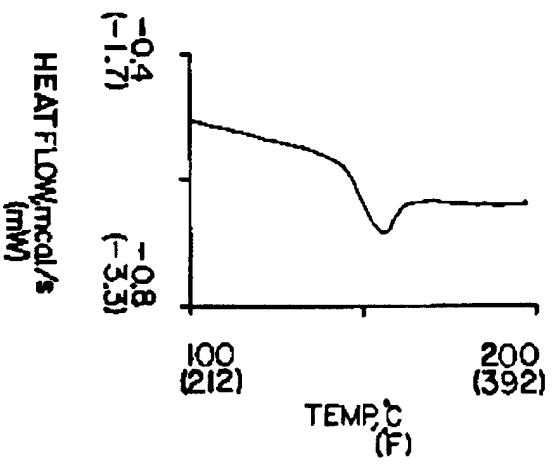
Table 18 lists the worst case degrees of cure found for the exposed specimens and control specimens generated in the various experimental runs with each of the six listed cure styles. With the exception of the PACM-20, 28.0 PHR, 210°F(99°C) 20 Hrs cure style, all specimens generated in this effort were cured to 99+% of full cure for that curing temperature. The two runs using the 210°F(99°C) cure were cured to 98+%. The two experimental runs which used the Tonox 250°F(121°C) cure style were cured so extensively that it was difficult for the PI to discern any H_{res}. To error on the conservative side, the PI declared them to be 99.99% cured. As also can be seen from Table 18 there was no effective difference between the degree of cure found in specimens cast while exposed to magnetic fields relative to those cast as their associated controls.

Table 18: Degrees Of Cure

Curing Agent	Concentration Range (PHR)	Thermal Cure Profile	Worst Case Degree Of Cure CONTROL (%)	EXPOSED (%)
PACM-20	28.0	250°F(121°C) 5 Hrs	99.6	99.4
PACM-20	28.0	210°F(99°C) 20 Hrs	98.9	98.3
Tonox Epi Rez	29.9 24.9	250°F(121°C) 5 Hrs	99.99	99.99
mPDA	14.0	250°F(121°C) 5 Hrs	99.8	99.9
MDA	25.5 to 26.0	250°F(121°C) 5 Hrs	99.5	99.5
MDA	27.0 to 28.0	300°F(149°C) 4 Hrs	99.9	99.9

Figures 29 thru 35 are the Heat Flow versus Temperature DSC curves of Runs 69, 72, 73, 78, 87, 97, and 111. These curves are representative of all of the DSC curves resulting from the thermal testing of specimens from all of the experimental runs and the curing styles used. As can be seen from these curves their is no discernable difference between those for specimens generated while exposed to a magnetic field relative to their associated controls.

DSC For Run 69 CONTROL:



DSC For Run 69 EXPOSED:

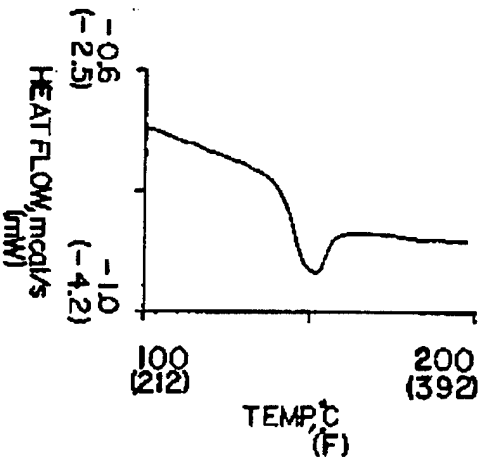
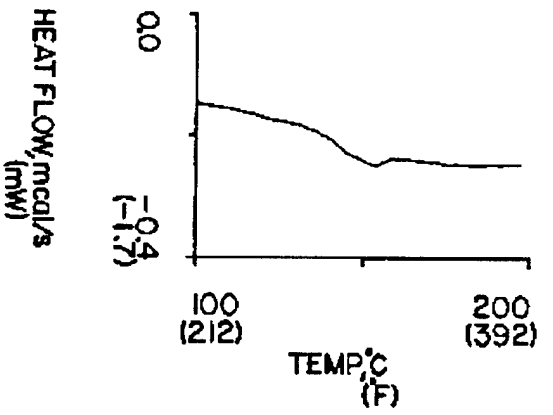


Figure 29: RUN 69 DSCs

Note: Epoxy Resin System Used EPON 830 - MDA

DSC For Run 72 CONTROL:



DSC For Run 72 EXPOSED:

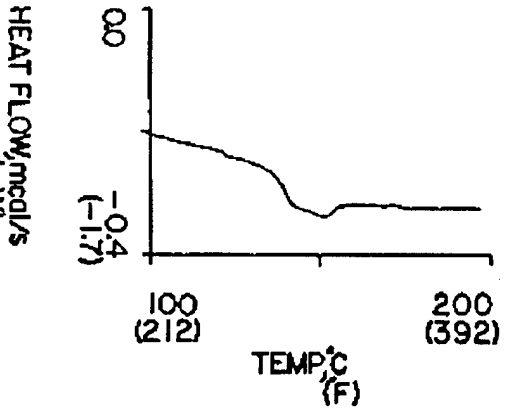
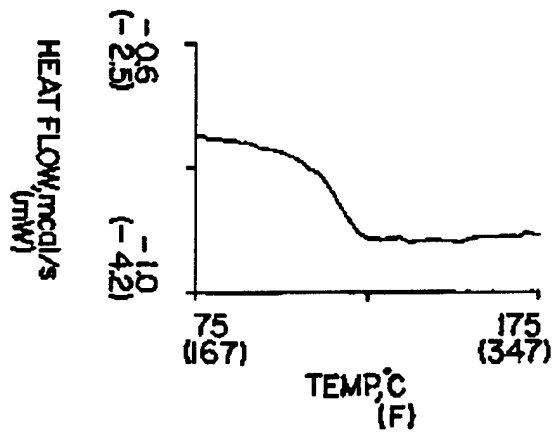


Figure 30: RUN 72 DSCs

Note: Epoxy Resin System Used EPON 830 - mPDA

DSC For Run 73 CONTROL:



DSC For Run 73 EXPOSED:

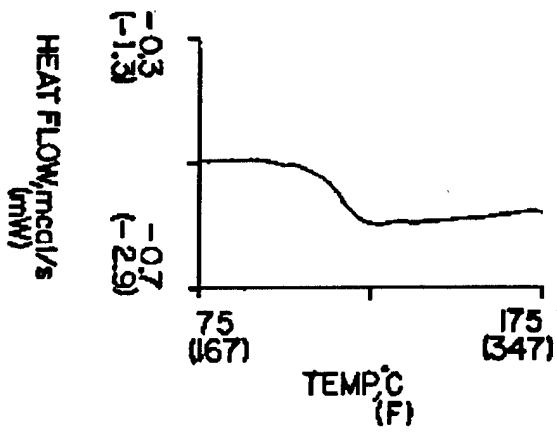
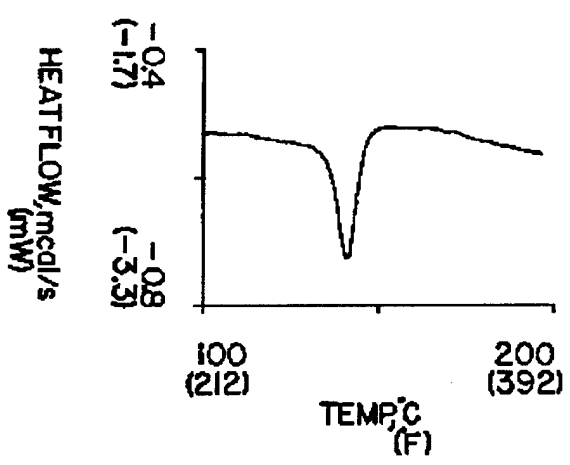


Figure 31: RUN 73 DSCs

Note: Epoxy Resin System Used EPON 830 - TONOX 60/40 - EPI REZ 5022

DSC For Run 78 CONTROL:



DSC For Run 78 EXPOSED:

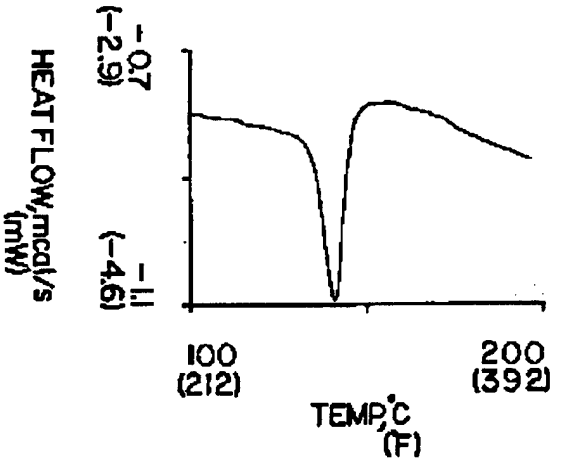
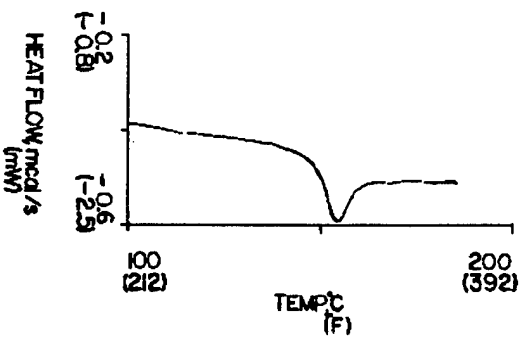


Figure 32: RUN 78 DSCs

Note: Epoxy Resin System Used EPON 830 - PACM-20

DSC For Run 87 CONTROL:



DSC For Run 87 EXPOSED:

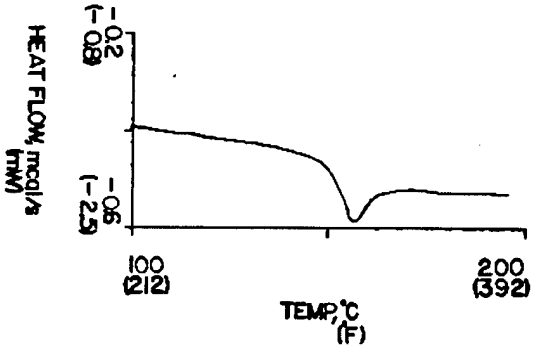
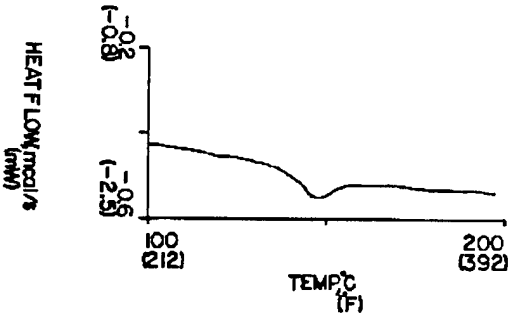


Figure 33: RUN 87 DSCs

Note: Epoxy Resin System Used EPON 830 - MDA

DSC For Run 97 CONTROL:



DSC For Run 97 EXPOSED:

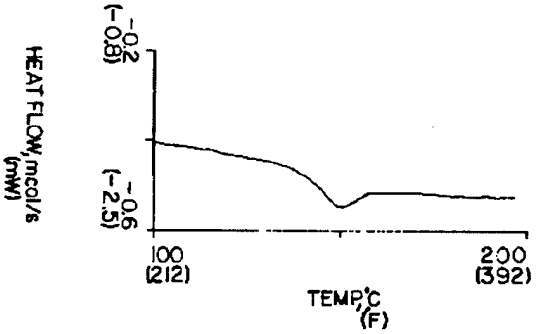
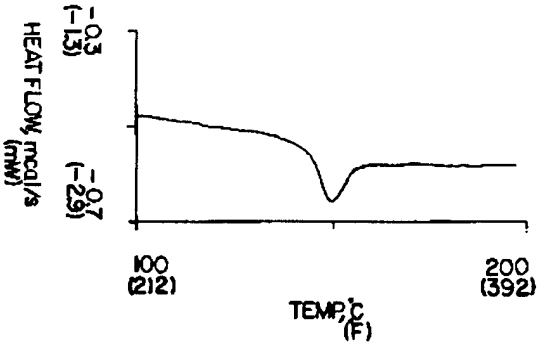


Figure 34: RUN 97 DSCs

Note: Epoxy Resin System Used EPON 830 - PACM - 20

DSC For Run 111 CONTROL:



DSC For Run 111 EXPOSED:

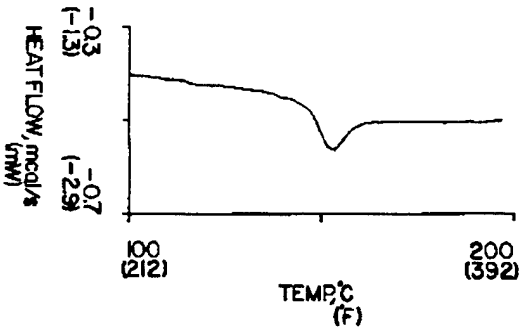


Figure 35: RUN 111 DSCs

Note: Epoxy Resin System Used EPON 830 - PACM - 20

Overall the thermal properties of resin systems that have been fully cured while simultaneously exposed to the magnetic field strengths and associated ranges as delineated in Table 5 are not enhanced by magnetic field exposure. While enhancements to the thermal properties of epoxy resin systems may exist when selected, very tightly controlled magnetic field strengths are used within this overall range, they are not indicated from this experimental effort's results.

These thermal results do not support the thermal property enhancement results published by the S-R's.(21-155) They indicated that they were able to achieve enhancements of up to 12°C in the Tgs of similar resin systems cured in similar ways while being simultaneously exposed to similar magnetic field strengths. These thermal property results cast serious doubt on the validity of those S-R claims.

Control Comparison Studies Results

Table 19 lists the various relevant control specimen derived mechanical and thermal properties for the three core curing styles used in this experimental effort. 25.5 PHR 99+% MDA 250°F(121°C) 5 hrs, 28.0 PHR 97+% PACM-20 250°F(121°C), and 14.0 PHR 99+% mPDA 250°F(121°C) are those three core and most commonly used cure styles. Table 20 lists the values of these same properties for similar base epoxy resins cured with analogous concentrations of the same curing agents, but with 302°F(150°C) multi-hour thermal cures. When the information in the two tables is compared three facts can be deduced. One, the stress values and the Tg values are effectively identical. Two, the modulus values for this experimental effort's control specimens are only slightly reduced from the reference values. And Three, the stain values are as much as twice as great for this effort's control generated specimens as compared to the reference values.

The slightly reduced values of the control's modulus relative to the reference's values and the substantially increased strain values of the controls relative to the reference's is the direct result of the cure temperatures used. The 250°F(121°C) temperature profile used to generate the specimens and their subsequent values listed on Table 19 resulted in the generation of moderately highly crosslinked, and subsequently less stiff and substantially tougher cured epoxy resin systems than the analogous resin systems listed on Table 20. Table 20's referenced values

all were reported to be generated from specimens which were cured at 50°F(29°C) hotter temperatures. This modest increase in cure temperature obviously resulted in more brittle, but stiffer cured epoxy resin systems.

Overall when the mechanical and thermal results tabulated in Table 19 for the control specimens of this effort are contrasted and compared to the reference values listed in Table 20 they are effectively equivalent. This effective equivalence indicates that the techniques used to generate the specimens and then test them are reasonable. It also indicates that any lack of difference between the properties of the magnetic field exposed specimens of any one run relative to its associated control's properties is the result of the nonexistence of any property enhancement resulting from said processing and not an unanticipated resultant of the experimental technique. In essence the technique produced reasonable and usable control specimens which when tested subsequently produced reasonable and valid control results. It therefore follows that this technique would have clearly indicated any enhancements to the properties of specimens generated while simultaneously exposed to a magnetic field if there had been any enhancements to find.

Table 19A: OVERALL OBSERVED CONTROL: STRESS

Curing Agent Type	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max
MDA	11.97+/-0.27 (82.6+/-1.9	10.30 71.0	12.47 86.0)	11.92+/-0.26 (82.2+/-1.8	10.30 71.0	12.46 85.9)
PACM-20	10.78+/-0.71 (74.3+/-4.9	7.76 53.5	11.51 79.4)	10.74+/-0.69 (74.0+/-4.7	7.76 53.5	11.49 79.2)
mPDA	12.14 (83.7	11.06 76.3	13.42 92.6)	12.14 (83.7	11.06 76.3	13.42 92.6)

Measurement Accuracy: +/- 0.09 KSI

Table 19B: OVERALL OBSERVED CONTROL: STRAIN

Curing Agent Type	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max
MDA	7.4+/-0.6	4.4	9.1	7.8+/-0.9	4.5	11.0
PACM-20	7.5+/-1.2	3.6	10.1	7.9+/-1.6	3.6	12.8
mPDA	5.6	3.9	8.1	5.6	3.9	8.1

Measurement Accuracy: +/- 0.5%

Table 19C: OVERALL OBSERVED CONTROL: MODULUS

Curing Agent Type	Modulus KSI Mean+/-Std	Min	Max	(GPa) Mean+/-Std	Min	Max
MDA	355+/-14	319	407	(2.45+/-0.10	2.20	2.81)
PACM-20	322+/-13	277	347	(2.22+/-0.09	1.91	2.39)
mPDA	391	330	443	(2.70	2.28	3.05)

Table 19D: OVERALL OBSERVED CONTROL: Tg

Curing Agent Type	Tg ^{o}F Mean+/-Std	Min	Max	(^{o}C) Mean+/-Std	Min	Max
MDA	306+/-8	291	319	(152+/-4	141	160)
PACM-20	301+/-6	291	315	(149+/-3	144	157)
mPDA	308+/-8	299	320	(153+/-4.5	148	160)

Measurement Accuracy: +/- 1.1 ^{o}C

Table 20A: REFERENCE REPORTED CONTROL: STRESS(157,163)

Curing Agent Type	Tensile Stress At Yield (Peak Stress) KSI (MPa) Mean+/-Std	Min	Max	Ultimate Tensile Stress (Break Stress) KSI (MPa) Mean+/-Std	Min	Max
MDA			12.80 (88)			
PACM-20						10.10 (70)
mPDA			12.40 (85)			
mPDA				13.0+/-0.4 (89.6+/-2.8)		

Table 20B: REFERENCE REPORTED CONTROL: STRAIN(157,163)

Curing Agent Type	Strain To Yield (Peak Strain) % Mean+/-Std	Min	Max	Strain To Failure (Break Strain) % Mean+/-Std	Min	Max
MDA						5.8
PACM-20						6.2
mPDA						5.1
mPDA				5.74+/-0.67		

Table 20C: REFERENCE REPORTED CONTROL: MODULUS(157,163)

Curing Agent Type	Modulus KSI Mean+/-Std	Min	Max	(GPa) Mean+/-Std	Min	Max
MDA			403			(2.8)
PACM-20			360			(2.5)
mPDA			480			(3.3)
mPDA	424+/-28			(2.9+/-0.19)		

Table 20D: REFERENCE REPORTED CONTROL: Tg(157,163)

Curing Agent Type	Tg °F Mean+/-Std	Min	Max	(°C) Mean+/-Std	Min	Max
MDA			319			(160)
MDA		302	319		(150	160)
PACM-20			302			(150)

Table 20D: REFERENCE REPORTED CONTROL: Tg (157,163) Continued

Curing Agent Type	Tg °F Mean+/-Std	Min	Max	(°C) Mean+/-Std	Min	Max
PACM-20			300			(149)
mPDA			302			(150)
mPDA			315			(158)

Discussion

Theory Synopsis

Based upon the successful results of the PI's 86 work, a theory was developed to explain the enhancements found. The theory explained them as being the direct and anisotropic result of the magnetic field's effect on the rotational behavior of the molecules in an epoxy resin system, with the field having a particularly significant effect on the DGEBA epoxy molecules through their aromatic groups. Overall, the magnetic fields suppress the disaligning effects of the randomizing thermal collisions experienced during cure on these previously flow field aligned molecules. If the initial degree of molecular alignment is substantial enough and if the magnetic field is strong enough, then the physical manifestation of simultaneously curing the resin system while exposing it to a magnetic field will be significant improvements in the mechanical and thermal properties of the final cured epoxy resin system.

When an organic molecule is placed in an external magnetic field, superconductive current loops are generated and restrained within each of the molecular orbitals defining the molecule.(21-5) The orientation dependence of the magnitude of the current on these current loops, the shape of these current loops, and the area encompassed by these current loops is defined by the specifics of the molecular orbital. Sigma molecular orbitals generate low magnitude currents on effectively the same small flux area sized current loops regardless of the orientation of the external magnetic field. They and the current loops that they generate are effectively isotropic. Conjugated pi aromatic ring molecular orbitals generate different magnitude currents on different flux area sized current loops depending upon the orientation of the aromatic ring

plane to the external magnetic field. They generate modest magnitude currents on modest flux area sized current loops when they are oriented plane parallel to the external magnetic field. But when they are oriented plane perpendicular to the external magnetic field, they generate high magnitude currents on current loops with relatively large flux areas. The EPON 830 DGEBA molecule mix contains at least two and sometimes four of these aromatic groups.

The theoretical explanation developed by the PI, which explained the results found in the PI's and Dr Mallon's efforts, is based upon the behavior of a current loop placed in an external magnetic field. For this explanation the current loop's behavior in an external magnetic field is dictated by the interplay of two associated electro-magnetic phenomena coupled with the motion restraining work they result in doing on the current loop. The two associated phenomena concern the effect which Faraday's Law and Lenz's Law have on the rotational motion of a current loop in an external magnetic field. Faraday's Law states that when a current loop is forced to rotate in a magnetic field a voltage occurs on the current in the loop. Lenz's Law compliments Faraday's Law by stating that the voltage sets up a complimentary current in the current loop which generates its own magnetic field to oppose the change in the flux of the magnetic field through the area encompassed by the current loop. This complimentary current will be acted upon by the original external magnetic field with a force. This force will apply a torque on the current loop which damps the rotational motion of the current loop and stops the flux change through the current loop.

The current loops generated in the aromatic groups of DGEBA epoxy molecules and aromatic based amine curing agents will also be acted upon by an external magnetic field in exactly the same fashion as previously described. Since there are two or four of these aromatic groups rigidly attached to and compromising the backbone of an epoxy or curing agent molecule, the external magnetic field will act upon all of those groups and the molecule in unison. Due to the molecule's rotation around its center of mass and the lever arm represented by the distance from that center of mass to the rigidly attached aromatic group, the molecule's overall rotation will be damped out even faster than just a single aromatic group's rotation would. As an example, the rotational damping rate of a basic DGEBA molecule (ie with only two aromatic groups in its molecular make up) initially rotating at a rate of one revolution (cycle) per min when placed in a 5000 Oe (0.5T) magnetic field was calculated by the PI to be $-1*10^{13}$ Cycles per

Second^2.(21-5) This initial rotation rate is in the range expected to be exhibited by the molecules comprising a liquid mass of the epoxy resin system. Obviously the faster the initial rotation rate and the stronger the magnetic field the faster the damping rate. That ratio is roughly one order of magnitude increase in the damping rate for each order of magnitude increase in the initial rotation rate or doubling of the magnetic field strength.

Obviously exposing the aromatic group containing molecules of an epoxy resin system to an external magnetic field would nearly instantaneously stop rotations in those molecules that caused flux changes through those aromatic groups. If the molecules in an epoxy resin system could be aligned by some mechanism, then proper alignment of the magnetic field relative to both the previously aligned molecules and the end bulk item could retain the alignment of the molecules in an epoxy resin system and so result in substantial improvements in that item's final properties.

Proposed Explanation

The theory elaborated in the previous section neatly explains the 60 to 100 percent improvements in the properties of the 75 percent room temperature aliphatic cured epoxy resin systems experimented on in the PI's 86 and early 90's efforts. At the described cure conditions these resins were still essentially just large molecules in an initially liquid, then turning into a glass like state, over the duration of the experimental run at room temperature. They were insufficiently cured to become the astronomically large molecules that are the hallmark of polymers. In essence, the resin system still behaved like a blend of liquid constituent monomers whose orientation could be constrained and controlled as previously described.

For this effort, substantially greater temperatures were used to drive the degree of cure of the epoxy resin systems experimented with to effective completion: ie 99+ percent. As the degree of cure increased, the aromatic cured epoxy resin systems stopped behaving like simple large molecules and started behaving like a polymer. Instead of the rotations, translations, and vibrations of simple monomer sized molecules now entire cured sections of the epoxy were vibrating, translating, and rotating as a unified part of the large mass subsections of the overall polymer. In addition to this, the now few and far between unreacted

epoxy and amine groups are being moved to and driven into each other by the motion of these large subsections of the already reacted epoxy-amine polymer molecule. This reactant movement is necessary to drive the overall degree of cure to 99+ percent. The amount of energy required to cause these subsection movements is at least between 10 and 16 Kcal/mole and probably larger.(161-2) This contrasts dramatically with the kT energy of between 1 and 1.5 Kcal/mole associated with the original liquid mixture of molecules that the magnetic field had to work against to suppress the disorientating rotations of those liquid state monomers.(21-5) This difference in the motion concentrated internal energies of the epoxy-amine resin system at the two different degrees of cure is substantial. It is the required activation energy to drive the epoxy-amine reaction. At the higher degrees of cure, collisions between these subsections are not completely elastic and would result in the repartitioning of the primarily translational energy of the moving subsections into some vibrational and a substantial degree of rotational energy. The rotations imparted to these subsections are then very quickly retarded away by the action of the external magnetic field. Unfortunately, due to the necessity of first having the current loops associated with the aromatic groups begin a flux changing rotation before the rotational damping effect can eliminate that rotation, their will be a degree of reorientation of the constituent monomers making up the collided subsections of the epoxy-amine polymer. If the original monomers were oriented to their highest degree by the shear field they experienced when they flowed into the casting cavities, then these collisions would over time result in the randomizing and degrading off of this original orientation. If every collision resulted in the successful reaction of one unreacted epoxy group with one unreacted amine groups, then these collisions would number at least into the 10^{10}s to 10^{15}s per mole over the course of the cure. Most probably they number into the 10^{20}s to 10^{25}s; if every 10,000,000,000th collision resulted in a successful reaction.

The results of this experimental effort, when contrasted with Dr Mallon's findings, bear out this proposed explanation. For all effects and purposes the epoxy resin systems used, the thermal cure profiles used, and the overall cure styles used in this effort were identical to those used in Dr. Mallon's effort. The only effective difference was in the magnetic field strengths used. The field strengths used in this effort were those that could be economically generated by permanent magnets and modest costing electromagnets: 1000 Oe (0.1T) to 9000 Oe (0.9T).

In essence, conventional, robust, economical, and proven magnetic field generation technologies. The magnetic field strengths used in Dr. Mallon's effort were those that could only be generated by extremely expensive superconducting electromagnets: 85000 Oe (8.5T) to 95000 Oe (9.5T). In essence, non-conventional, delicate, extremely expensive to procure and operate magnetic field generation technologies. Based upon the results of the PI's earlier efforts, the PI fully expected to find enhancements in the properties of the resin systems cured at elevated temperatures and at the magnetic fields used in this effort. The flow field induced orientation of the monomers was seen in the PI's earlier efforts for both the resin systems cast and cured at room temperature and with similar magnetic field strength exposure and their associated controls. This orientation was measured by using white light transmission birefrengence. When the resin systems in this experimental effort were heated up to substantially hotter temperatures and the cure was driven to effectively full cure, the end results of the collisions described in the proposed explanation were not capable of being effectively suppressed by the magnetic field strengths used and their cumulative result over the duration of the cure sufficiently randomized out the original flow field induced orientation in the epoxy resin system. With this randomizing any property enhancements resulting from orientation were also lost. Where as with Dr. Mallon's effort, using magnetic fields that were 10 to 90 times stronger, the magnetic fields were more than sufficiently capable of suppressing out the results of the orientation randomizing collisions found in substantially cured epoxy resin systems. (In fact the fields used in that effort were so strong that they were capable of initially inducing the orientation in the monomers of the epoxy resin system via the orientation dependency of the rotational dampening rates.) The magnetic field strengths used in his experimental effort were so strong that they suppressed the orientation randomizing results of the polymer subsection collisions so successfully as to preserve orientation induced Tg enhancements of 45^{o}F to full cure. Orientation induced enhancements to a resin system's Tg are unheard of and would require an extremely high degree of orientation to be induced.(164) To determine if this Tg enhancement was the result of orientation in the resin system, Dr. Mallon post cured the magnetic field exposed resin system and its control at a higher temperature without simultaneously exposing either of them to another external magnetic field. He found that the enhanced Tg of the specimens cured while previously exposed to the magnetic field was completely eliminated and that the Tgs of the previously exposed specimen and its associated control were identical after the post cure.

Conclusions

This experimental effort's objective was to determine if enhancements to the properties of conventional high temperature epoxy resin systems could be generated by fully thermally curing them while simultaneously exposing them to magnetic fields whose strengths could be economically generated. Previous efforts by the PI to 75 percent cure at room temperature with aliphatic curing agents an epoxy resin system while simultaneously exposing them to similar magnetic fields generated 60 to 100 percent improvements in the resultant resin system's mechanical properties. An independent effort by Dr. Mallon, then at the Aerospace Corp, to fully cure at elevated temperatures a stiochiometric mPDA epoxy resin system while simultaneous exposing it to the roughly 90000 Oe (9T) magnetic field generated by a superconducting electromagnet generated the heretofore unheard of enhancement to the resin's Tg of 45^{O}F. Also the foreign literature, primarily written by Russians and other members of the former Soviet Union, is replete with hundreds of their efforts to enhance almost every conceivable property of, almost every conceivable polymer, processed by almost every conceivable technique, into almost every conceivable end product by coprocessing in a magnetic field. These previous efforts indicated that the potential to enhance particular properties of epoxy resin systems, by processing them with conventional production techniques into end items while simultaneously exposing them to magnetic fields of strengths that could be generated by permanent magnets and conventional electromagnets, was highly probable.

This effort used stoichiometric mixes of mPDA, MDA, PACM-20, and Tonox curing agents with EPON 830 as the base epoxy resin. These epoxy resin systems were cured with one of the following thermal cure profiles: 20 Hrs at 210^{O}F(99^{O}C), 5 hrs at 250^{O}F(121^{O}C), and 4 Hrs at 300^{O}F(149^{O}C). These resin systems were thermally cured while being exposed to magnetic fields of strengths stepped up from 1250 Oe (0.1250T) to 8800 Oe (0.8800T). These step sizes were selected to be roughly 400 Oe between 1250 Oe and 5000 Oe and 1100 Oe between 5000 Oe and and 8800 Oe. These step sizes represented the robustness requirements which any prospective enhancements resulting from the exposure to magnetic field would need to exhibit in order to be suitable for incorporation into an existing processing technique.

In each of this effort's experimental runs specimens were generated that were exposed to one of many magnetic fields and associated control specimens were also generated from the same epoxy resin system. Both sets of associated specimens were cured by the same thermal cure profile. These specimens were mechanically and thermally tested to deduce the relevant and important properties of these resins and most importantly to deduce any differences between those specimens cast while exposed to a magnetic field relative to those cast as controls. This effort decisively determined that under no conditions of conventional elevated temperature cure, using many of the common high temperature curing agents available, and economically generated magnetic field strengths was there any modification to the important properties of these fully cured epoxy resin systems relative to their associated controls.

From the results of this and previous experimental efforts, the PI concludes that this effect is, one real and two not economically viable for incorporation into conventional epoxy resin system based item production devices. In the final analysis, this effect constitutes the basis for an interesting laboratory technique which would be capable of deliberately inflicting a repeatable and predictable degree of orientation into organic materials which do not intrinsically take to being oriented, but it constitutes nothing more.

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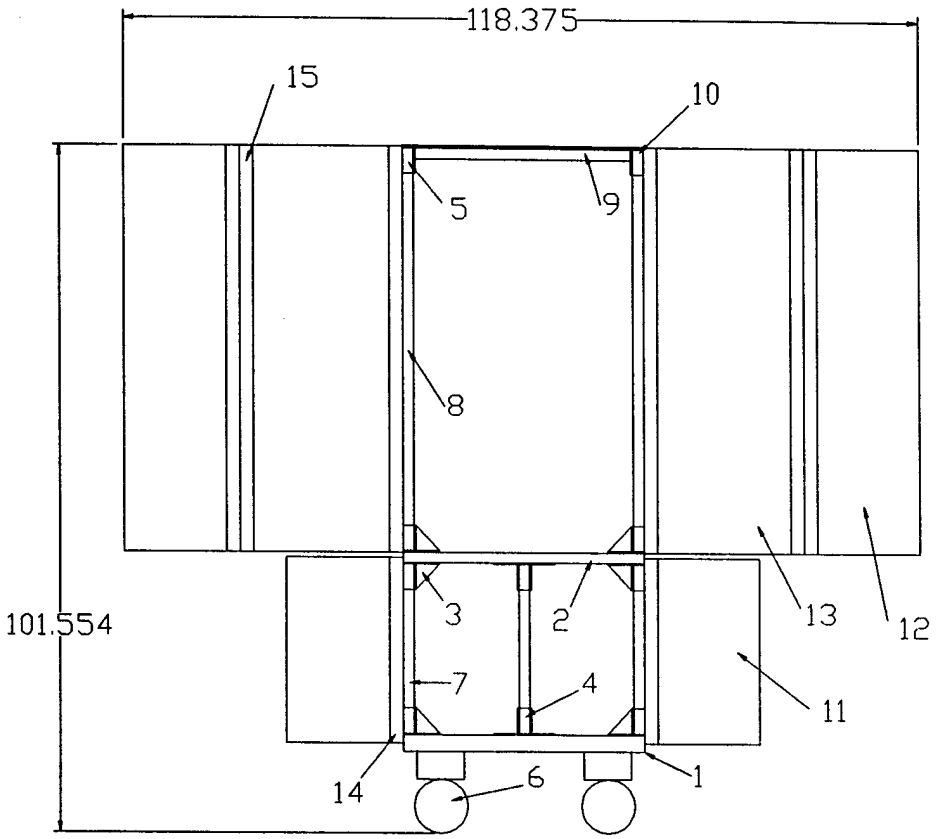
Appendix

Vibration Isolation

Figure A1: Mobile Balance Bench: Assembly 160
Figure A2: Mobile Balance Bench: Upper Plate 161
Figure A3: Mobile Balance Bench: Lower Plate 162
Figure A4: AE 200 Pedistal Block 163
Figure A5: BB 3000 Pedistal Block 164



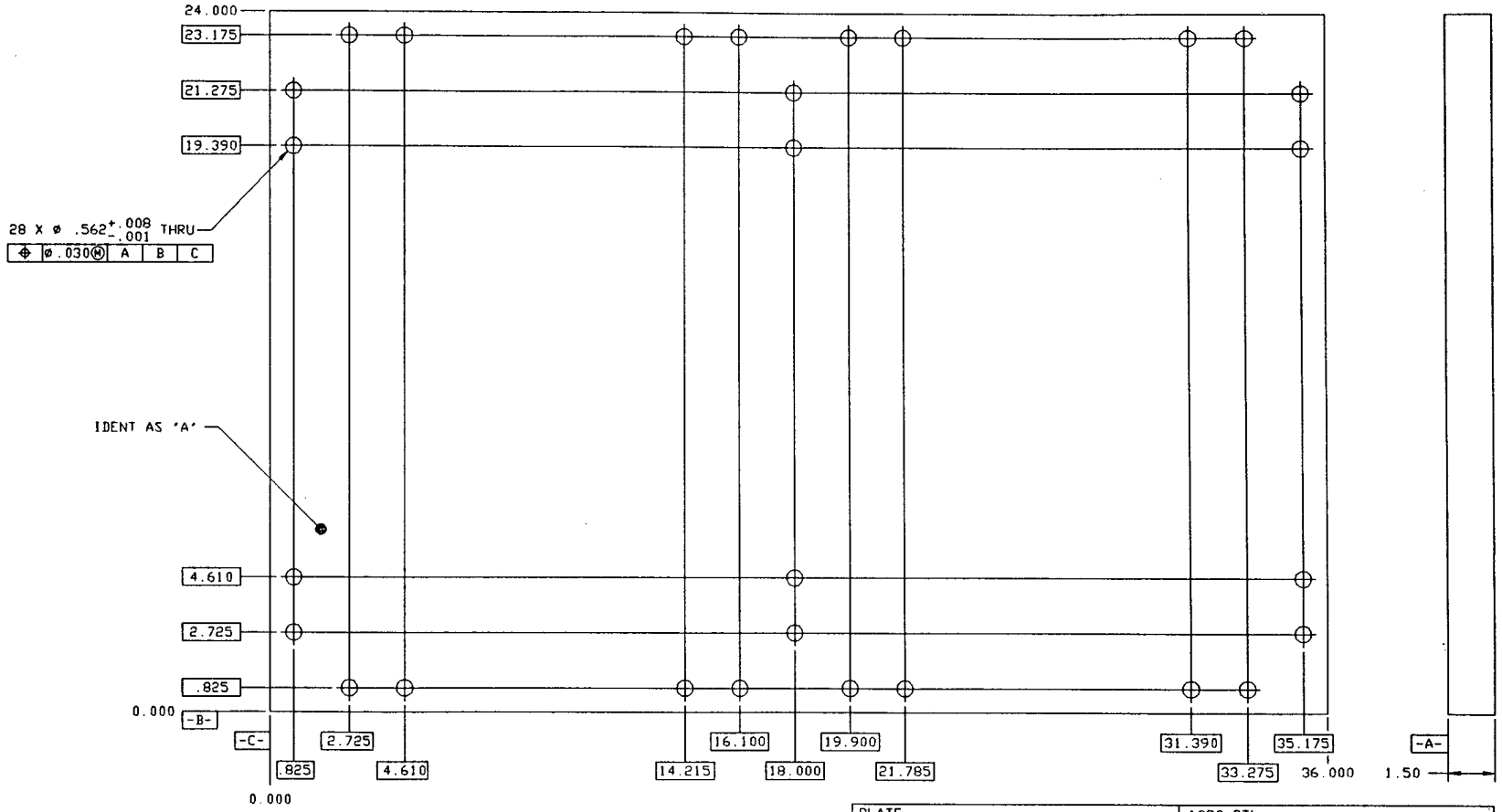
Note: Figure Depicts Bench With Its' Doors Open.

Tolerances: XX.XXX" +/- 0.050"
Draftsman/Engineer: Roger H. Gerzeski
Date: 23 Feb 92

Components List:

1. Lower Steel Plate: See Drawing X9227530
2. Upper Steel Plate: See Drawing X9227531
3. 12 Unistrut P2245 Corner Fittings
4. 4 Unistrut P2229 Joint Fittings
5. 4 Unistrut P2225 Corner Fittings
6. Four 1000 Lb Urethane Casters
7. Six P1000 Unistrut Channels 25.000" Long
8. Four P1000 Unistrut Channels 59.500" Long
9. Two P1000 Unistrut Channels 32.250" Long
10. Two P1000 Unistrut Channes 20.250" Long
11. Two Lower Swinging Doors 27.500" By 17.180" By 0.063" Steel Plate
12. Two Upper Outer Swinging Doors 60.000" By 17.180" By 0.063" Steel Plate
13. Two Upper Inner Swinging Doors 60.000" By 24.000" By 0.063" Steel Plate
14. Two 27.500" Long Continuous Steel Hinges
15. Four 60.000" Long Continuous Steel Hinges
16. Two 29.500" By 24.000" By 0.063" Steel Lower Compartment Side Pannels
17. One 29.500" bY 36.000" By 0.063" Steel Lower Compartment Back Pannel
18. One 61.000" By 36.000" By 0.063" Steel Upper Compartment Back Pannel
19. One 36.000" By 24.000" By 0.063" Steel Open Diamond Grid With 1.000" Open Diamonds Top Pannel
20. 1/2-13 Bolts As Necessary To Fasten All Unistrut To The Major Upper And Lower Steel Plates And Casters To The Lower Steel Plate
21. Any Mechanical Fasteners To Attach 0.063" Steel Plates To The Outer Sides And Hinges.

Figure A1: Mobile Balance (Vibration Isolation) Bench: Assembly

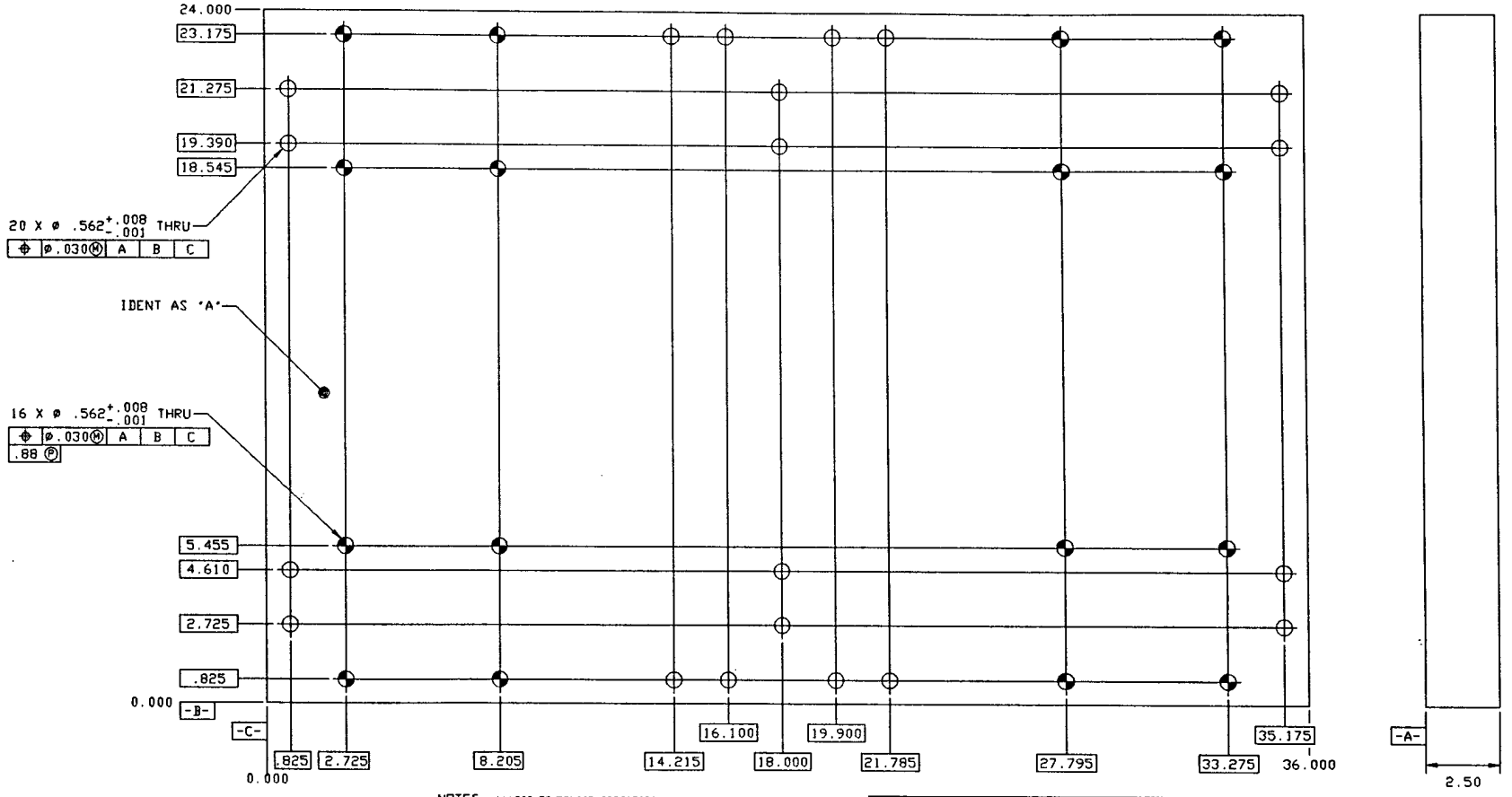


NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES

PLATE		1020 STL
NOMENCLATURE		MATERIAL / SPECIFICATION
	PARTS LIST	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG GERZESKI, R 17 MAY 92	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 14MAY92	TITLE PLATE UPPER BALANCE SUPPORT BALANCE CART
	HS	DRAWING NO. X9227531

Figure A2: Mobile Balance Bench: Upper Plate

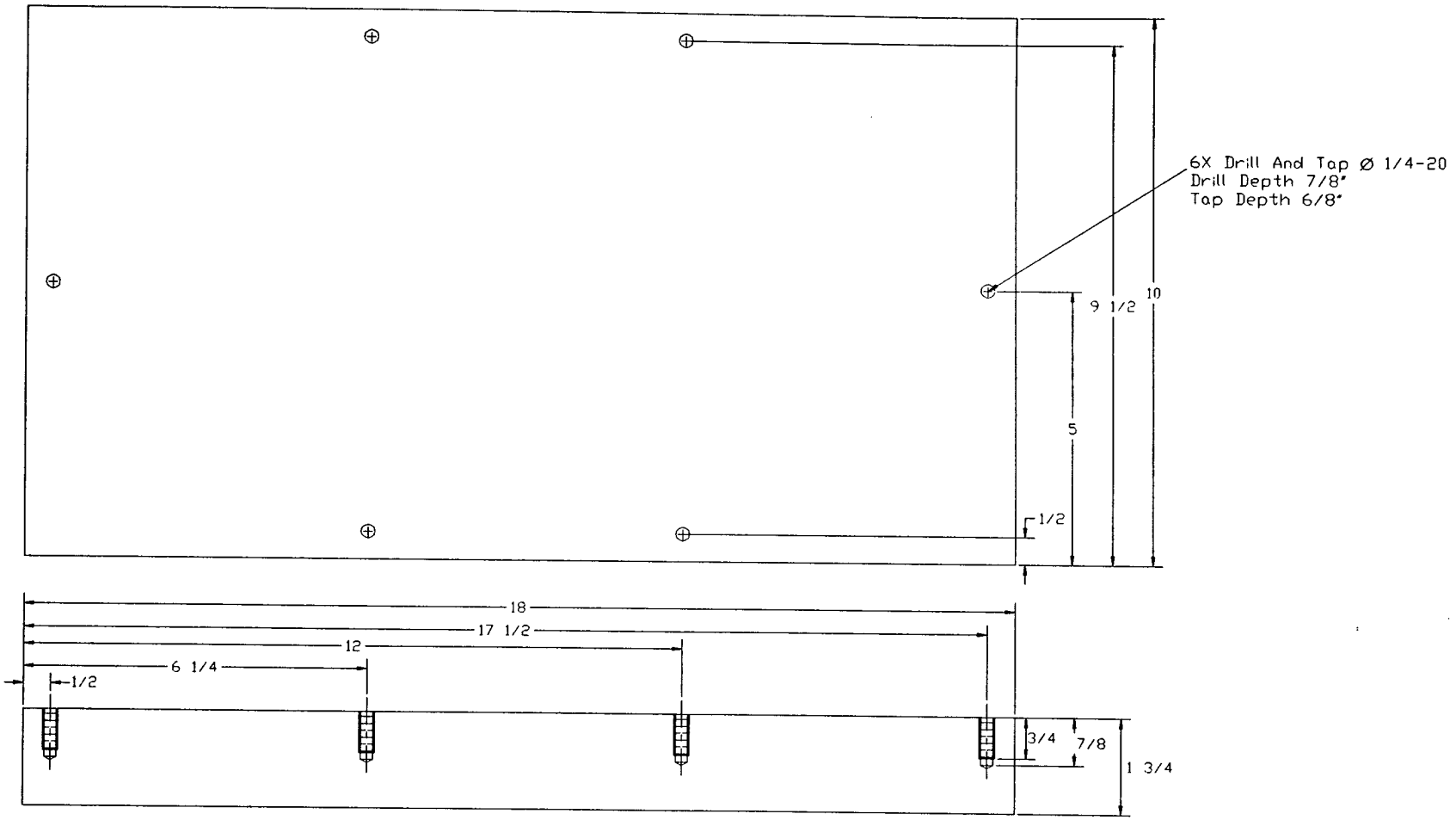


NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES

PLATE		1020 STL
NOMENCLATURE		MATERIAL / SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX± .03 ±0°15' .XXX± .010	ENG GERZESKI, R 17 MAY 92	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 13MAY92	TITLE PLATE LOWER BALANCE SUPPORT BALANCE CART
	HS	DRAWING NO. X9227530

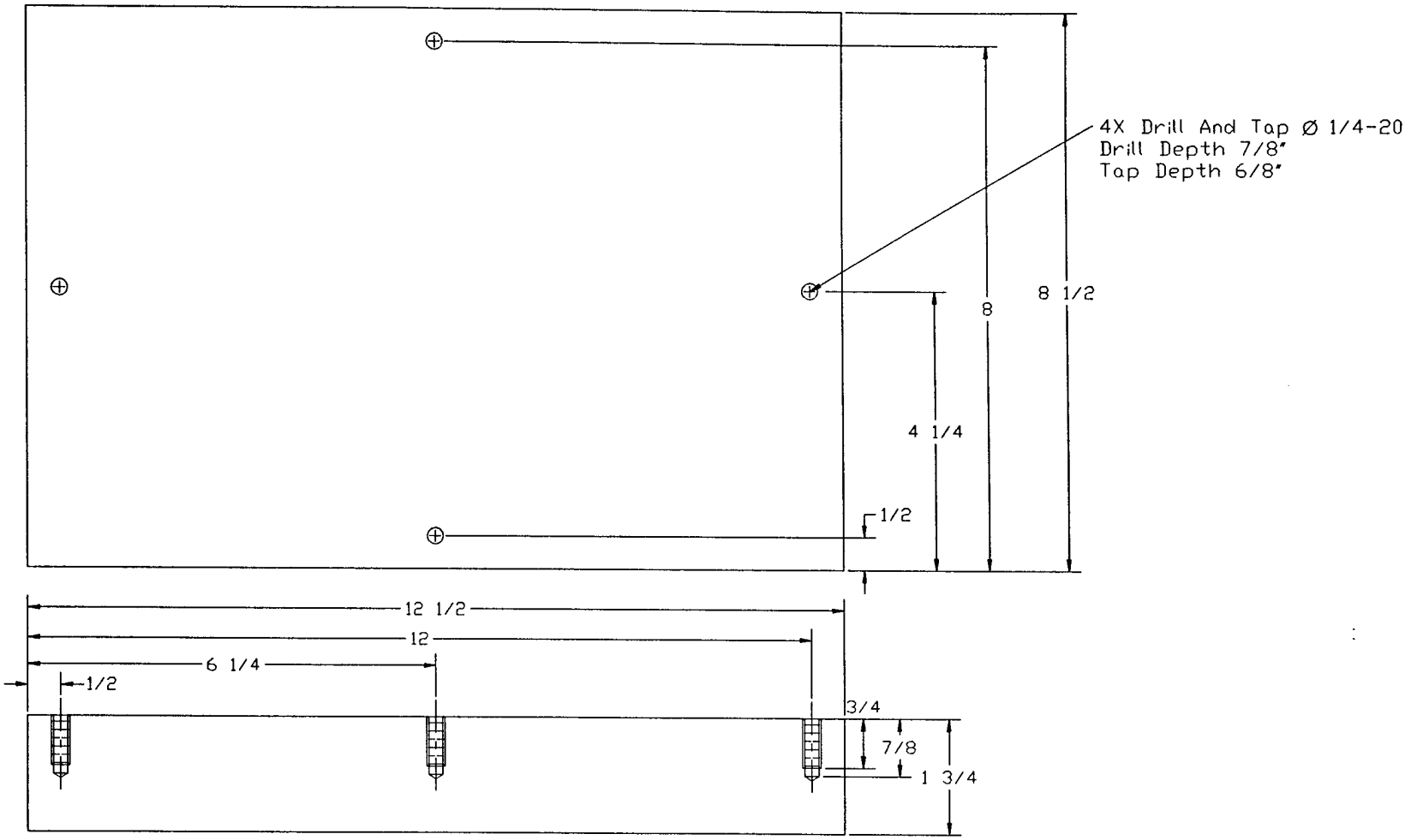
Figure A3: Mobile Ballance Bench: Lower Plate



Material Of Construction:
Plate Steel

Tolerances: X x/x" +/- 1/16"
Engineer / Draftsman:
Roger H. Gerzeski
Date: 9 Feb 92

Figure A4: AE 200 Pedistal Block



Material Of Construction:
Plate Steel

Tolerances: X x/x" +/- 1/16"
Engineer / Draftsman:
Roger H. Gerzeski
Date: 9 Feb 92

Figure A5: BB 3000 Pedistal Block

NonMagnetic Hall Probe Extension

Figure A6: Link Plate To 3 Axis Positioner 166
Figure A7: Bar: Link Plate To Box Beam Connector 167
Figure A8: Bar: Box Beam Connector 168
Figure A9: Bar: Box Beam To Hall Probe Connector 169
Figure A10: Lower Holder Clamp 170
Figure A11: Upper Holder Clamp 171

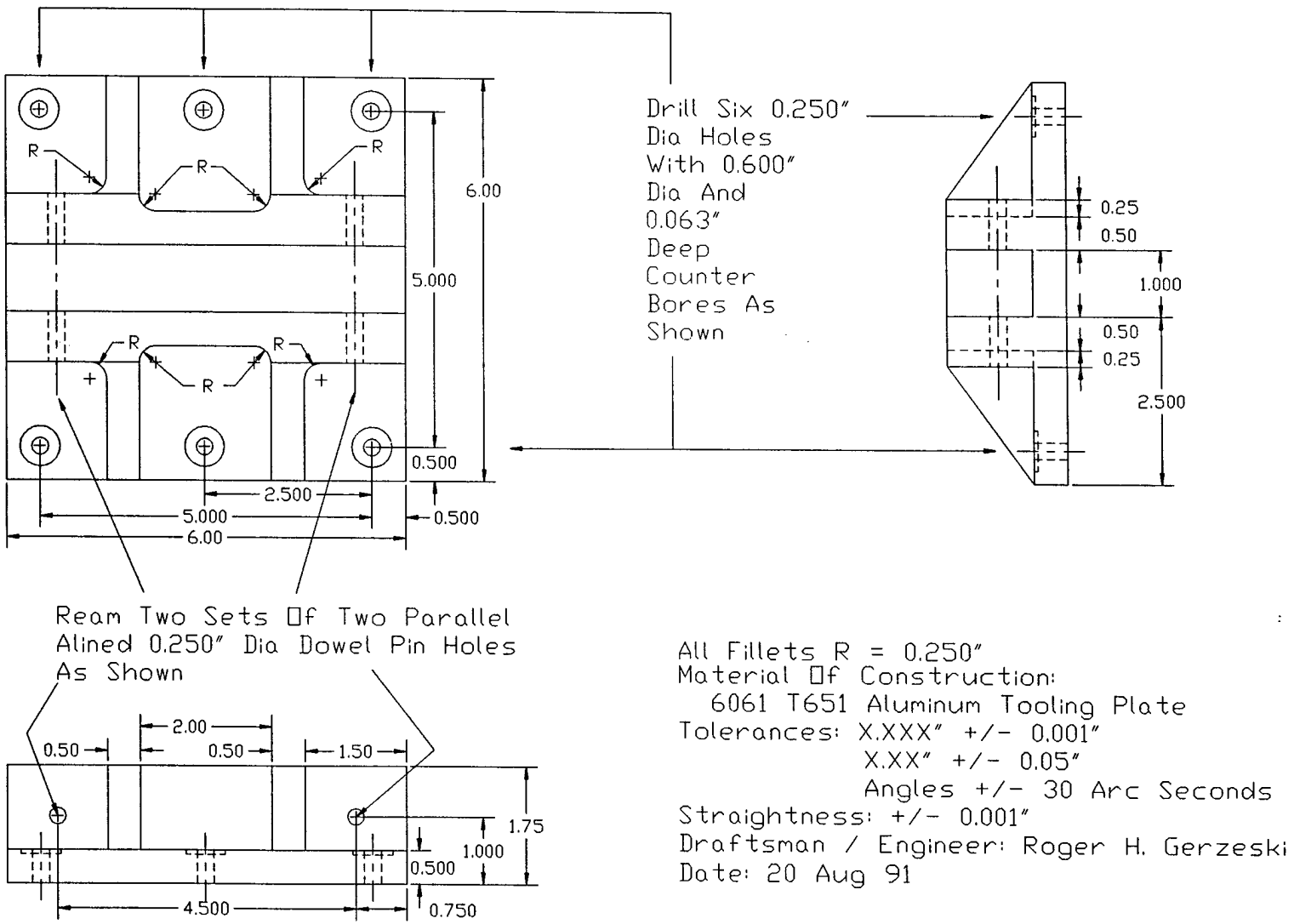
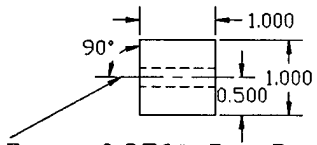


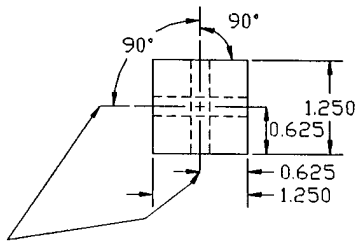
Figure A6: NonMagnetic Hall Probe Extension: Link Plate To 3 Axis Positioner

A--A

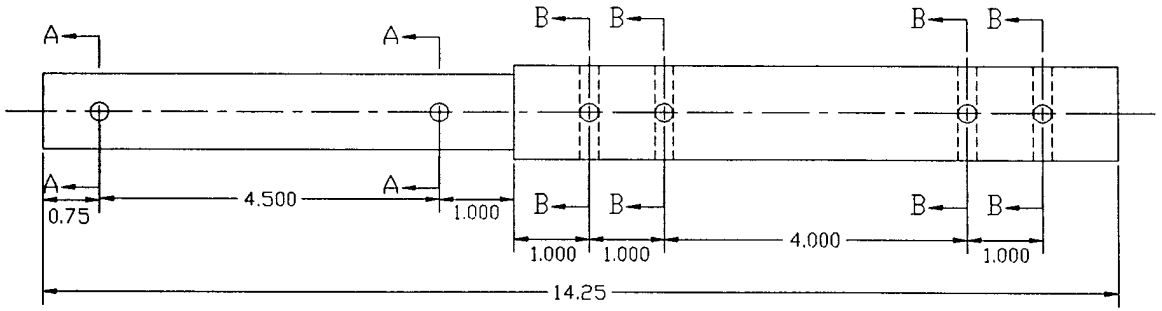


Ream 0.250" Dia Dowel Pin Hole As Shown At Both A--A Sections
Ream All Dowel Pin Holes Perpendicular To Surface

B--B



Ream Two Intersecting Crossed 0.250" Dia Dowel Pin Holes As Shown At All Four B--B Sections
Ream All Dowel Pin Holes Perpendicular To Surface



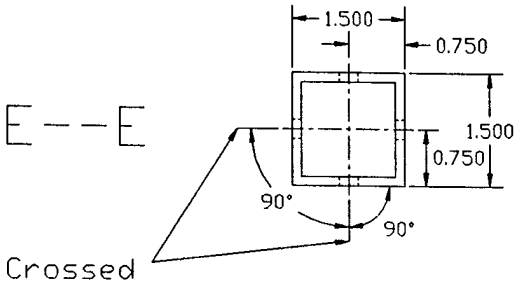
Central Axis Line

Material Of Construction:
6061 T651 Aluminum Tooling Plate

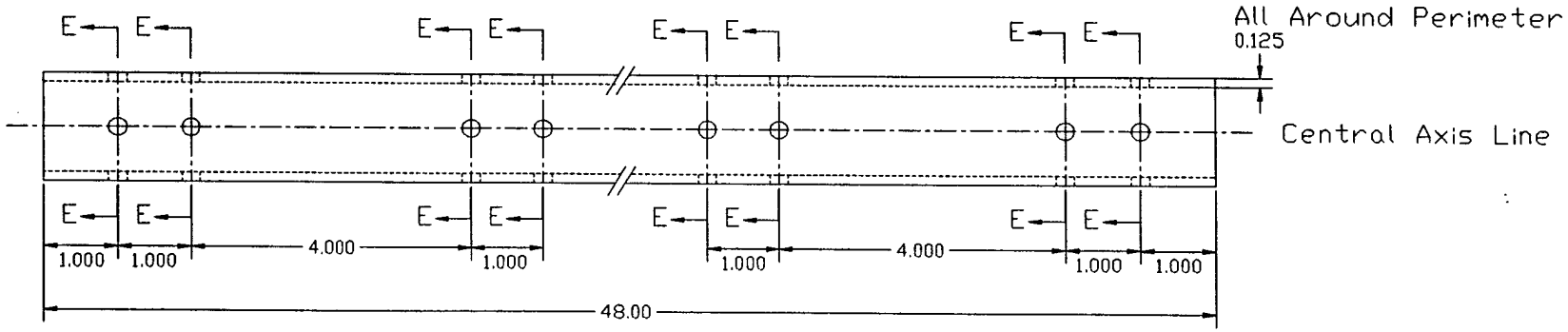
Tolerances: X.XXX" +/- 0.001"
X.XX" +/- 0.05"
Angles: XX +/- 30 Arc Seconds
Straightness: +/- 0.001"
Dowel Pin Clearance Fit: +0.001"-0.000"

Draftsman / Engineer:
Roger H. Gerzeski
Date: 6 Sep 91

Figure A7: NonMagnetic Hall Probe Extension: Bar: Link Plate To Box Beam Connector



Ream Two Intersecting Crossed
0.250" Dia Dowel Pin Holes As
Shown At All Eight E-E Sections
Ream All Dowel Pin Holes
Perpendicular To Surface



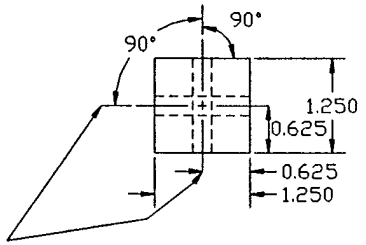
Material Of Construction:
2024 T6 Aluminum Box Beam

Tolerances: X.XXX" +/- 0.001"
X.XX" +/- 0.05"
Angles: XX +/- 30 Arc Seconds
Straightness: +/- 0.001"
Dowel Pin Clearance Fit: +0.001"-0.000"

Draftsman / Engineer:
Roger H. Gerzeski
Date: 6 Sep 91

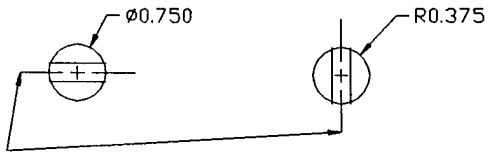
Figure A8: NonMagnetic Hall Probe Extension: Bar: Box Beam Connector

B--B



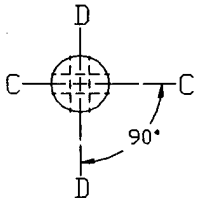
Ream Two Intersecting Crossed 0.250" Dia Dowel Pin Holes As Shown At All Four B--B Sections
Ream All Dowel Pin Holes Perpendicular To Surface

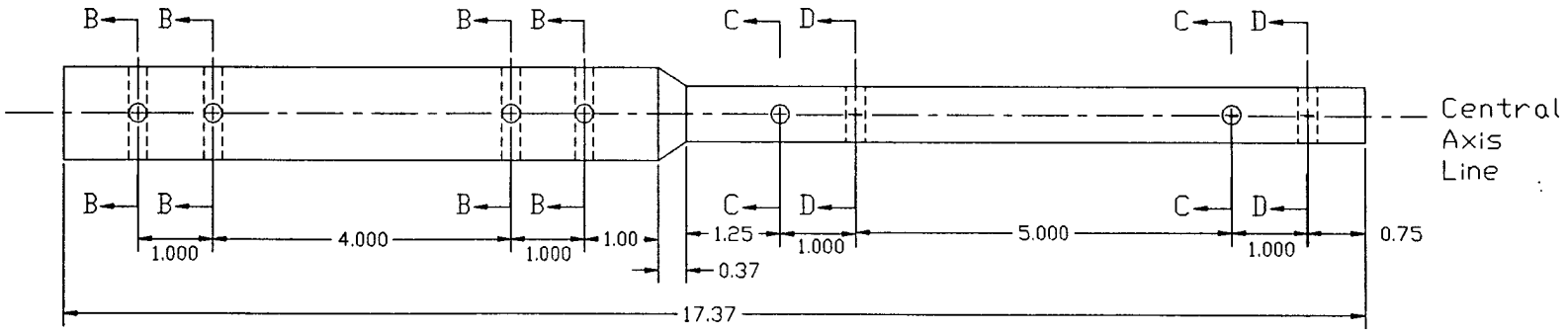
C--C D--D



Ream One 0.250" Dia Dowel Pin Hole As Shown At Both Of The Two C--C and D--D Sections For A Total Of Four Dowel Pin Holes

C--C Relative To D--D





Material Of Construction:
6061 T651 Aluminum Tooling Plate

Tolerances: X.XXX" +/- 0.001"
X.XX" +/- 0.05"
Angles: XX +/- 30 Arc Seconds
Straightness: +/- 0.001"
Dowel Pin Clearance Fit: +0.001"-0.000"

Draftsman / Engineer:
Roger H. Gerzeski
Date: 6 Sep 91

Figure A9: NonMagnetic Hall Probe Extension: Bar: Box Beam To Hall Probe Connector

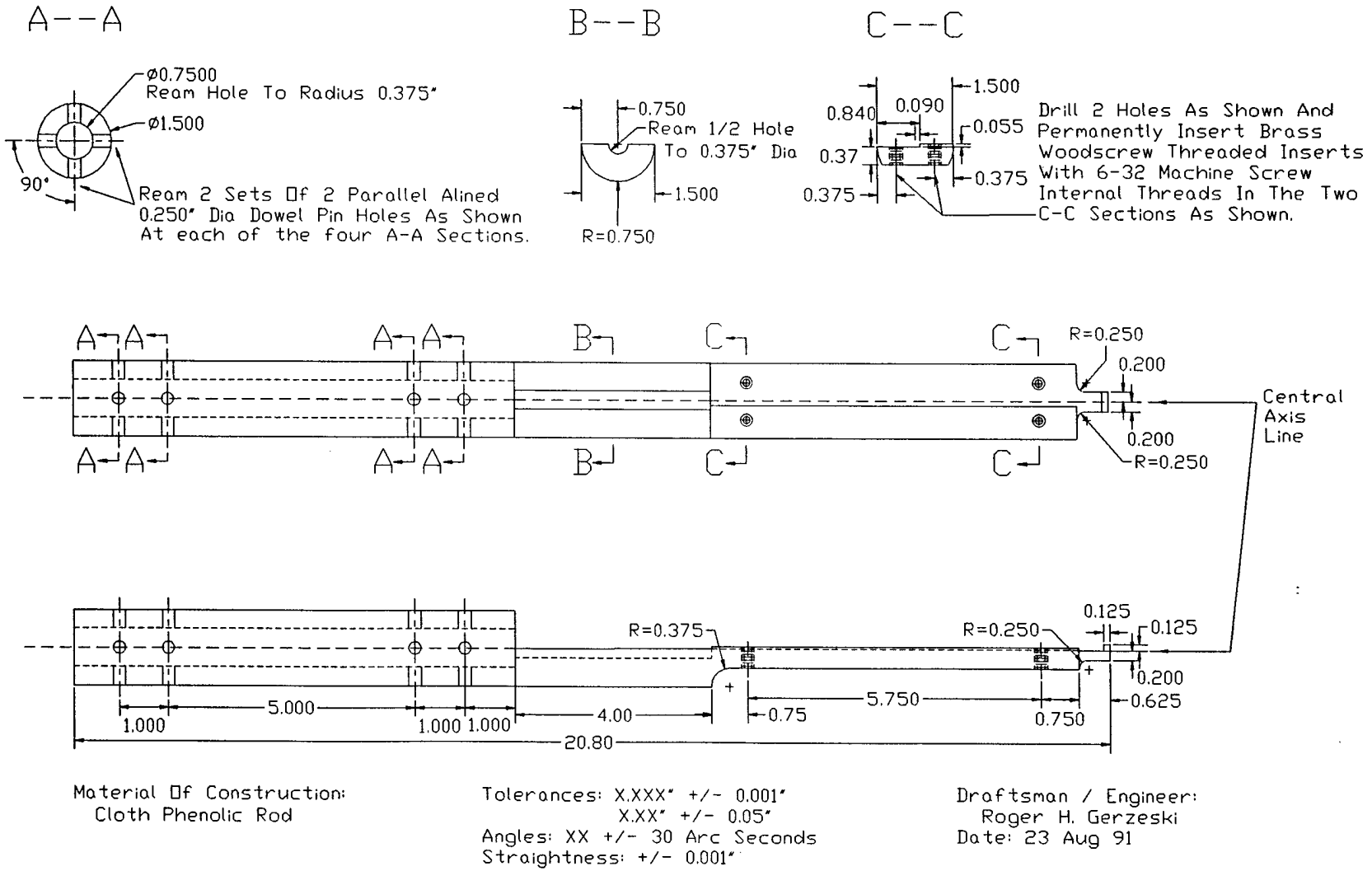


Figure A10: NonMagnetic Hall Probe Extension: Lower Holder Clamp

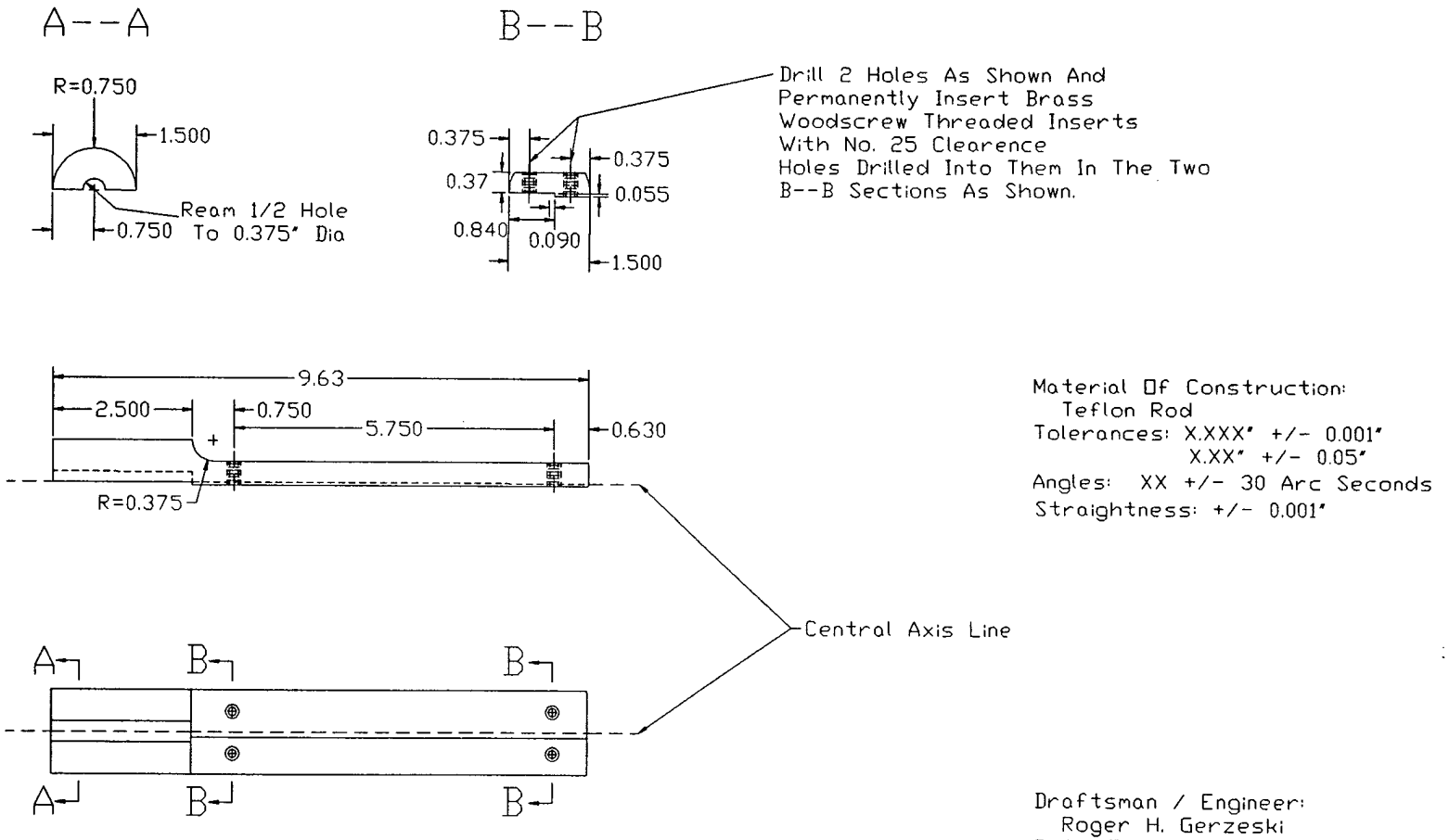
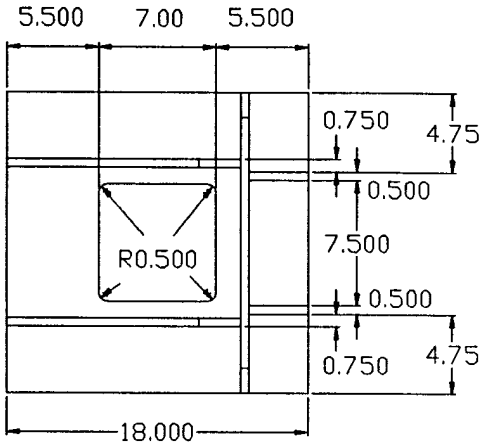
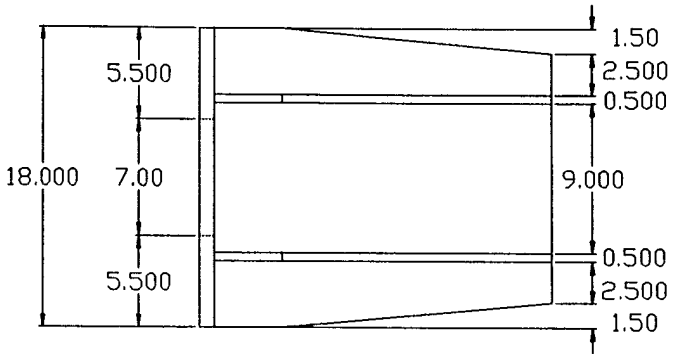


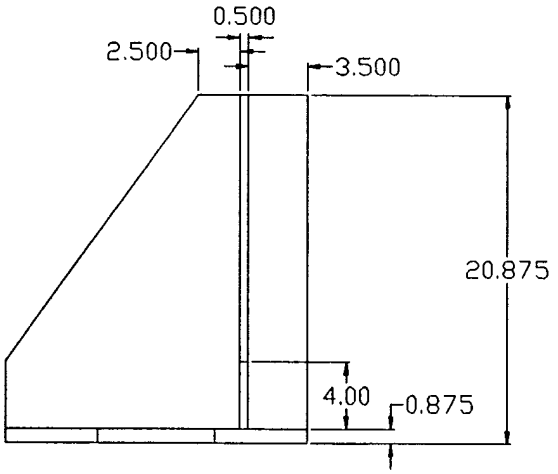
Figure A11: NonMagnetic Hall Probe Extension: Upper Holder Clamp

Three Axis Positioner System: X=12", Y=12", Z=12"

Figure A12: Z Axis Bracket 173
Figure A13: Base Plate 174







Material Of Construction:
6061 or 2024 Aluminum
Mechanically Fastened
As Necessary
Draftsman/Engineer:
Roger H. Gerzeski
Tolerances:
X.XXX" +/- 0.001"
X.XX" +/- 0.01"
Date: 8 Jun 89

Figure A12: Three Axis Positioner System: X=12", Y=12", Z=12": Z Axis Bracket

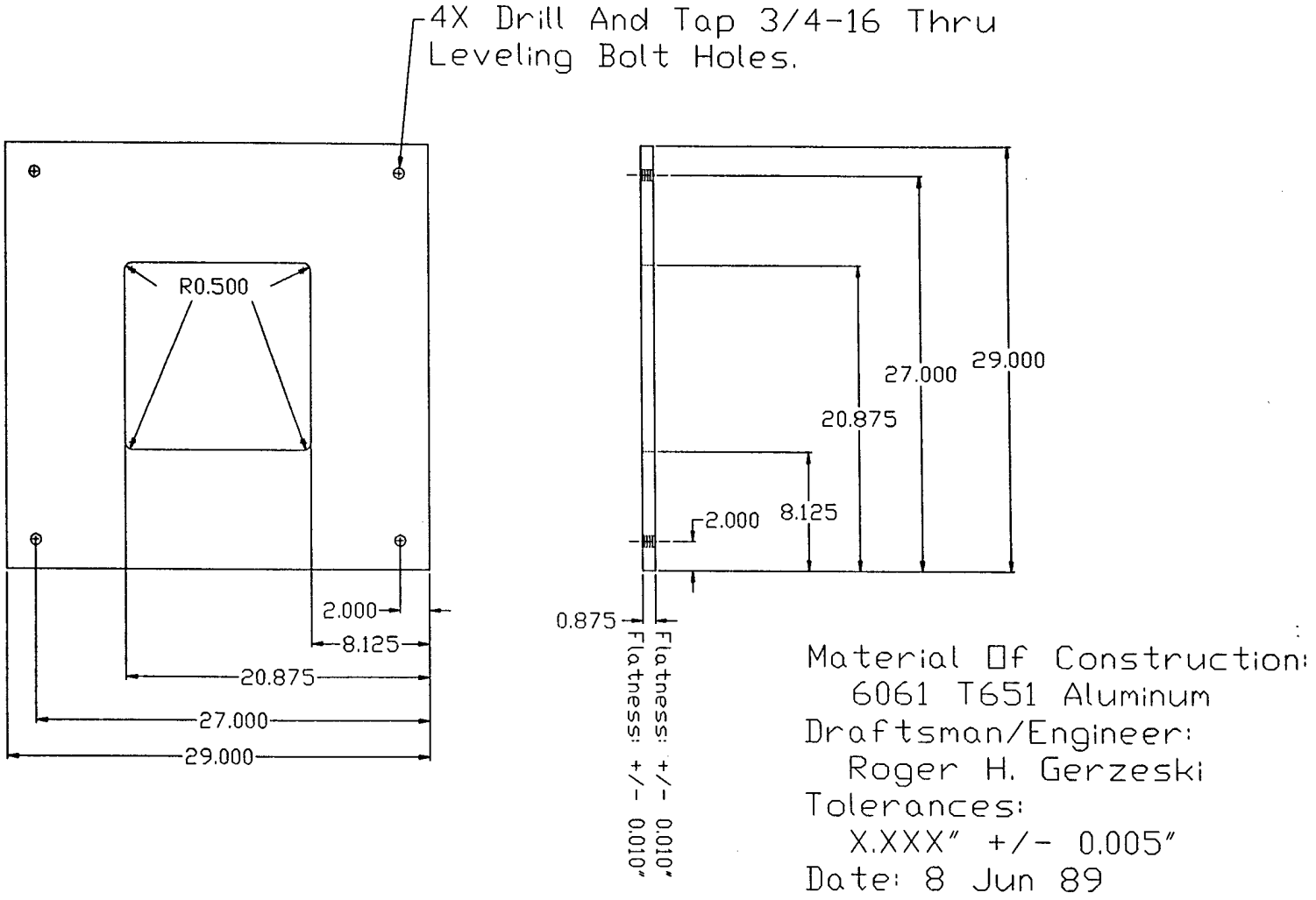


Figure A13: Three Axis Positioner System: X=12", Y=12", Z=12": Base Plate

Rail Car

Figure A14: Long Arm Support Channel/Beam 176
Figure A15: Short Arm Support Channel/Beam 177
Figure A16: Leveling Pad Receiver Blocks 178
Figure A17: Alinement Blocks 179

Notes: Tolerance: X.XXX +/- 0.005"
X.XX +/- 0.05"
X.X +/- 0.1"
Material Of Construction: 6" Steel Channel

Engineer / Draftsman: Roger H. Gerzeski
Date: 29 Jan 91
Simultaneously Match Drill A Mirror Image Set Of These Channels

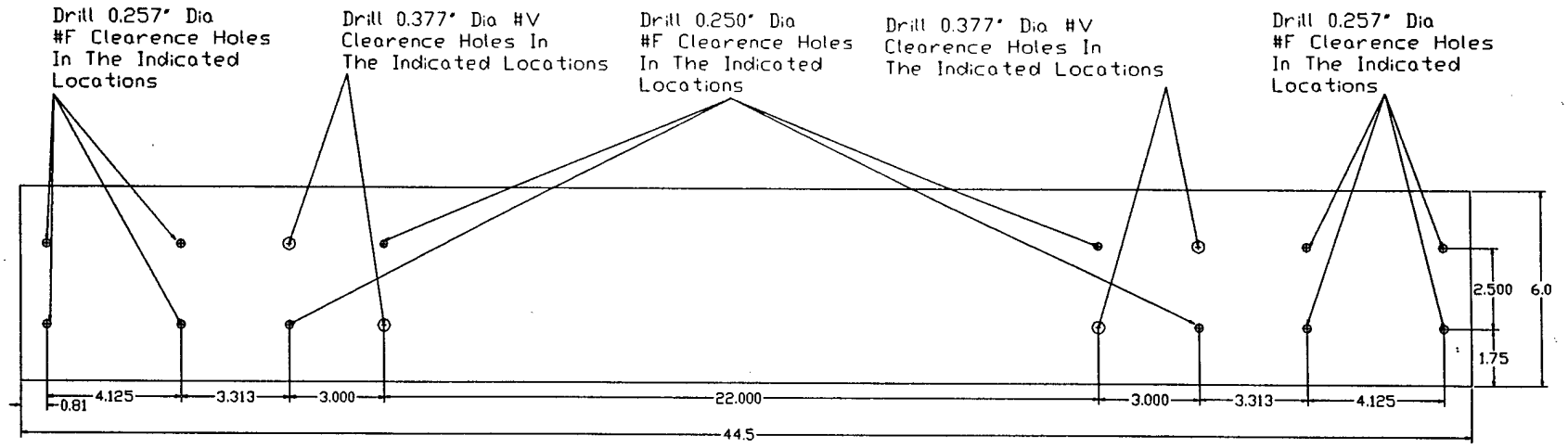


Figure A14: Rail Car: Long Arm Support Channel / Beam

Notes: 1. Tolerances: X.XXX"+/-0.005"
X.XX"+/-0.05"
X.X"+/-0.1"
2, Materials Of Construction:
6" Steel Channel
3, Engineer/Draftsman: Roger H. Gerzeski
4, Date: 29 Jan 91
5, Match Drill A Mirror Image Set Of These Channels By Placing Two Of Them Back To Back And Simultaneously Drilling The Holes With The Same Drill Strokes.

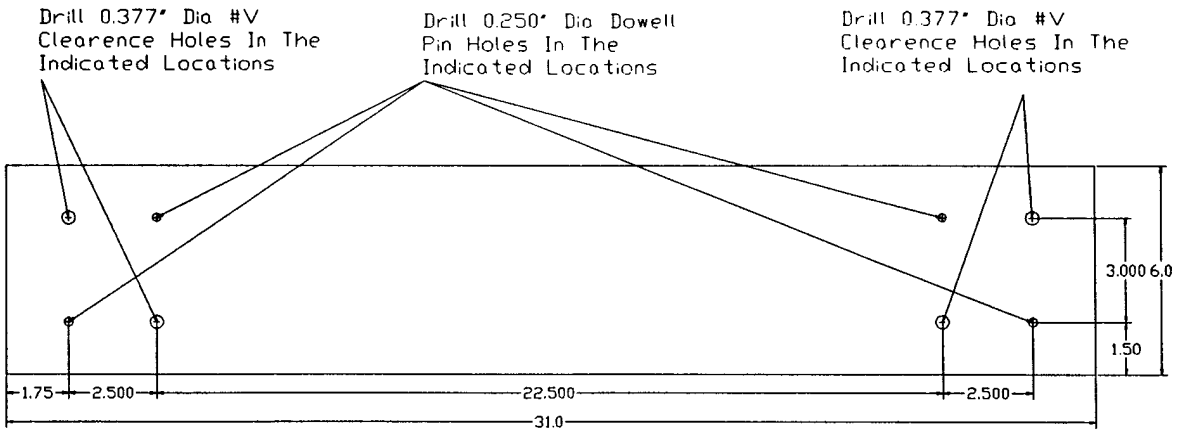


Figure A15: Rail Car: Short Arm Support Channel / Beam

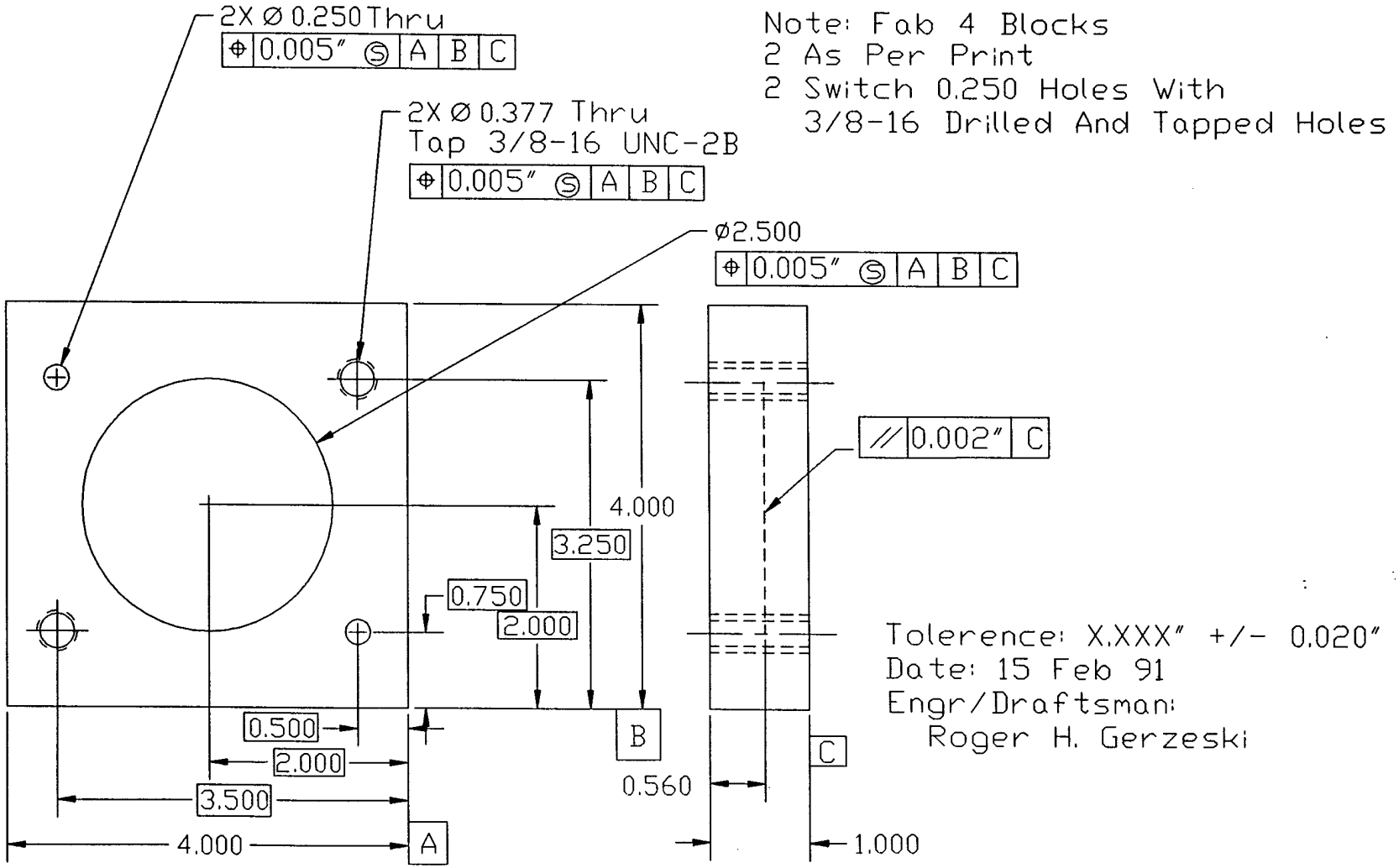
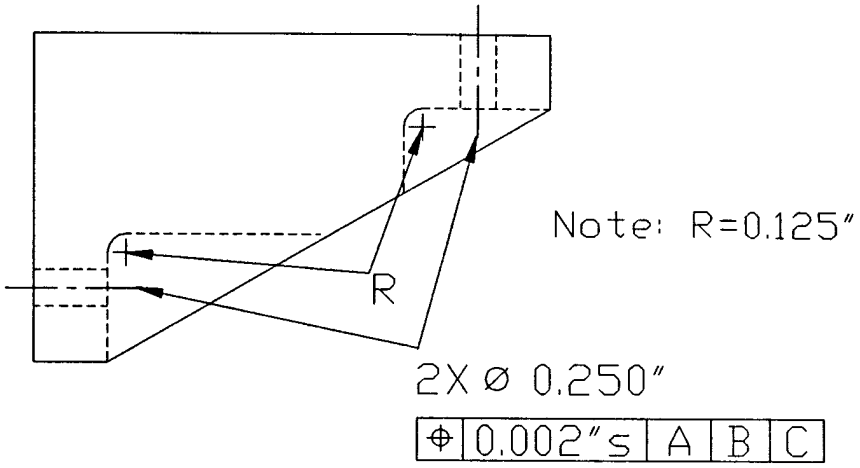
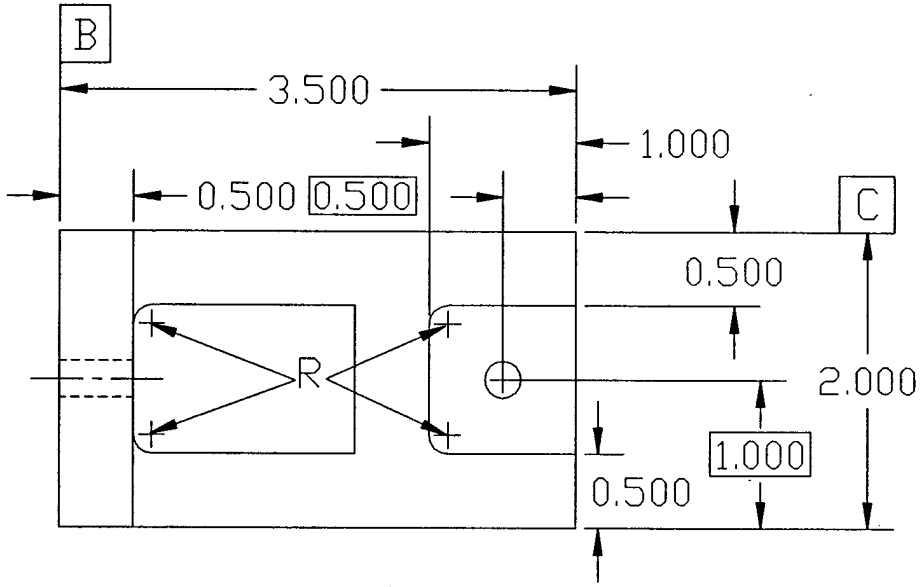


Figure A16: Rail Car: Leveling Pad Receiver Blocks



Material Of Construction:
4130 Steel
Tolerance: X.XXX"+/-0.005"
Engineer/Draftsman:
Roger H. Gerzeski
Date: 24 Dec 91



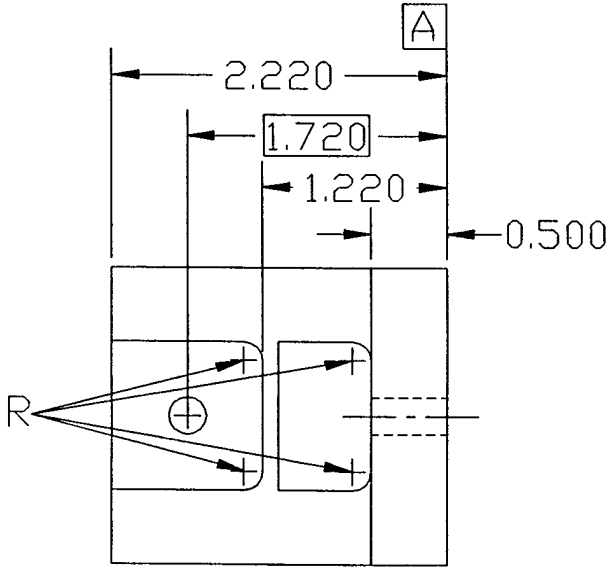
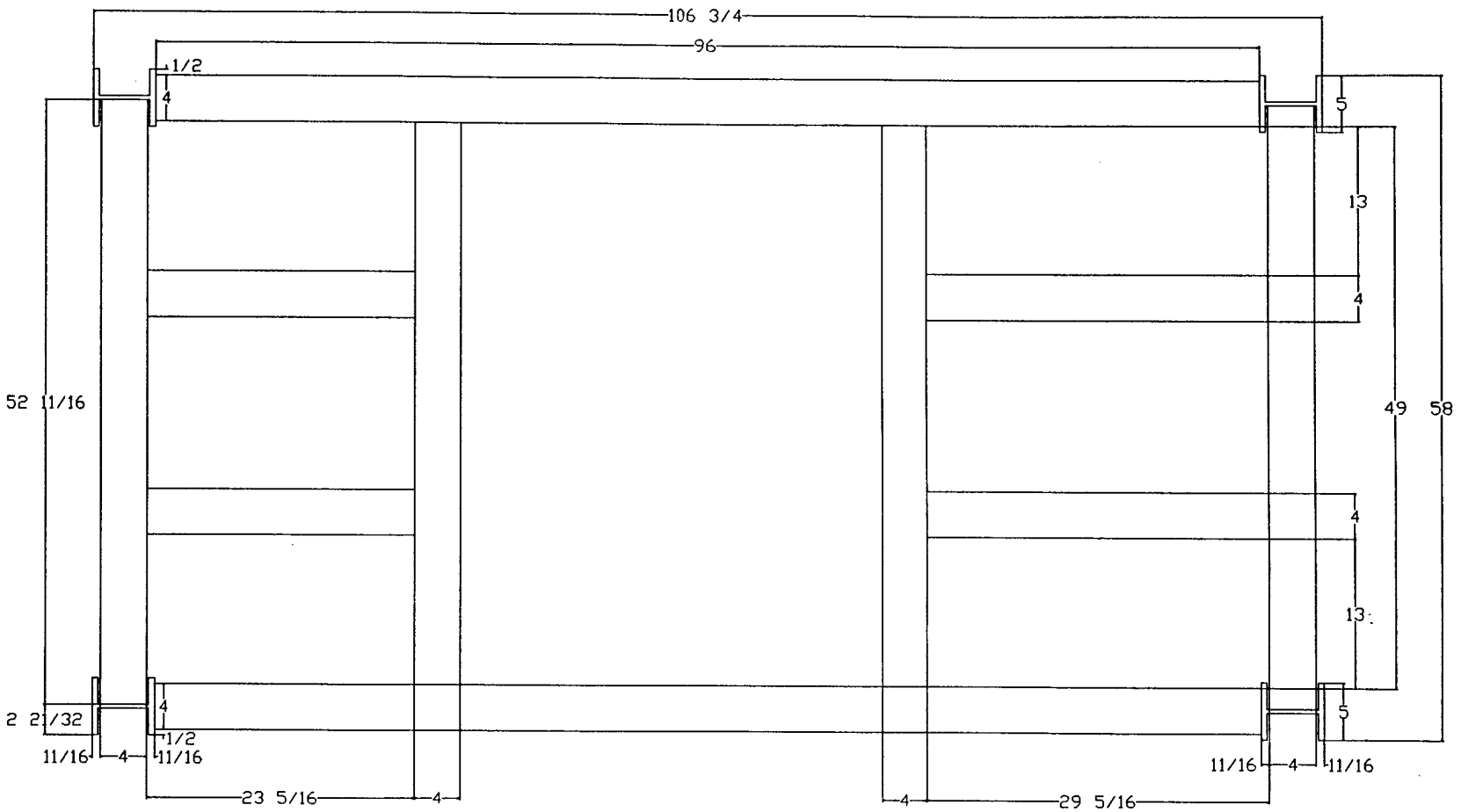


Figure A17: Rail Car: Alinement Brackets

Scaffold Support Structure

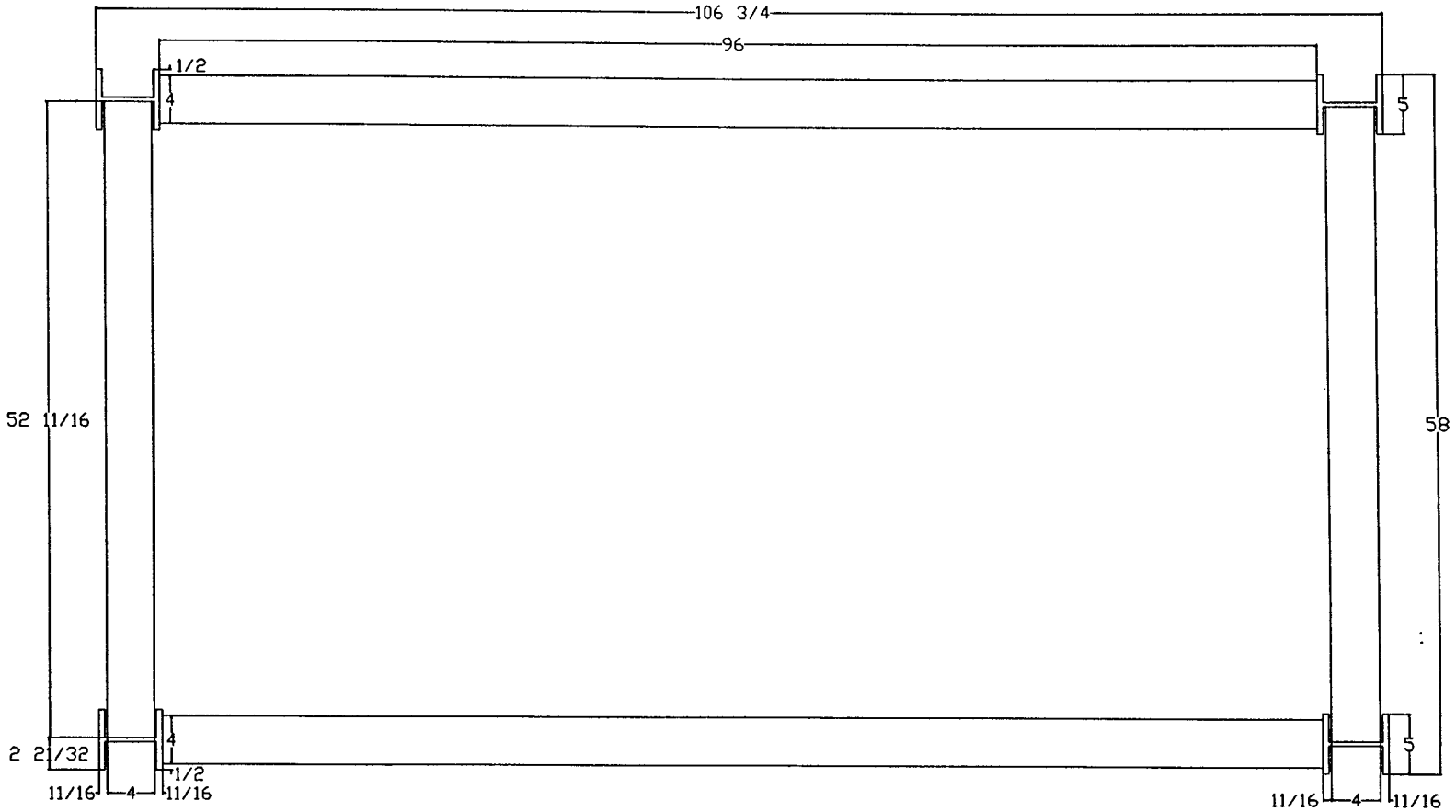
Figure A18: A--A Projection: Electromagnet Level 181
Figure A19: B--B Projection: Positioner Level 182
Figure A20: Support Base Plates: Electromagnet Level 183
Figure A21: Leveling Bolt Base Plate 184
Figure A22: Leveling Bolt Base Plate To 5" H Beam Interface: Plain View 185



Notes: 1. All Angles Are 90 Degrees
2. All Joints Are To Be Welded Along All Contacting Faces.

Tolerances: Fractions: +/- 1/32"
Angles: Shop
Draftsman / Engineer: Roger H. Gerzeski
Date: 1/9/89

Figure A18: Scaffold Support Structure: A--A Projection: Electromagnet Level



Notes: 1. All Angles Are 90 Degrees
2. All Joints Are To Be Welded Along All Contacting Faces.

Tolerances: Fractions: +/- 1/32"
Angles: Shop
Draftsman / Engineer: Roger H. Gerzeski
Date: 1/9/89

Figure A19: Scaffold Support Structure: B--B Projection: Positioner Level

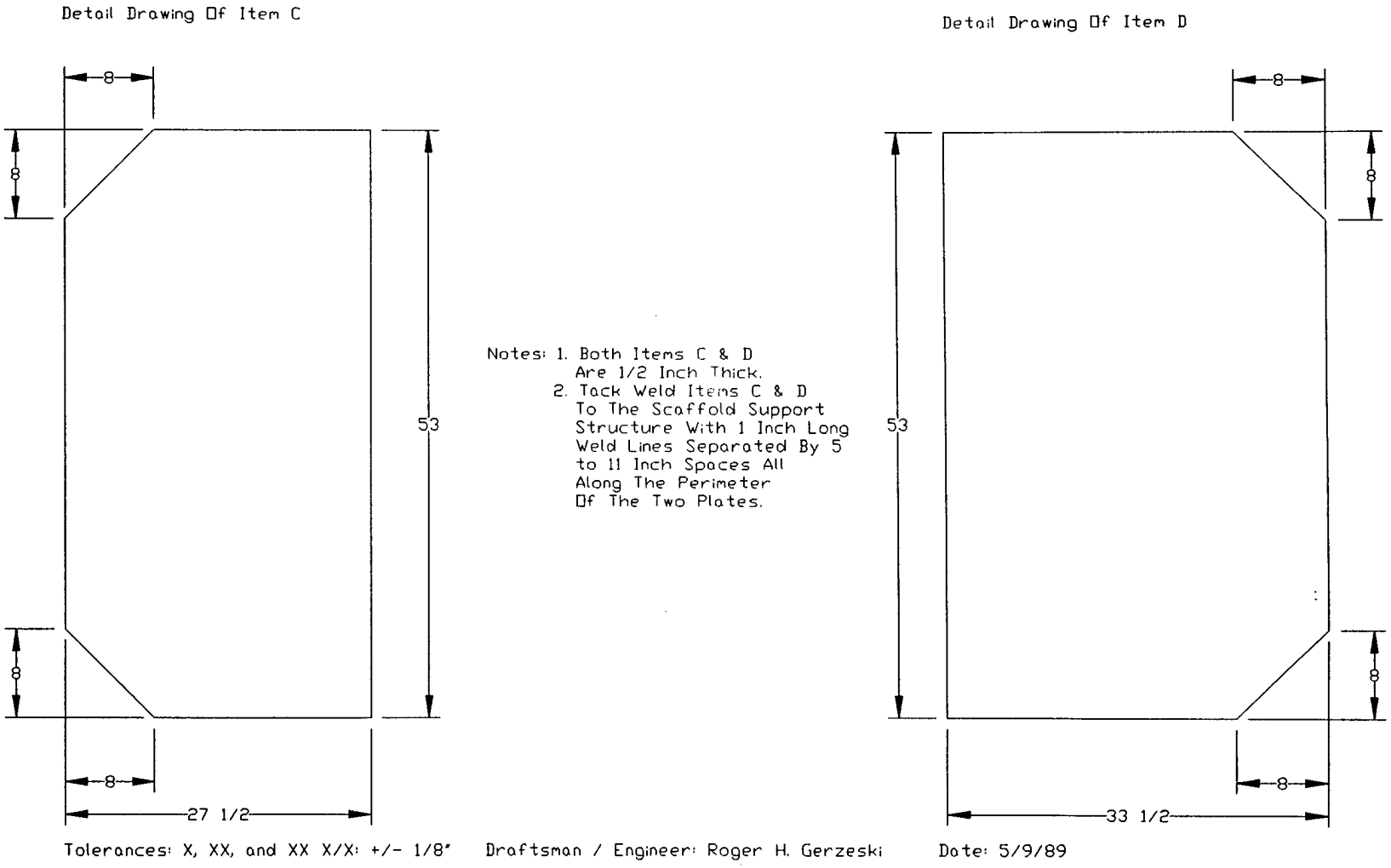
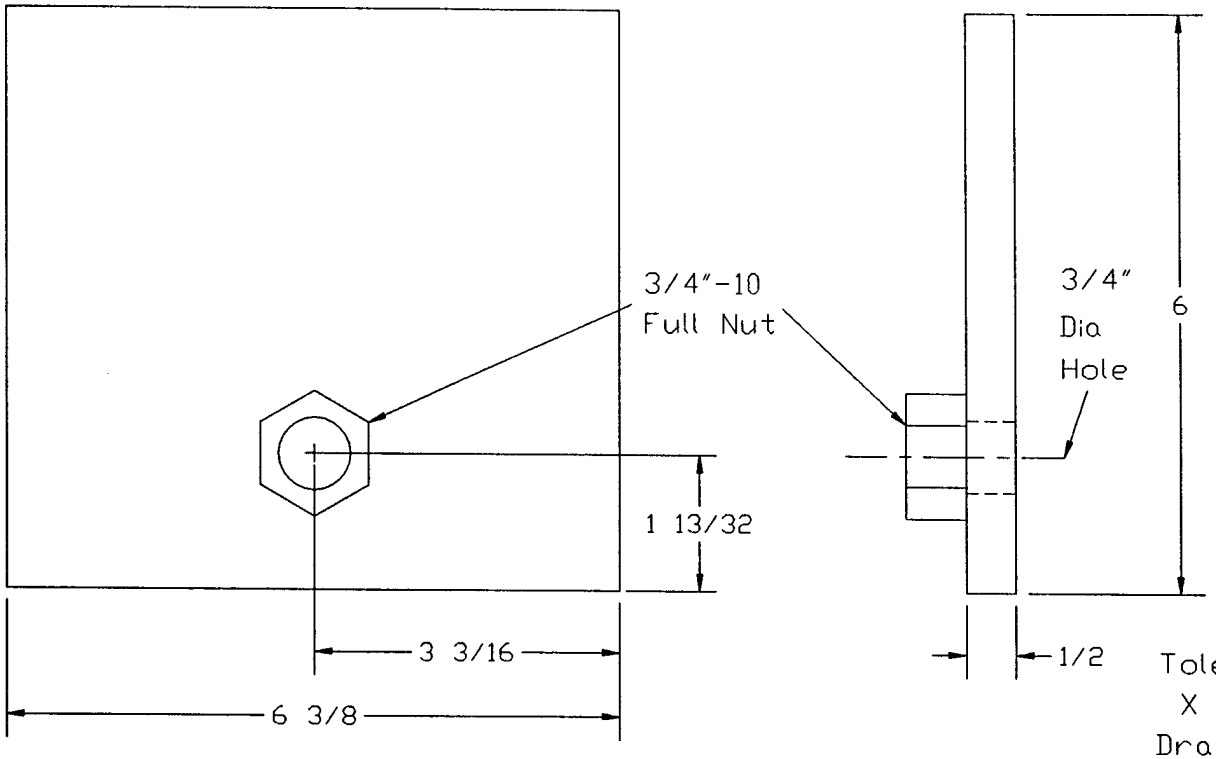


Figure A20: Scaffold Support Structure: Support Base Plates: Electromagnet Level

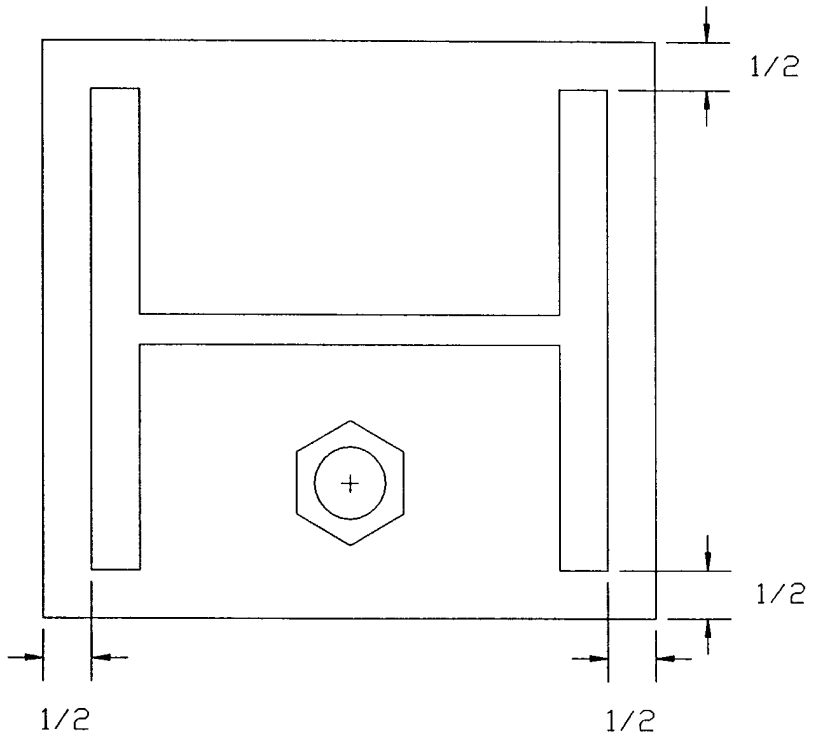
Notes: 1. All Angles Are 90 Degrees.
2. The Full Nut Is To Be Continuously Welded To The Base Plate.

Detail Drawing Of Item E



Tolerances:
X X/X +/- 1/32"
Draftsman/Engineer:
Roger H. Gerzeski
Date: 18/10/89

Figure A21: Scaffold Support Structure: Leveling Bolt Base Plate



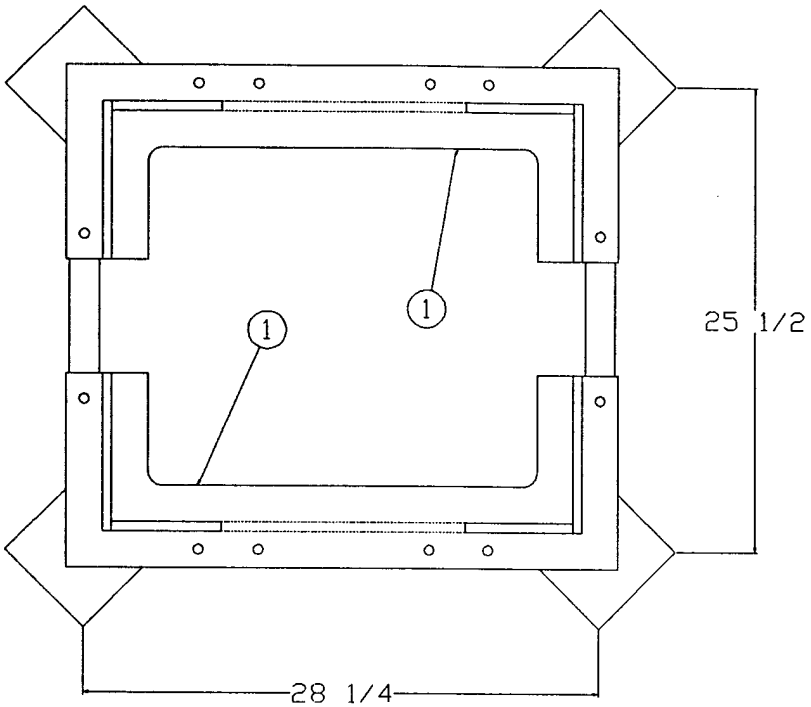
Notes: 1. All Angles
Are 90 Degrees.
2. All Joints Between The
H Beam And The Leveling
Bolt Base Plate Are To
Be Welded All Around Their
Intersecting Circumference.

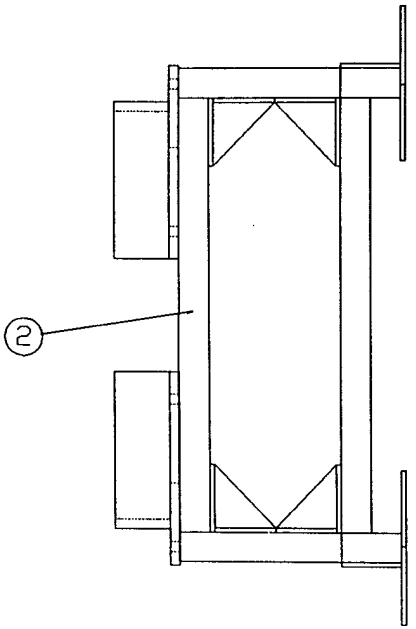
Tolerances:
X/X +/- 1/32"
Draftsman/Engineer:
Roger H. Gerzeski
Date: 18/10/89

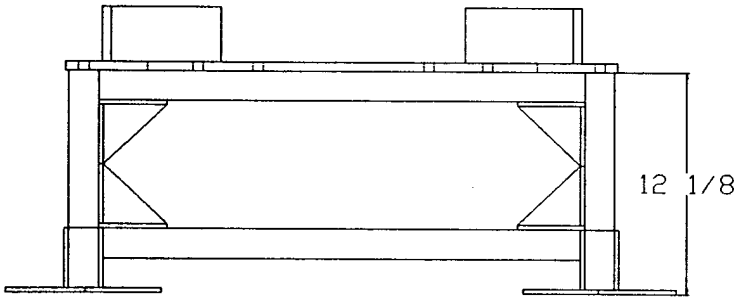
Figure A22: Scaffold Support Structure:
Leveling Bolt Base Plate To 5" H Beam Interface Plain View

Walker Electromagnet Support Structure

Figure A23: Assembly 187
Figure A24: Cradle Plates 188
Figure A25: Stand 189





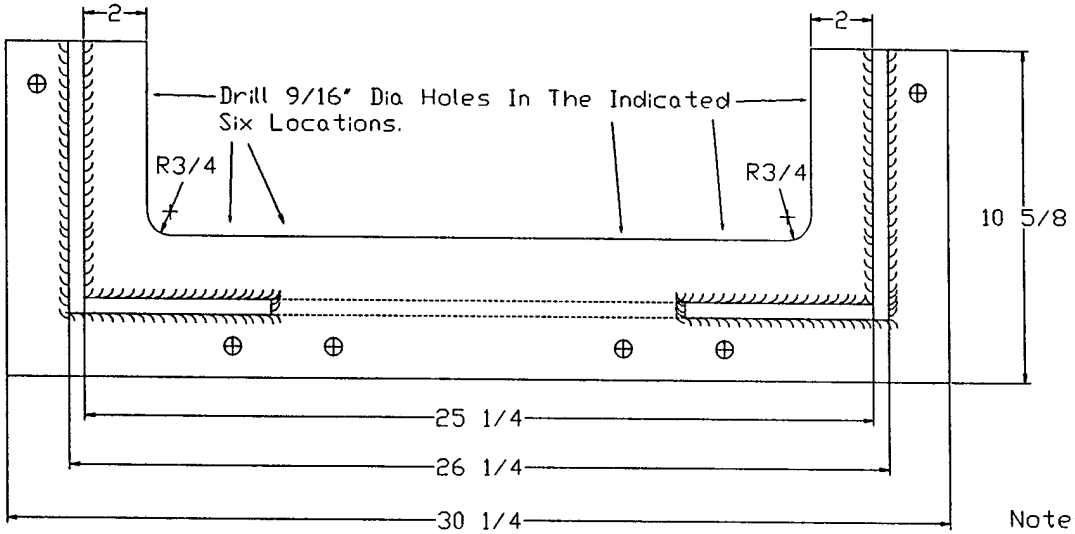


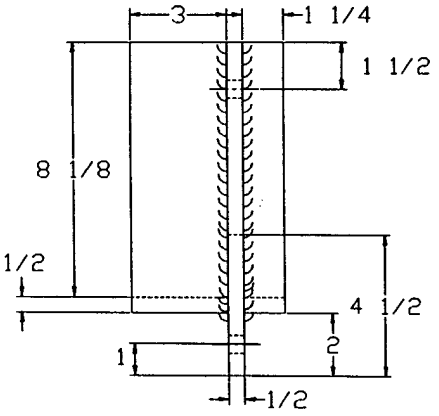
List Of Components:
1. Cradle Plates
2. Unistrut Stand

Assembly Note: The two Cradle Plates Are to be Mechanically Attached To The Unistrut Stand Via 12 Five Inch Long 1/2"-13 All thread Studs.

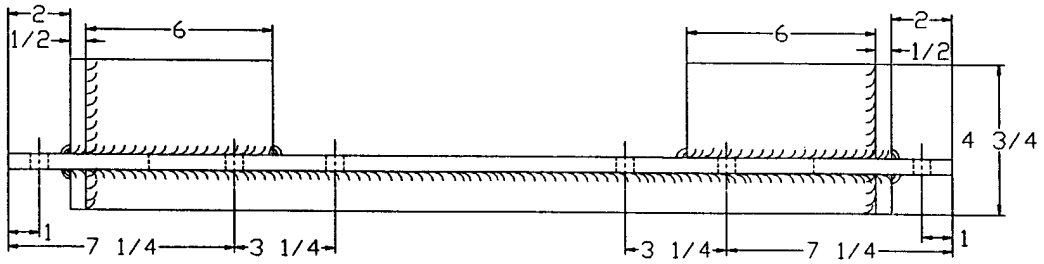
Draftsman/Engineer: Roger H. Gerzeski
Date: 4/1/91

Figure A23: Walker Electromagnet: Support Structure: Assembly



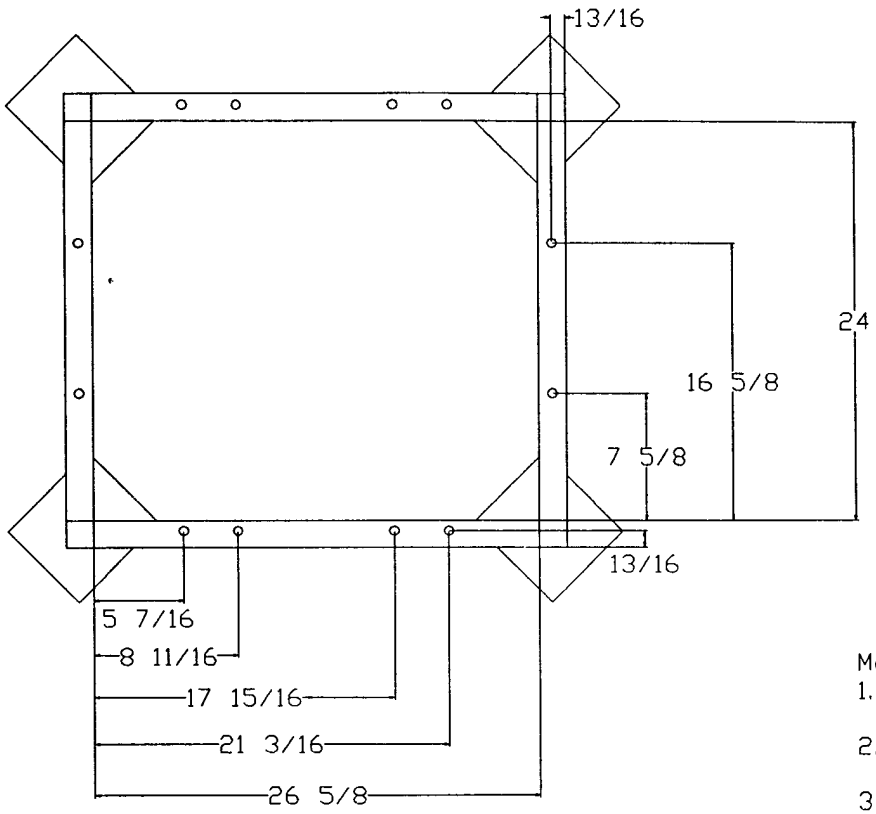


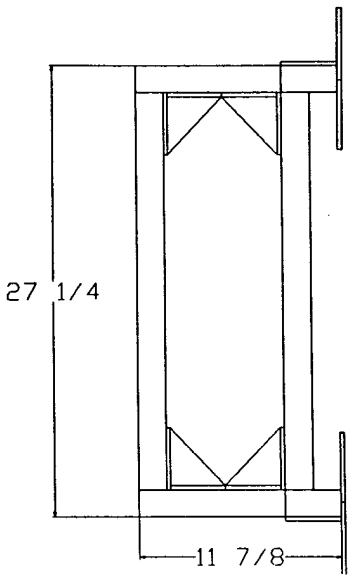
Notes: Continuous weld all contacting edges of all contacting subcomponents without warping the gusset or the main plate out of tolerance.
Fabricate Two Of The Above Plates.

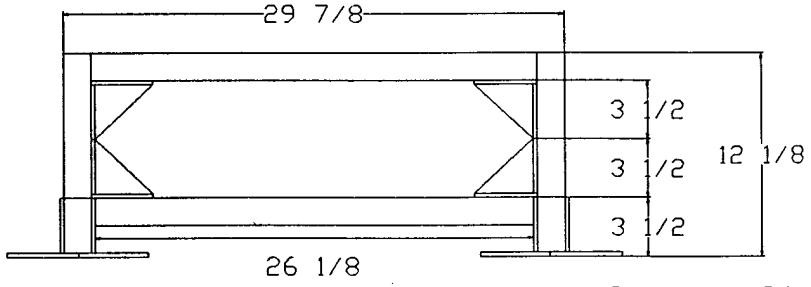


Material Of Construction: Steel Plate
Tolerance: +/- 1/16" and Shop on Angles
Draftsman / Engineer: Roger H. Gerzeski
Date: 28/12/90

Figure A24: Walker Electromagnet: Support Structure: Cradle Plates







Material Of Construction:
1. 8 Unistrut P 2245 Fittings Machined Down To A Height Of 3 1/2 Inches.
2. 4 Unistrut P2072A Fittings Machined Down To A Height Of 3 1/2 Inches.
3. P1000 Unistrut Channels Of The Following Lengths:
   2 Bars 26 1/8 Inches Long.
   4 Bars 24 Inches Long.
   2 Bars 26 5/8 Inches Long.
   4 Bars 11 7/8 Inches Long.
4. Drill 9/16 Inch Dia Holes In The two 26 5/8 Inch Long Bars As Indicated.
5. Drill 9/16 Inch Dia Holes In 2 Of The 24 Inch Long Bars As Indicated.

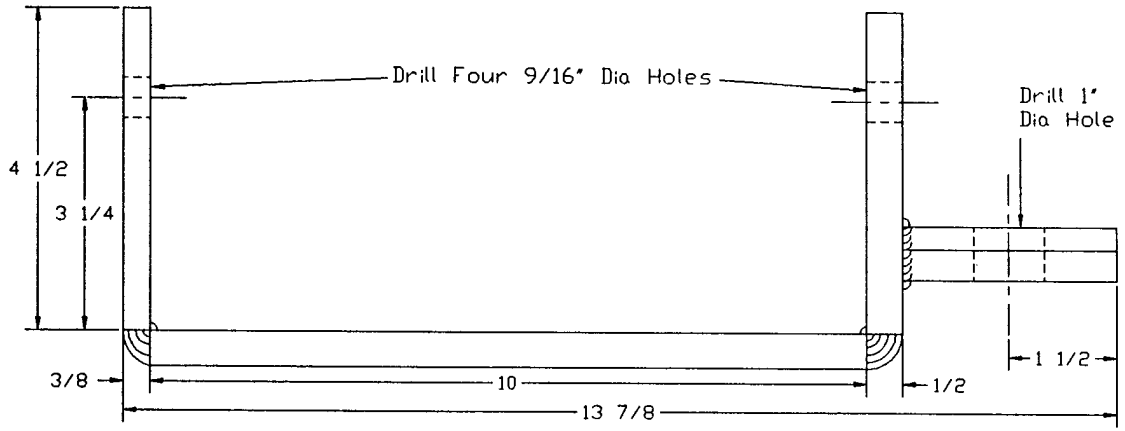
Draftsman/Engineer: Roger H. Gerzeski
Tolerances: X X/X" +/- 1/32"
Date: 2/1/91

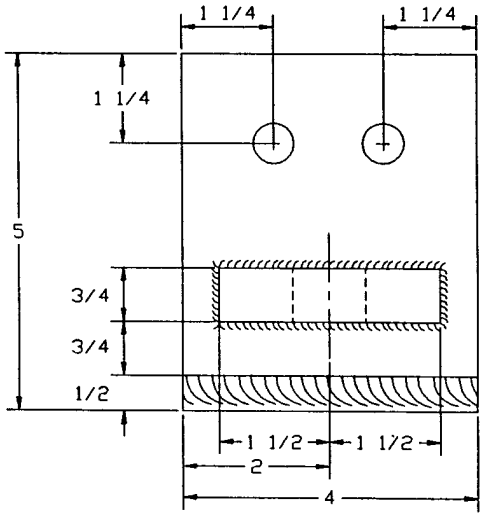
Figure A25: Walker Electromagnet: Support Structure: Stand

Walker Electromagnet

Figure A26: Lifting Hook 191
Figure A27: Bolt To Magnet Bushing 192

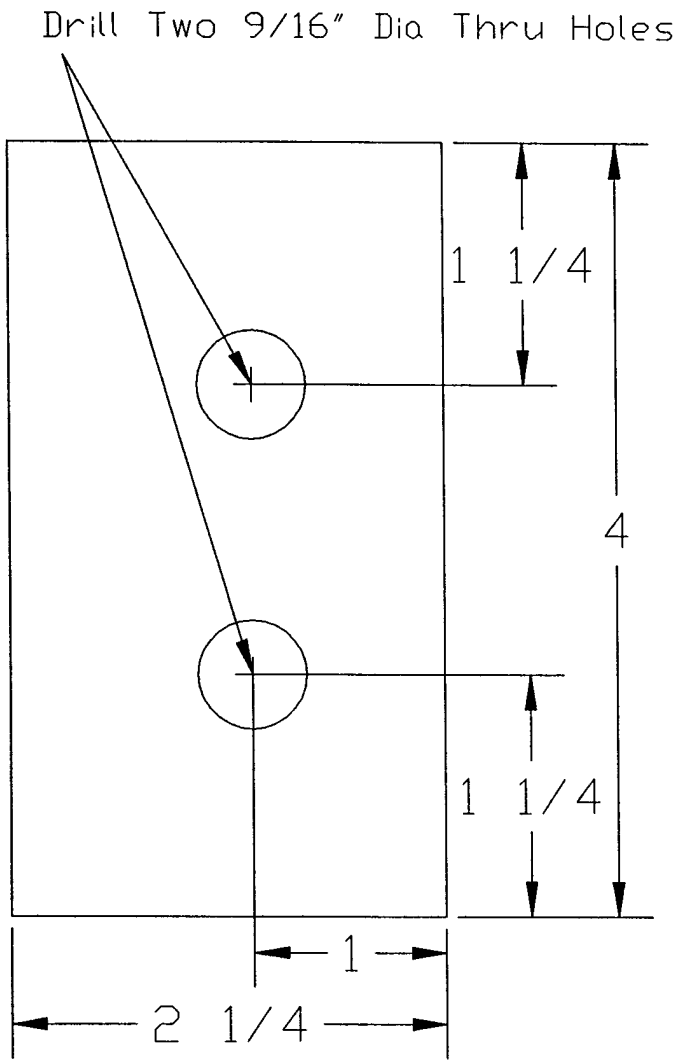
Notes: 1. Continuous Weld The 1/2" Thick Plate And The Bottom 3/8" Thick Plate To The 1/2" Thick Side PLate As Indicated.
2. Continuous Weld The 3/4" Thick Eye Plate To The Top 1/2" Thick Plate As Indicated.
3. Keep The Top 1/2" Thick Plate And The Bottem 3/8" Thick Plate Parallel To Each Other And At Right ie 90 Degree Angles To The Side 1/2" Thick Plate.





Material Of Construction: Steel
Tolerances: X x/x" +/- 1/16"
Angles: Shop
Engineer / Draftsman: Roger H. Gerzeski
Date: 20 Mar 91

Figure A26: Walker Electromagnet: Lifting Hook



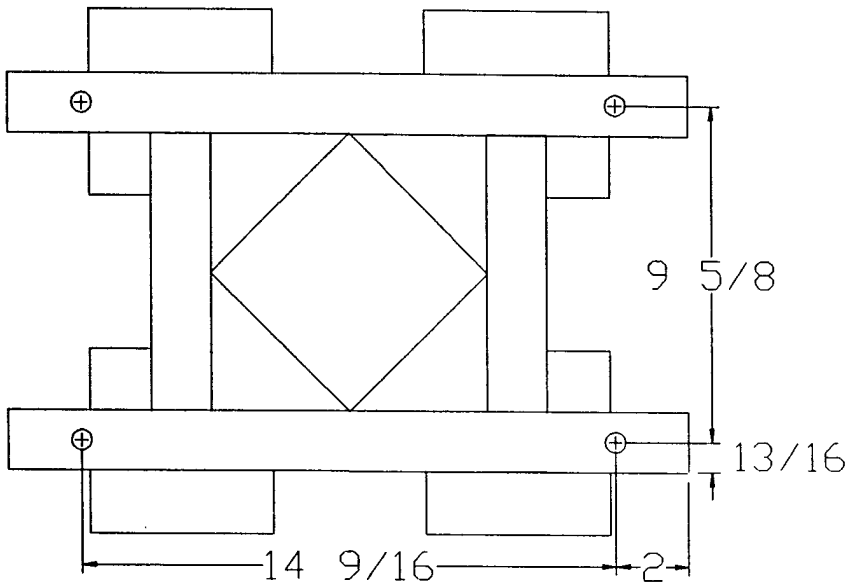
Notes: Fab Eight Bushings 1-1/4" Thick
Fab One Bushing 1" Thick

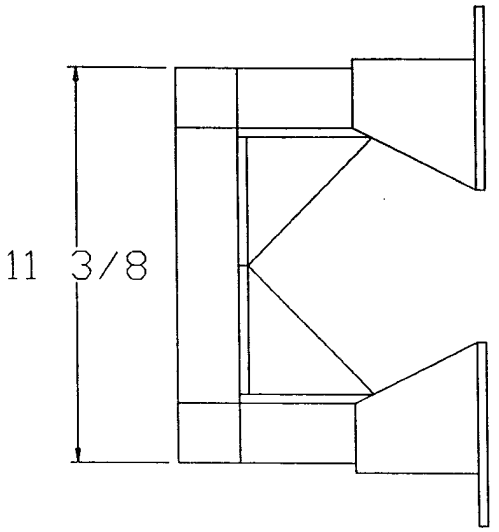
Material Of Construction:
Aluminum
Tolerances: X-x/x" +/- 1/64"
Engineer / Draftsman:
Roger H. Gerzeski
Date: 12 Apr 91

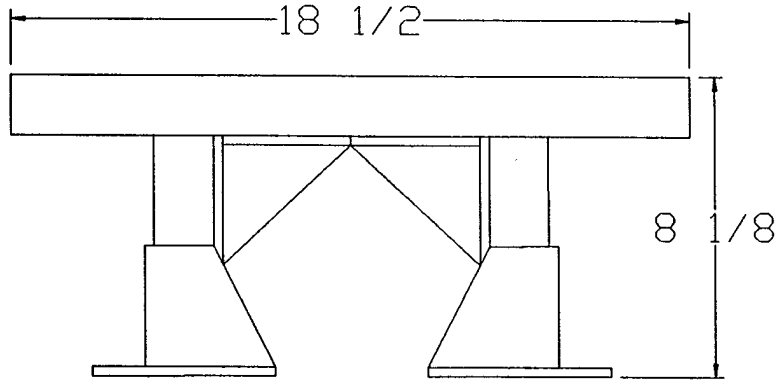
Figure A27: Walker Electromagnet: Bolt To Magnet Bushing

Alpha Scientific Electromagnet

Figure A28: Support Stand 194





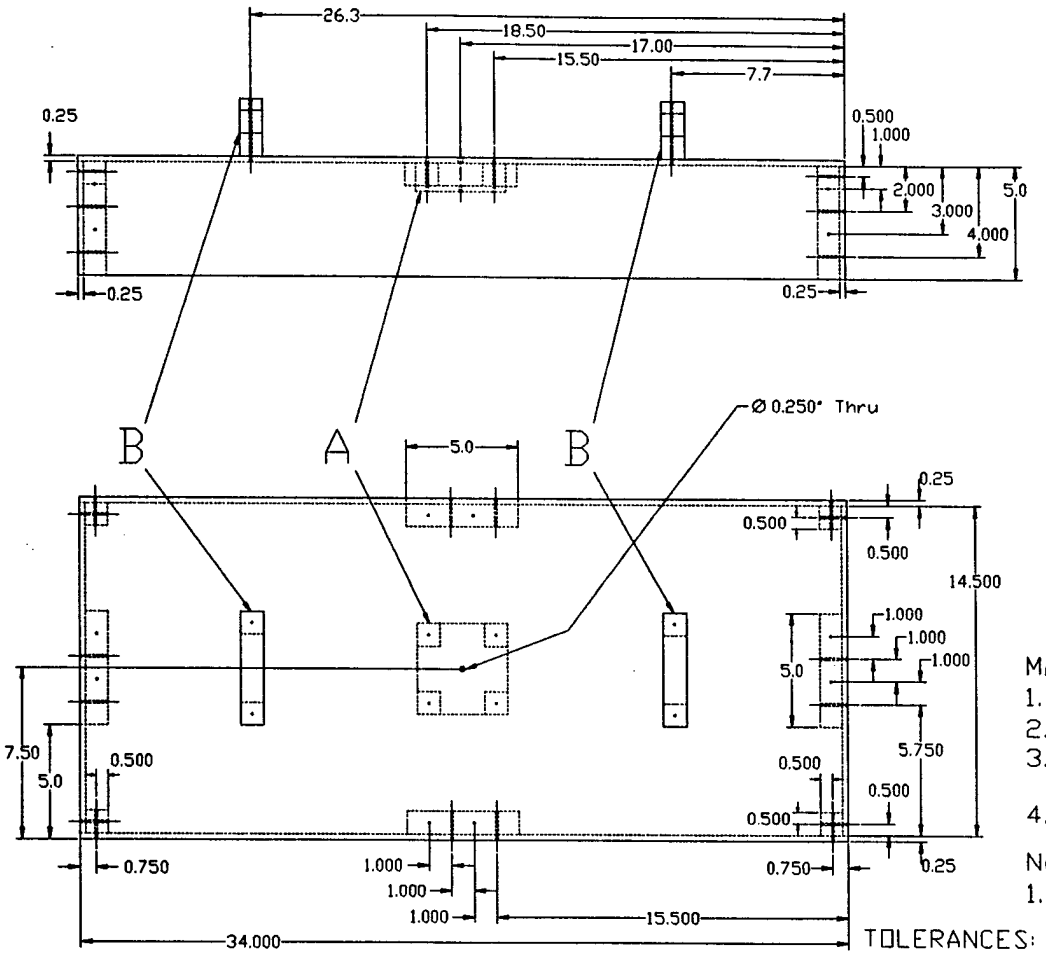


Materials Of Construction:
1. 4 P2245 Three Way Joints
2. 4 P2070 Foot Pads
3. P1000 Unistrut Channels
   Of The Following Lengths:
   2 Bars 18 1/2" Long
   2 Bars 7 7/8" Long
   4 Bars 6 1/4" Long
4. Drill Two 9/16" Dia Holes In The
   Two 18 1/2" Long Bars As Indicated.

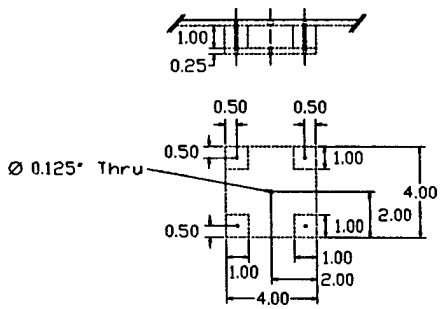
Draftsman / Engineer: Roger H. Gerzeski
Tolerances: X X/X" +/- 1/32"
Date: 9 Mar 92

Figure A28: Alpha Scientific Electromagnet: Support Stand

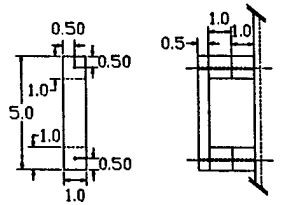
Figure A29: Overpressure Vault 196



DETAIL A



DETAIL B



MATERIALS OF CONSTRUCTION:
1. 1/4" THICK PLEXAGLASS SHEET
2. 1" SQUARE PLEXAGLASS ROD
3. 8-32 SCREWS, NUTS, AND WASHERS
   SCREW LENGTHS 3"
4. ACRYLIC GLUE

Note:
1. Drill 92 Holes 0.166" Dia As Indicated

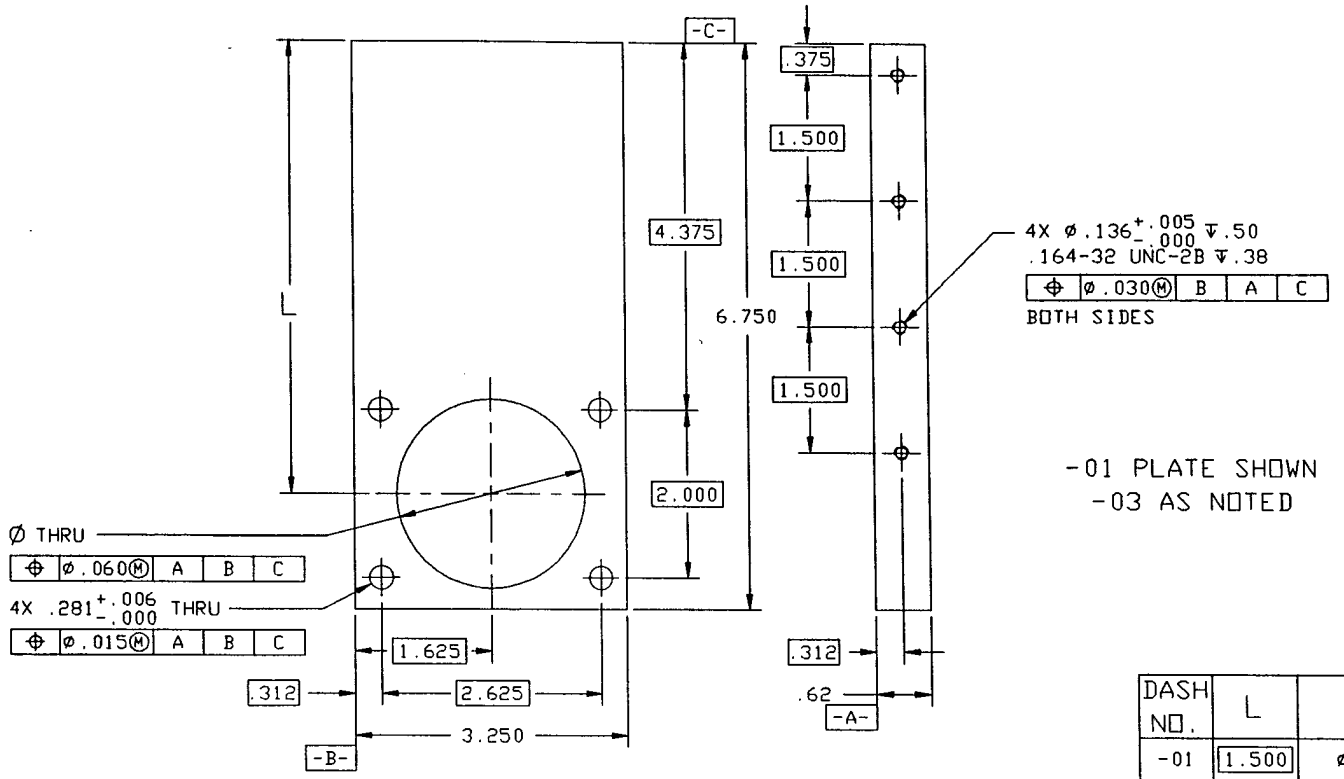
TOLERANCES: X.XXX" +/- 0.005"
X.XX" +/- 0.02"
X.X" +/- 0.1"

DRAFTSMAN/ENGINEER:
ROGER H. GERZESKI
DATE: APR 1993

Figure A29: Overpressure Vault

Type 2 Oven

Figure A30: End Plate 198
Figure A31: Gas Tubes 199
Figure A32: Side Plate 200
Figure A33: Spacer 201
Figure A34: Support Plate 202
Figure A35: Leveling Screw 203
Figure A36: Tapered Nut 204



DASH NO.	L	Ø
-01	1.500	ø 2.250
-03	5.375	ø 2.000 +.010 -.000

QUANITY REQUIRED		NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION
1		PLATE	-03	ANY ALUM .625 PLATE
	1	PLATE	-01	

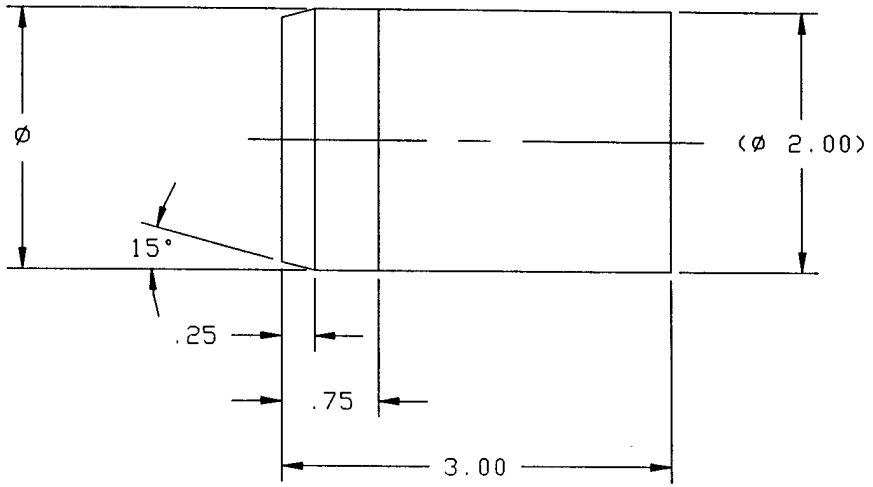
PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX± .03 .XXX± .010 ±0°15'	ENG GERZESKI, R. 1 JUN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR. BOCOCK, B 06MAY94	TITLE END PLATE CURING OVEN
	H5	DRAWING NO. X947133

NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125/
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

Figure A30: Type 2 Oven: End Plate



-03 TUBE SHOWN
-01 AS NOTED

Dash No.	Ø
-01	2.250 $^{+0.000}_{-0.010}$
-03	2.000 $^{+0.000}_{-0.010}$

NOTES UNLESS OTHERWISE SPECIFIED

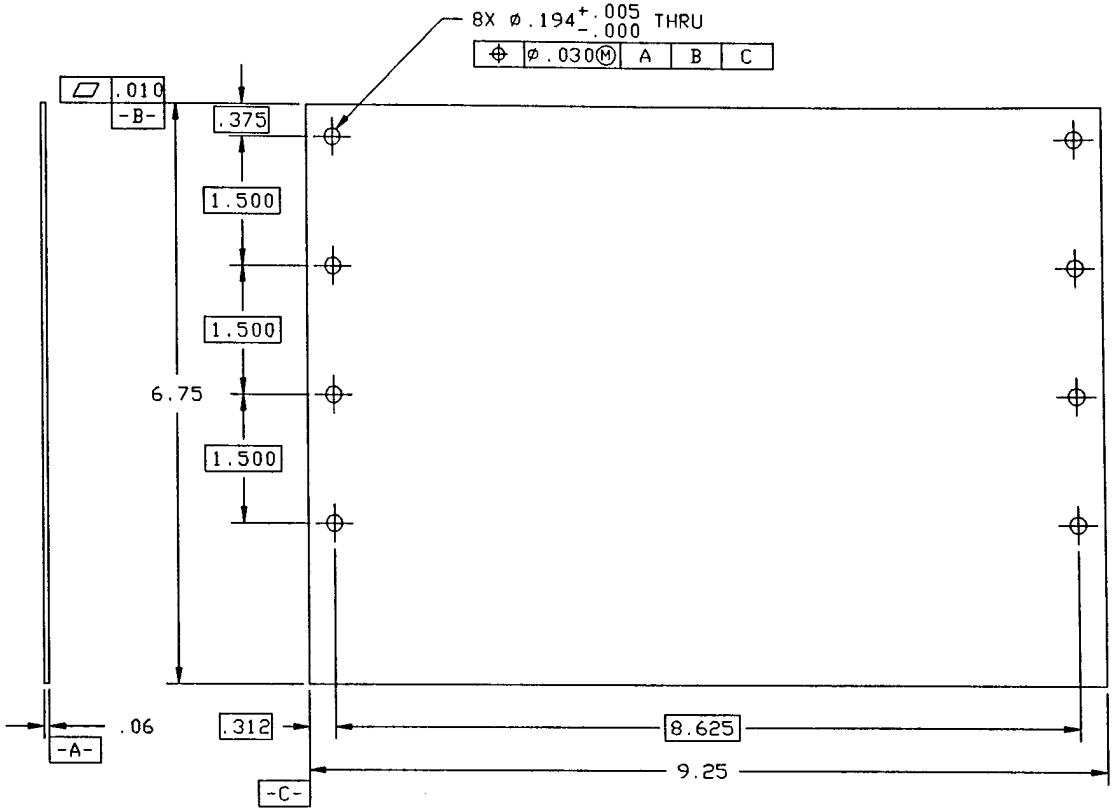
1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

TUBE	-03	ALUM TUBE ø 2.00 X .125 WALL
TUBE	-01	ALUM TUBE ø 2.50 X .125 WALL
NOMENCLATURE	Dash No.	MATERIAL/SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± .XX±.03 ± .XXX±.010 ±0°15'	ENG GERZESKI, R 3 JUN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 11MAY94	TITLE TUBE OUTLET CURING OVEN
	H5	DRAWING NO. X9436135

Figure A31: Type 2 Oven: Gas Tubes

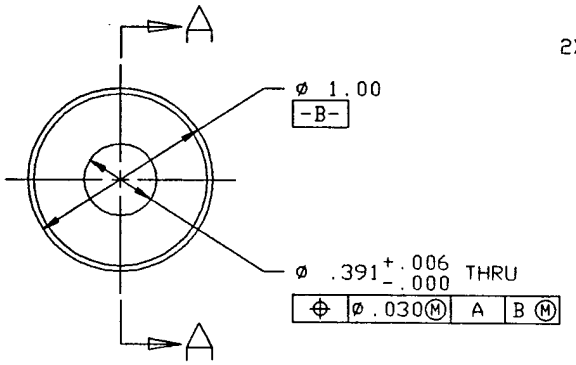


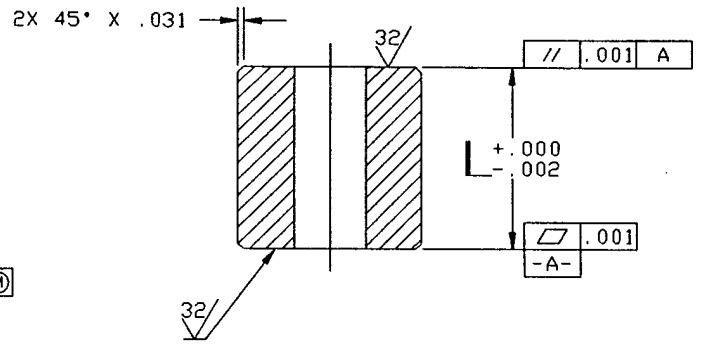
NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

NOMENCLATURE: PLATE	MATERIAL / SPECIFICATION: INCONEL X-750
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG Gerzeski R. 1JUN94
	DR BOCOCK, B 06MAY94
	H5
	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	TITLE SIDE PLATE CURING OVEN
	DRAWING NO. X947134

Figure A32: Type 2 Oven: Side Plate





SECTION A-A

L	DASH NO
1.000	-01
.950	-03
.900	-05
.750	-07

15				SPACER	-07	ANY ALUM
	15			SPACER	-05	
		15		SPACER	-03	
			40	SPACER	-01	
QUANITY REQUIRED				NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 .XXX±.010 ±0°15'	ENG GERZESKI, R 1 JUN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR. BOCOCK, B 01MAY94	TITLE SPACER CURING OVEN
	H5	DRAWING NO. X947132

NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

Figure A33: Type 2 Oven: Spacer

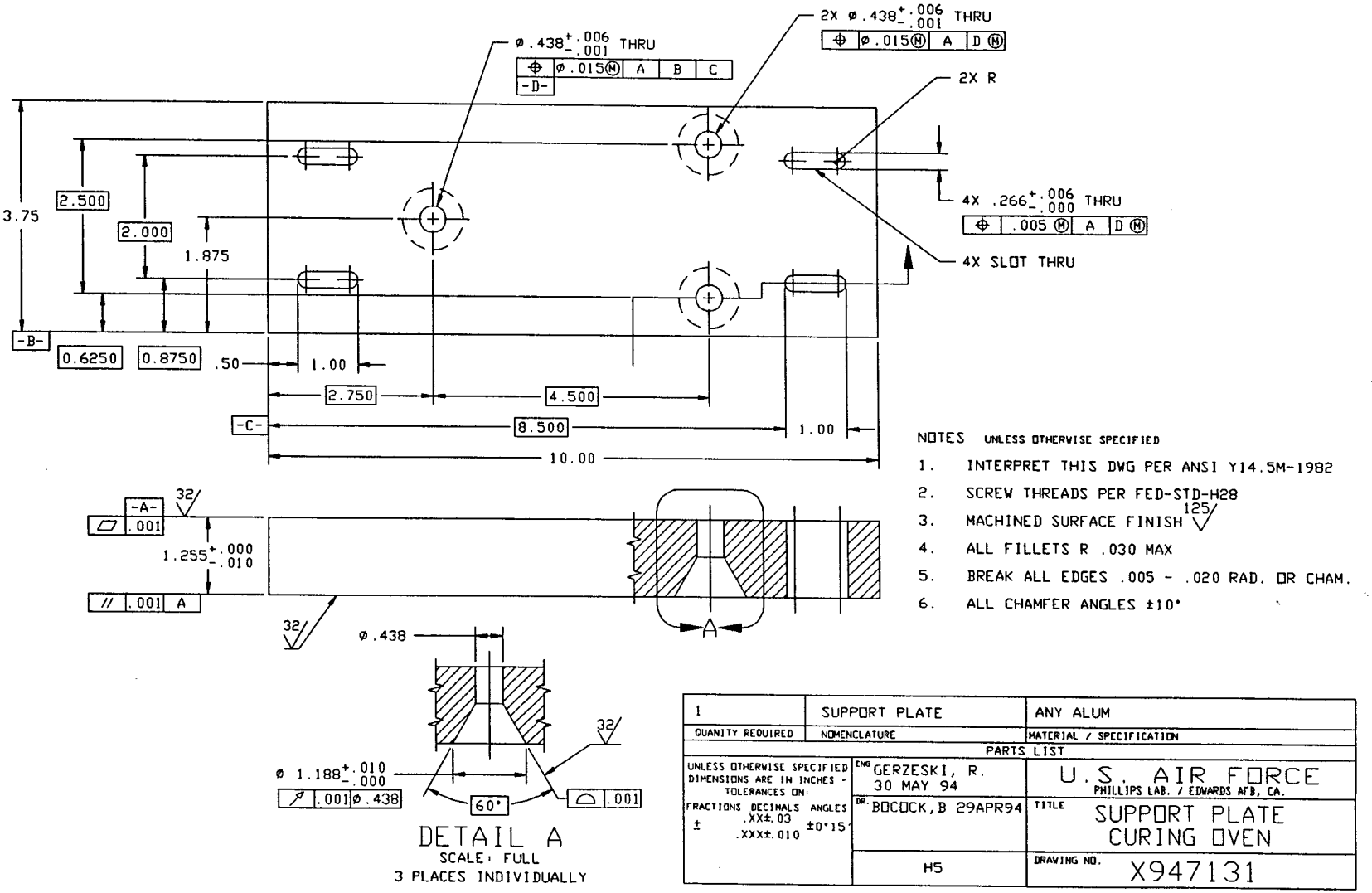
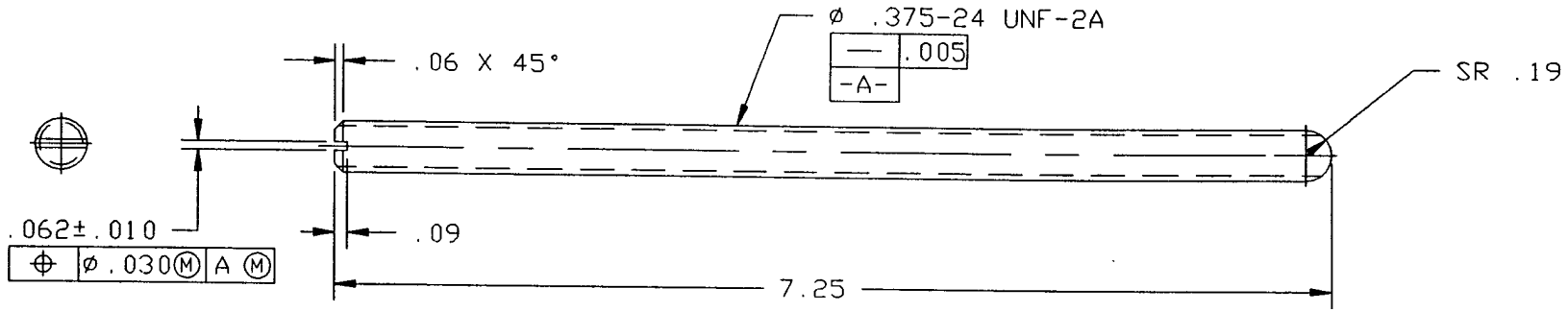


Figure A34: Type 2 Oven: Support Plate

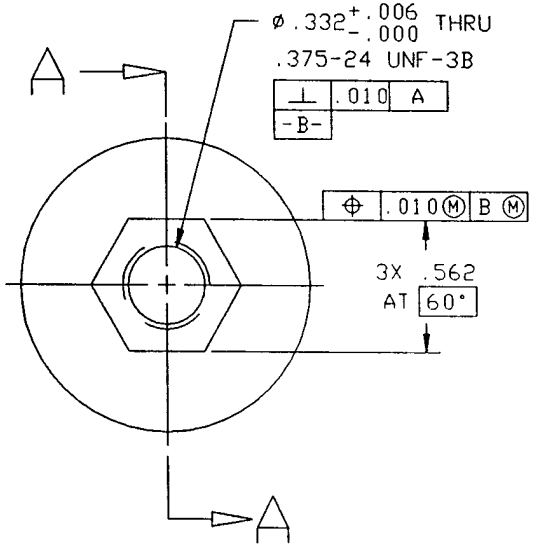


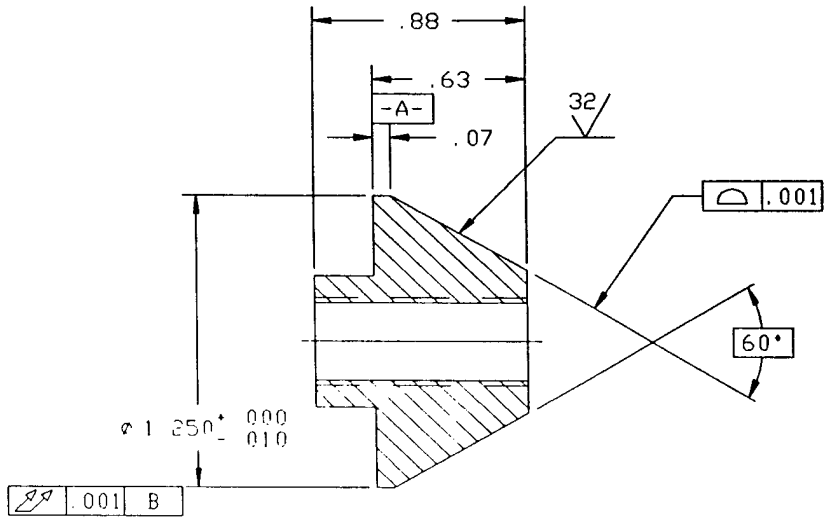
NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

SCREW, LEVELING		BRASS
NOMENCLATURE		MATERIAL/SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES + .XX±.03 ±0°15' − .XXX±.010	ENG GERZESKI, R 14 MAR 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 10DEC93	TITLE SCREW, LEVELING CURING OVEN
	H5	DRAWING NO. X936166

Figure A35: Type 2 Oven: Leveling Screw





SECTION A-A

NOTES UNLESS OTHERWISE SPECIFIED

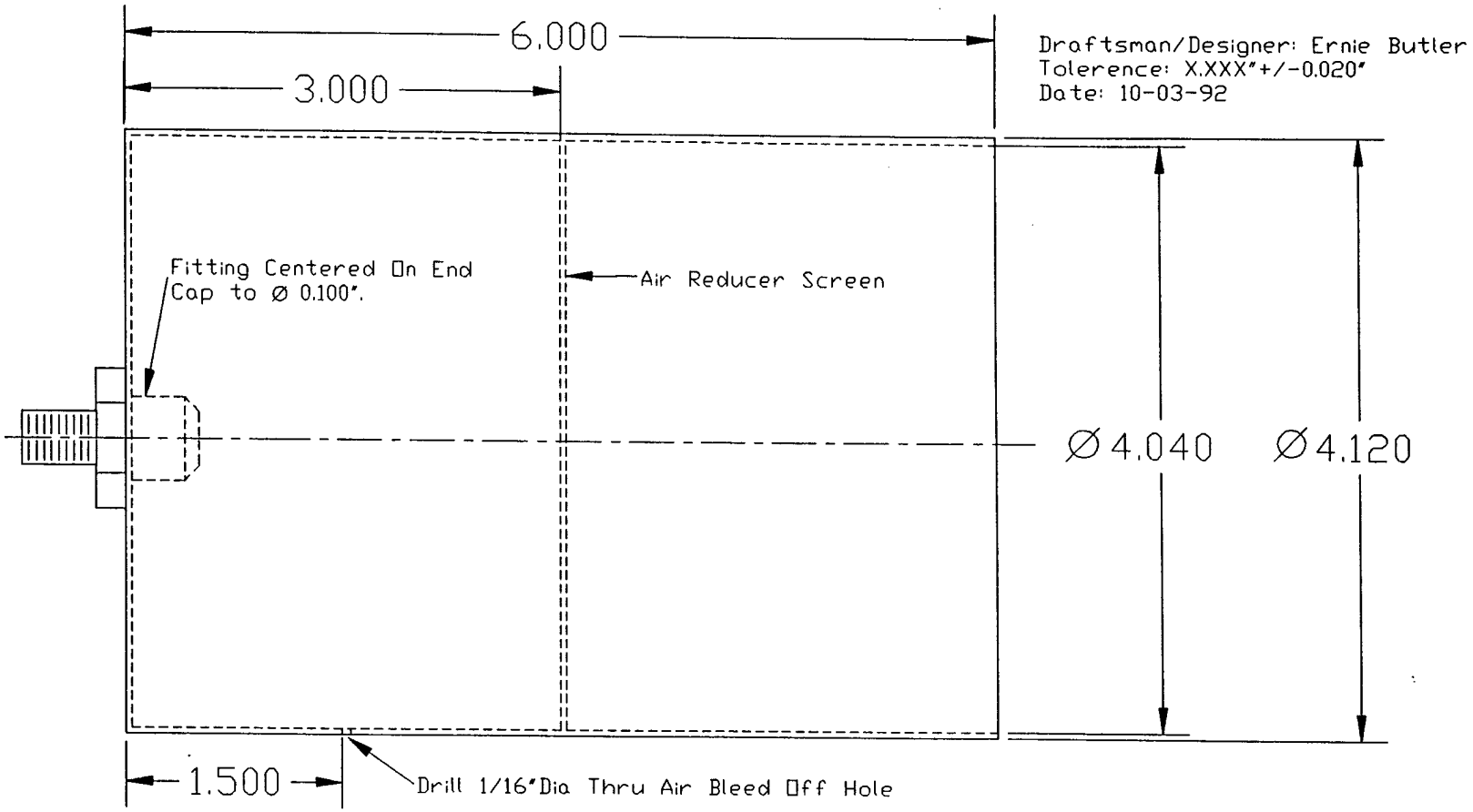
1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .030 MAX
5. BREAK ALL EDGES .005 - .020 RAD. OR CHAM.
6. ALL CHAMFER ANGLES ±10°

TAPERED NUT		ANY ALUM
NOMENCLATURE		MATERIAL/SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± .XX±.03 .XXX±.010 ±0°15'	ENG GERZESKI, R 10 JUN 94	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 24MAY94	TITLE NUT, TAPERED .375-24 UNF CURING OVEN
	H5	DRAWING NO. X947154

Figure A36: Type 2 Oven: Tapered Nut

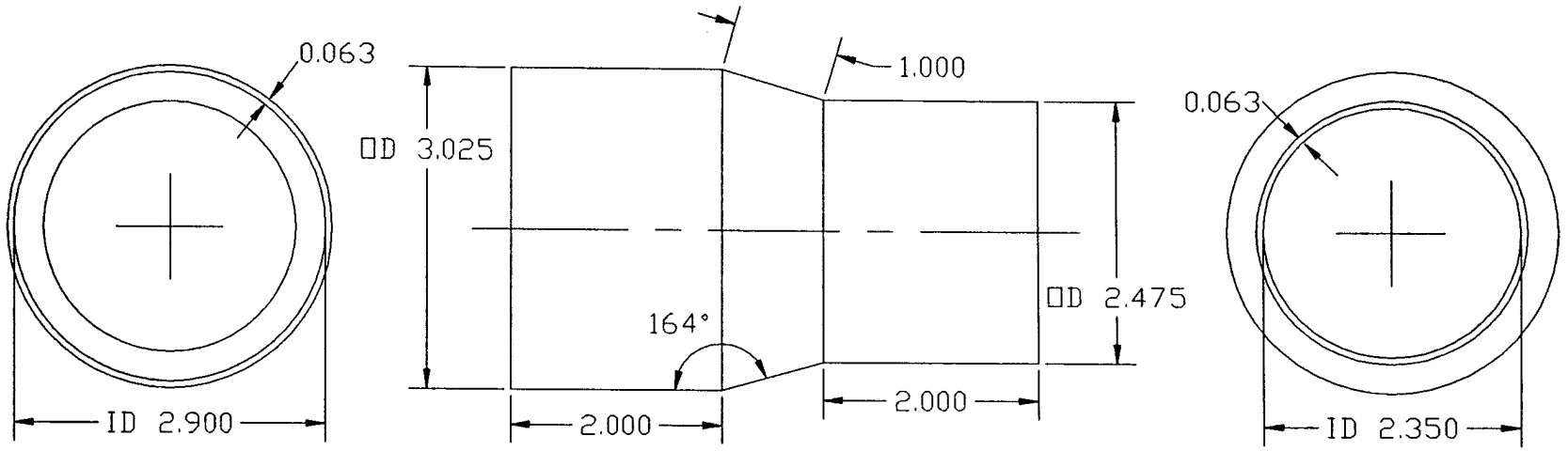
Heat Transport Fluid Equipment

Figure A37: Gas Pressure Reducer 206
Figure A38: Gas Heater To Hose Coupler 207



Notes: 1. Air Reducer: Tack Weld Stainless Steel Screen With less than 1/16" Dia Hex Centered Holes.
2. End Cap: Continuous Weld To Top Of 4.120" OD Stainless Steel Tube Main Body.
3. End Cap Air Inlet: Continuous Weld 1/4 Male Pipe To 3/8 Flared Pipe Fitting Made Of Stainless Steel.
4. Air Reducer Screen: Screen Thickness 0.063" Min 0.100" Max.

Figure A37: Gas Pressure Reducer

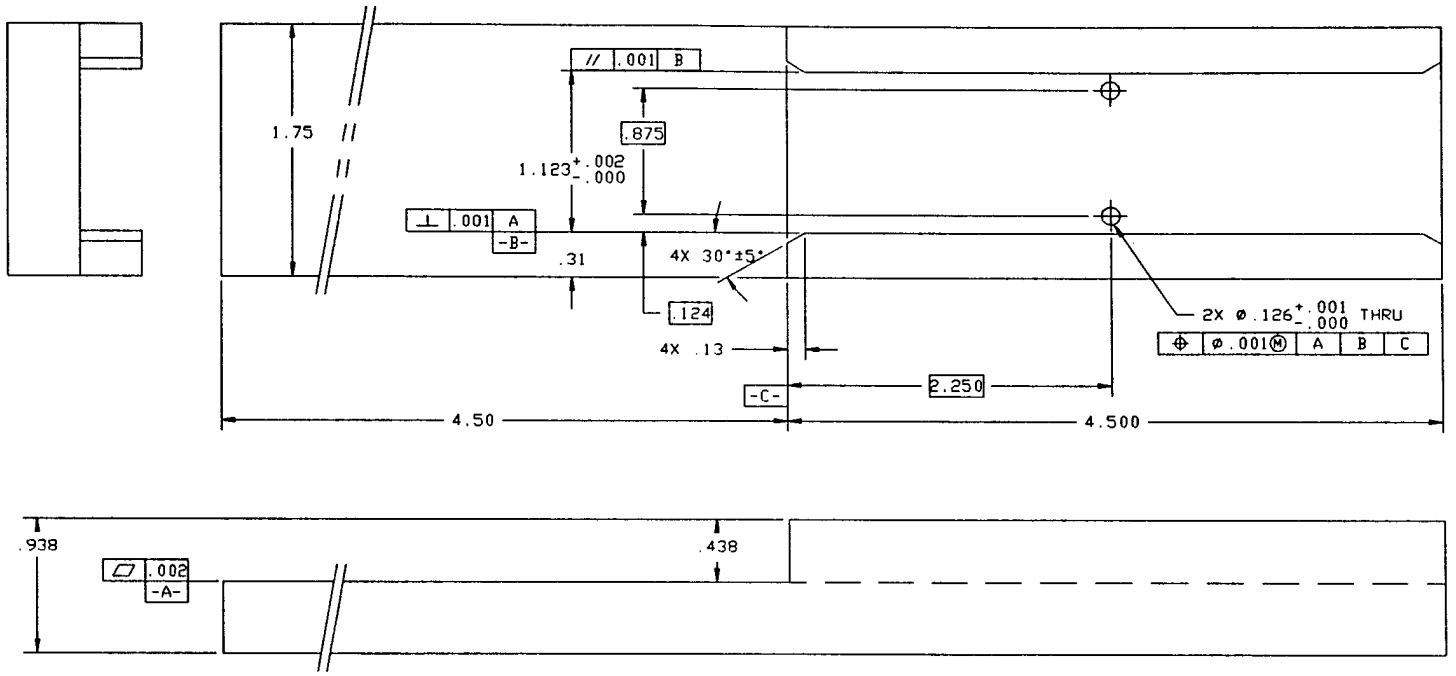


DRAFTSMAN: ERNIE BUTLER
DATE: 5 NOV 91
TOLERANCES: X.XXX' +/- 0.010"
MATERIAL OF CONSTRUCTION: 304 STAINLESS STEEL
NOTE: CONTINUOUS AIR TIGHT WELD THE TWO CYLINDER SECTIONS TO THE TRUNCATED CONE SECTION. ALL WELDS ARE TO BE CONTINUOUS AIR TIGHT.

Figure A38: Gas Heater To Hose Coupler

Tensile Test Fixture

Figure A39: Alignment Block 209
Figure A40: Lower Grip 210
Figure A41: Upper Grip 211
Figure A42: Spacer 212
Figure A43: Alignment Pins 213
Figure A44: Top And Bottom Clevis 214

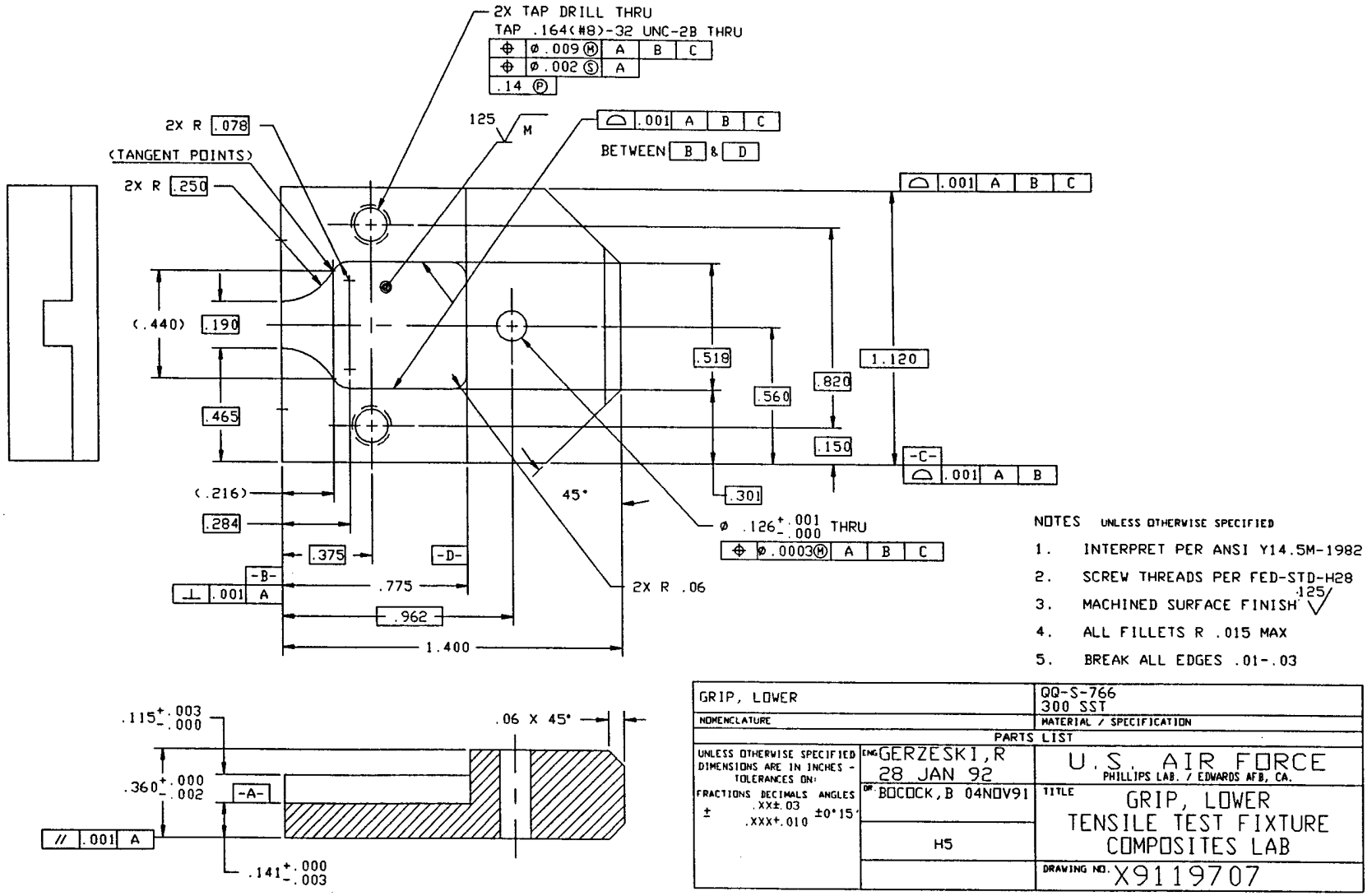


NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .005 MAX
5. BREAK ALL EDGES .01-.03

BLOCK		QQ-S-766 300 SST
NOMENCLATURE		MATERIAL / SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG GERZESKI, R 14 JAN 92	U.S. AIR FORCE PHILLIPS LAB EDWARDS AFB CA
	DR. BOCOCK, B 04NOV91	TITLE BLOCK, ALIGNMENT TENSILE TEST FIXTURE COMPOSITES LAB
	H5	DRAWING NO. X9119706

Figure A39: Tensile Test Fixture: Alignment Block

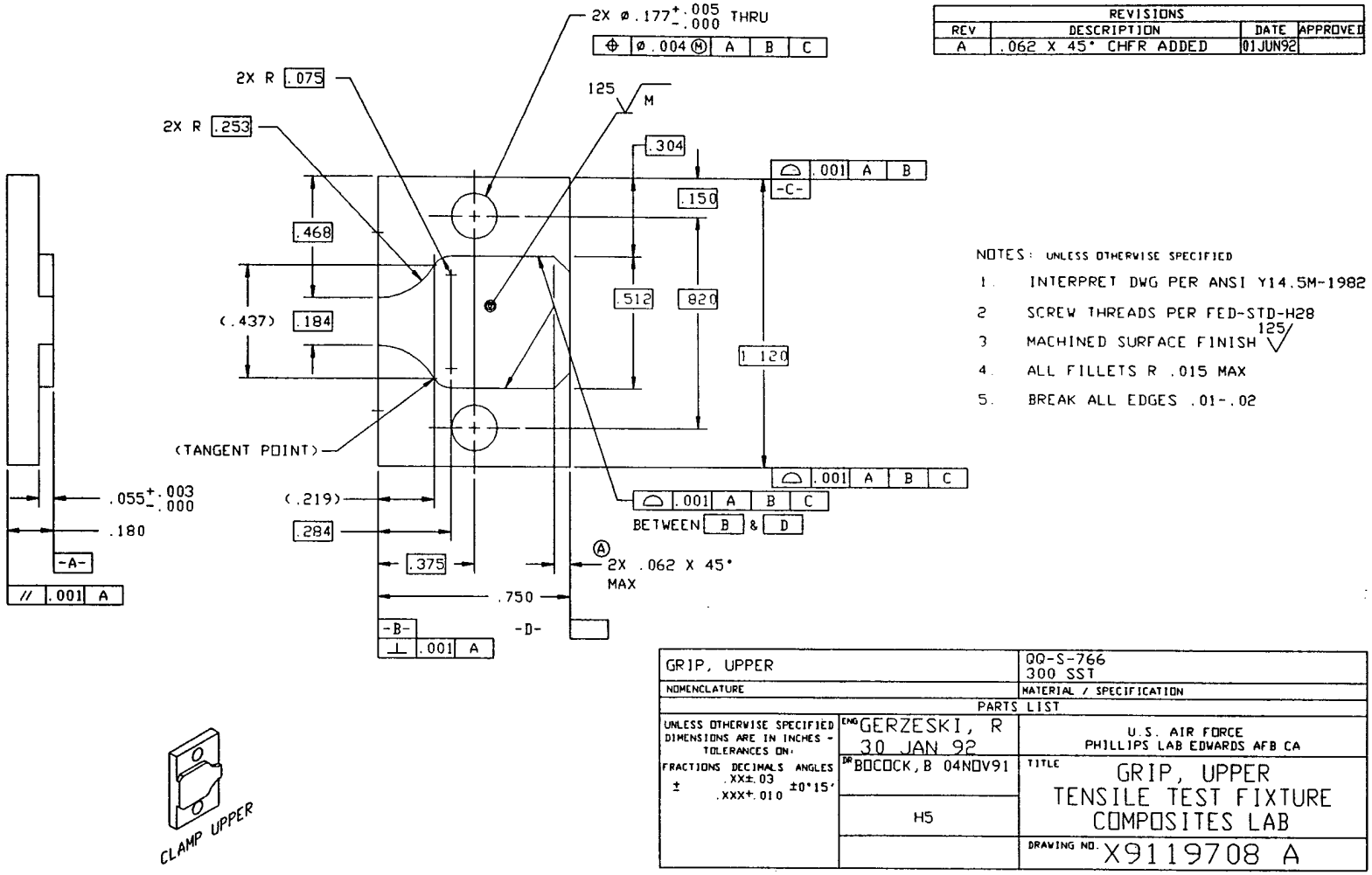


NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125 V
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES .01-.03

GRIP, LOWER		QQ-S-766 300 SST
NOMENCLATURE		MATERIAL / SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±0°15' .XXX±.010	ENG GERZESKI, R 28 JAN 92	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 04NOV91	TITLE GRIP, LOWER TENSILE TEST FIXTURE COMPOSITES LAB
	H5	
		DRAWING NO. X9119707

Figure A40: Tensile Test Fixture: Lower Grip



REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
A	.062 X 45° CHFR ADDED	01JUN92	

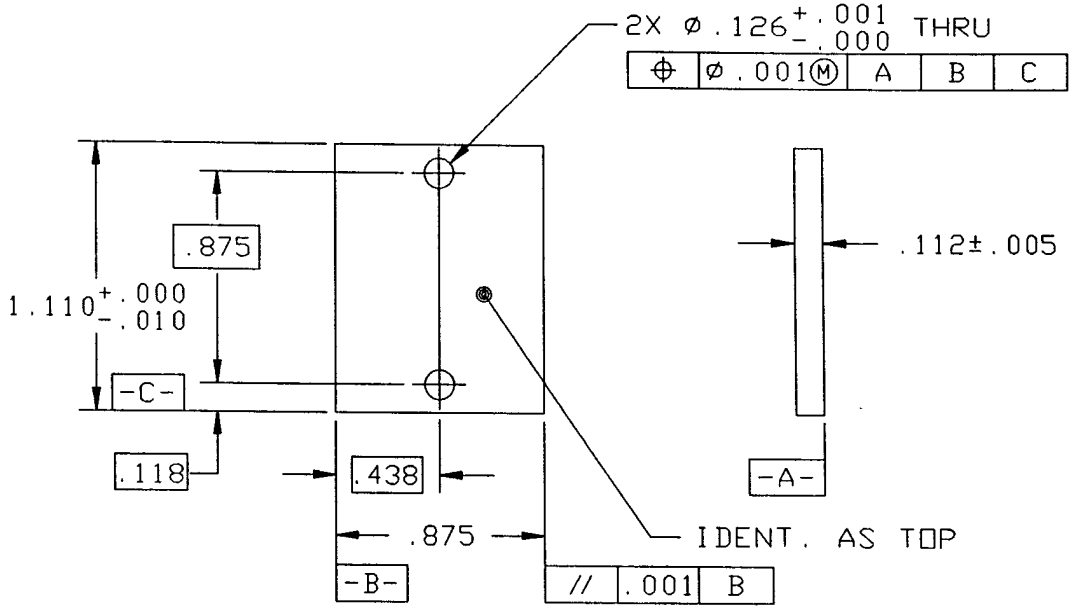
NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES .01-.02

GRIP, UPPER	QQ-S-766 300 SST
NOMENCLATURE	MATERIAL / SPECIFICATION
PARTS LIST	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX±.03 .XXX±.010 ±0°15'	ENG GERZESKI, R 30 JAN 92	U.S. AIR FORCE PHILLIPS LAB EDWARDS AFB CA
	DR BOCOCK, B 04NOV91	TITLE GRIP, UPPER TENSILE TEST FIXTURE COMPOSITES LAB
	H5	
		DRAWING NO. X9119708 A

Figure A41: Tensile Test Fixture: Upper Grip

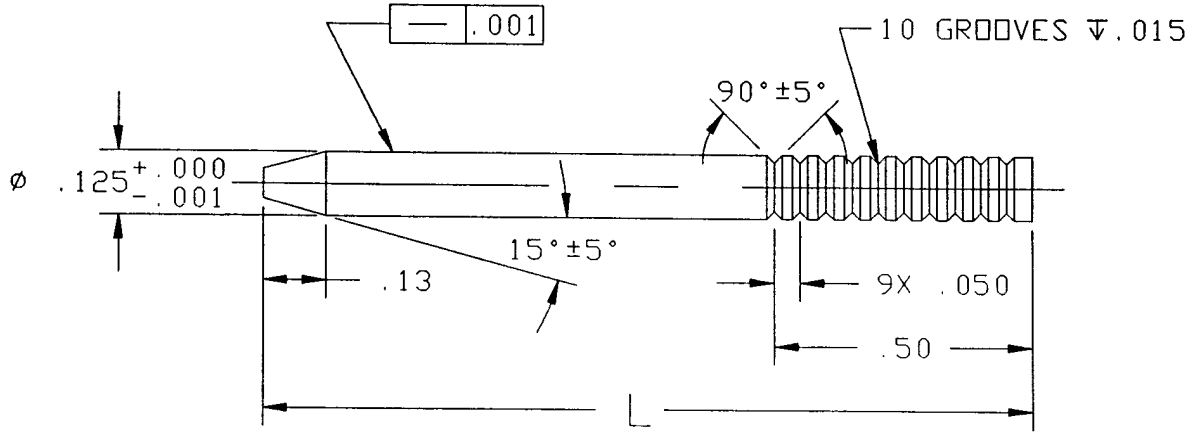


NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES .01-.02

SPACER		QQ-S-766 300 SST
NOMENCLATURE		MATERIAL/SPECIFICATION
PARTS LIST		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES + .XX±.03 ±0°15 - .XXX±.010	ENG GERZESKI,R 20 JAN 92	U.S. AIR FORCE PHILLIPS LAB EDWARDS AFB CA
	DR BOCOCK,B 04NOV91	TITLE SPACER TENSILE TEST FIXTURE COMPOSITES LAB
	H5	DRAWING NO. X9119709

Figure A42: Tensile Test Fixture: Spacer



PART NO	L
-01	1.50
-03	2.50

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET THIS DWG PER ANSI Y14.5M-1982
2. SCREW THR'DS PER ANSI Y14.6-1978
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .005 MAX
5. BREAK ALL EDGES .01-.03

QTY	NOMENCLATURE	IDENTIFYING NO	MATERIAL/SPECIFICATION
2	PIN, PULL	-03	QQ-T-570 DRILL ROD ø .125 X 2.50
2	PIN, ALIGNMENT	-01	QQ-T-570 DRILL ROD ø .125 X 1.50

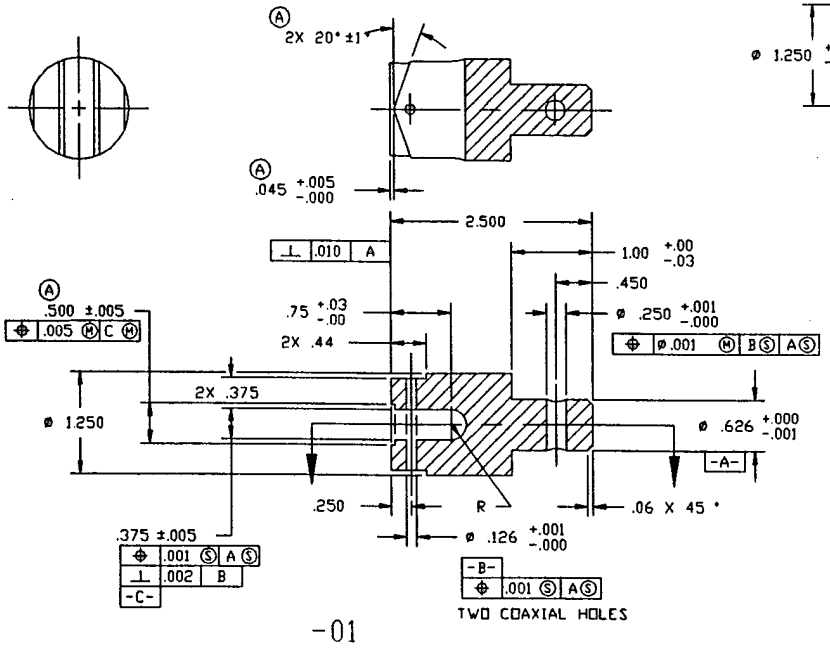
PARTS LIST

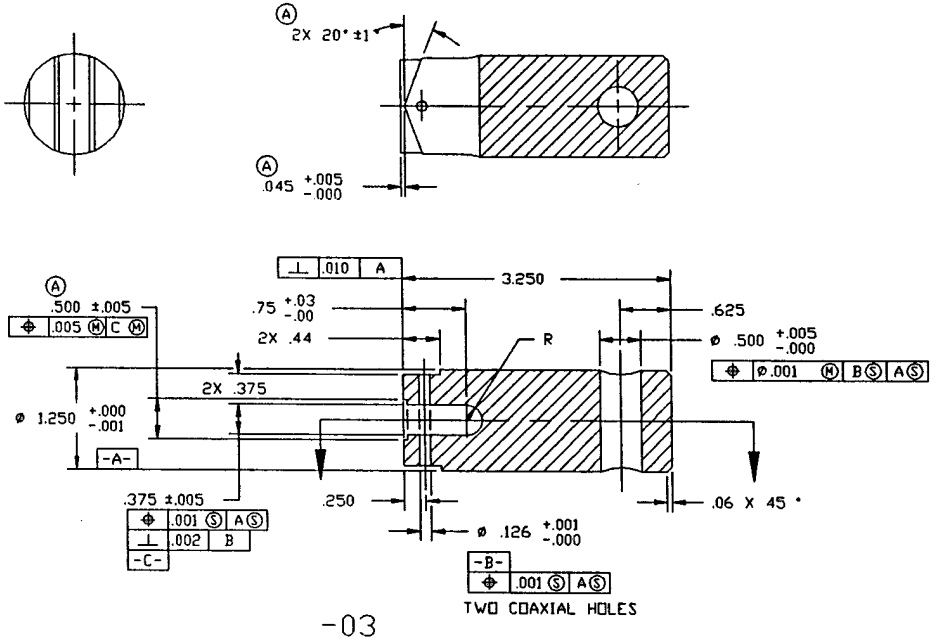
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± .xx±.03 .xxx±.010 ±	ENG GERZESKI, R 5 JAN 92	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR BOCOCK, B 04NOV91	TITLE PIN, ALIGNMENT TENSILE TEST FIXTURE COMPOSITES LAB
	H5	DRAWING NO. X9119712

Figure A43: Tensile Test Fixture: Alignment Pins

NOTES UNLESS OTHERWISE SPECIFIED

1. INTERPRET DWG PER ANSI Y14.5M-1982
2. SCREW THREADS PER FED-STD-H28
3. MACHINED SURFACE FINISH 125
4. ALL FILLETS R .015 MAX
5. BREAK ALL EDGES .01-.03





REVISIONS		
REV	DESCRIPTION	DATE
A	20° ANGLE - .500 DIM AND .045 DIM ADDED	29MAY92

CLEVIS: BOTTOM	-03	QQ-S-763 ANY 300 SERIES STN STL
CLEVIS: TOP	-01	
NOMENCLATURE	IDENTIFYING NO.	MATERIAL / SPECIFICATION

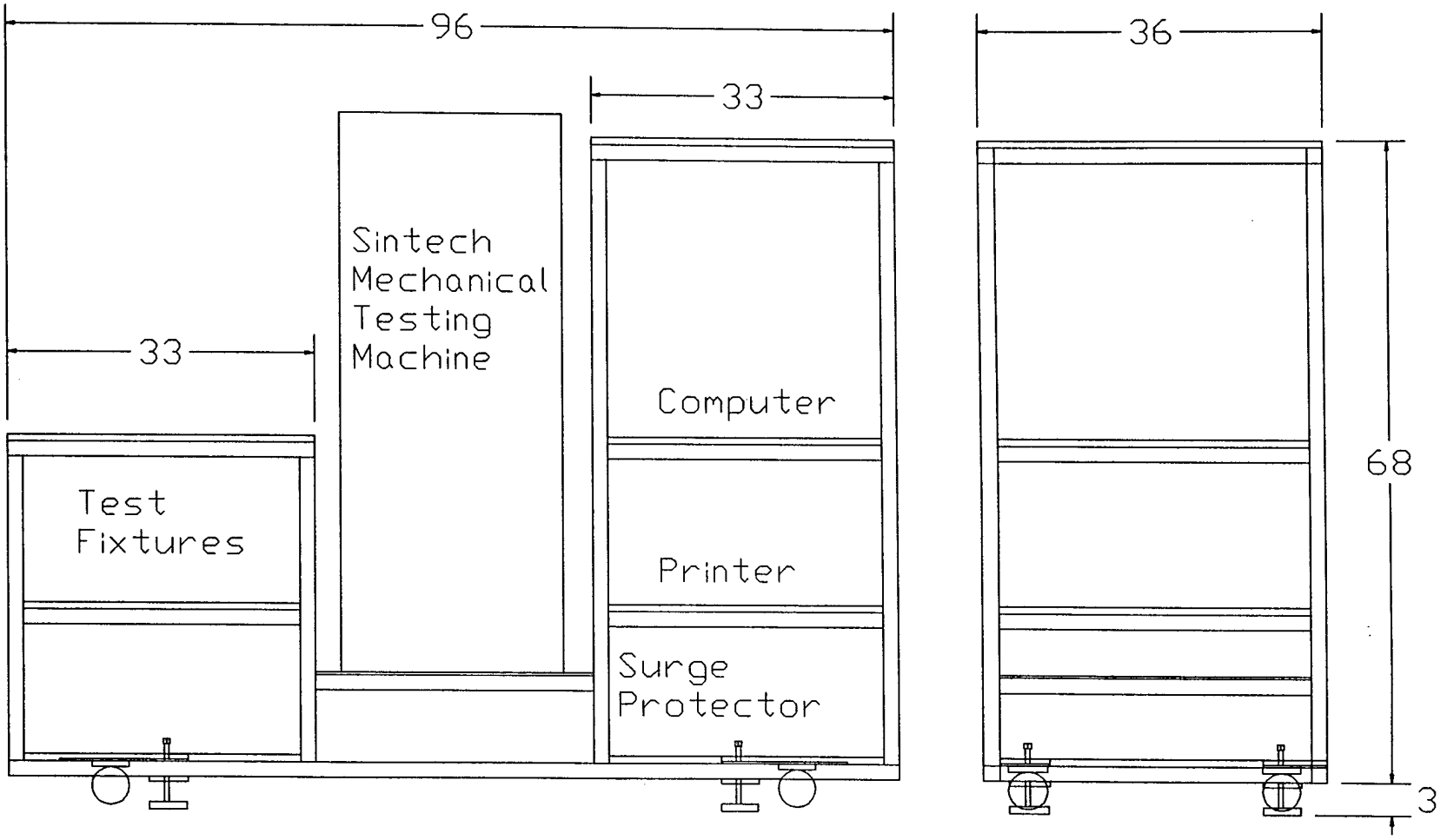
PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES - TOLERANCES ON: FRACTIONS DECIMALS ANGLES ± .XX ±03 ±0°15' .XXX ±010	ENG GERZESKI, R 12 FEB 92	U.S. AIR FORCE PHILLIPS LAB. / EDWARDS AFB, CA.
	DR. BOCOCK,B 04NOV91	TITLE CLEVIS TENSILE TEST FIXTURE COMPOSITES LAB
	H5	
		DRAWING NO. X9119710 A

Figure A44: Tensile Test Fixture: Top And Bottom Clevis

Tensile Testing Machine Support Bench

Figure A45: Mobile Testing Machine Bench 216



Draftsman: Neil Vaughn And Roger H. Gerzeski
Engineer: Roger H. Gerzeski Date: 15-04-90

Figure A45: Mobile Testing Machine Bench

DISTRIBUTION LIST

AUL/LSE **Bldg 1405 - 600 Chennault Circle** **Maxwell AFB, AL 36112-6424**	**1 cy**
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AFSAA/SAI **1580 Air Force Pentagon** **Washington, DC 20330-1580**	**1 cy**
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