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COMPOSITES MANUFACTURING

Filament Winding

SCENE 1.
FW01A, GRAPHIC: FBI warning
white text centered on black to blue gradient

WARNING

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SCENE 2.
FW02A, GRAPHIC: disclaimer
white text centered on black to blue gradient

Always read the operating manual and safety information provided by the manufacturer before operating any filament winding equipment.

Make sure all machine guards are in place, and follow all safety procedures when working with or near filament winding equipment.

SCENE 3.
FW03A, GRAPHIC: EMA/SME screen
white text centered on black to blue gradient

This program was produced using the technical resources of the Engineering Materials Applications Community of SME.

For more information on composites and compression molding, please visit our website at:

www.sme.org

SCENE 4.
FW04A, SME logo open, with music

SCENE 5.
FW05A, composites manufacturing open, with music
FW05B, peter carey narration

MUSIC UP AND UNDER

NARRATION (VO):

THE COMPOSITES MANUFACTURING SERIES, EXAMINING THE MATERIALS, TOOLS AND TECHNIQUES USED FOR COMPOSITES FABRICATION.

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SCENE 6.
FW06A, GRAPHIC: Filament Winding
white text centered on black

NARRATION (VO):

THIS PROGRAM IS AN INTRODUCTION TO FILAMENT WINDING.

SCENE 7.
FW07A, tape 700, 13:08:46-13:09:06
wide, filament winding operation

NARRATION (VO):

FILAMENT WINDING IS THE HIGH-SPEED, PRECISE DEPOSITION OF CONTINUOUS RESIN-IMPREGNATED FIBERS ALONG A PREDETERMINED PATH ON A MANDREL OF ALMOST ANY SHAPE.

SCENE 8.
FW08A, tape 695, 11:23:00-11:23:13
zoom out, tow material being used

NARRATION (VO):

THE MOST COMMON FILAMENT WOUND MATERIAL IS CONTINUOUS TOW, WHICH IS A BUNDLE OF TYPICALLY TEN THOUSAND OR MORE UNTWISTED CONTINUOUS FILAMENTS.

SCENE 9.
FW09A, tape 29, 01:06:03-01:06:36
filament winding operation
FW09B, tape 29, 01:17:36-01:17:47
zoom out, filament winding operation stopping

NARRATION (VO):

THE PART OR COMPONENT BEING PRODUCED IS WOUND IN ADJACENT BANDS OF ONE OR MORE TOWS, OR IN REPEATED BANDS TO COVER THE MANDREL SURFACE WITHOUT GAPS OR WRINKLES BETWEEN BANDS. WINDING CONTINUES UNTIL DESIRED COMPONENT THICKNESS HAS BEEN ACHIEVED.

SCENE 10.
FW10A, tape 696, 12:10:15-12:10:27
thick filament wound part being produced
FW10B, tape 695, 11:22:08-11:22:22
odd shaped filament wound part

NARRATION (VO):

FILAMENT WINDING PERMITS THE MANUFACTURE OF THE LARGEST AND THICKEST-WALL COMPOSITE SHAPES. ADDITIONALLY, THERE ARE ESSENTIALLY NO LIMITATIONS ON CONVEX CURVATURES THAT CAN BE PRODUCED.

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SCENE 11.
FW11A, tape 700, 13:16:48-13:17:04
zoom out, filament winding of tube
FW11B, tape 385, 01:16:55-01:17:05
filament winding of cylinder
FW11C, tape 13, 13:28:13-13:28:20
pan, storage tanks
FW11D, tape 702, 16:20:27-16:20:34
wide, cantilever springs being filament wound
FW11E, tape 376, 01:14:28-01:14:42
helicopter taking off

NARRATION (VO):

TYPICAL APPLICATIONS FOR FILAMENT WINDING INCLUDE PIPE AND TUBULAR PRODUCTS OF MANY KINDS,
CYLINDRICAL OR SPHERICAL PRESSURE VESSELS,
STORAGE TANKS,
CANTILEVER SPRINGS,
AND SPECIALLY FORMED SHAPES SUCH AS HELICOPTER AND PROPELLER BLADES.

SCENE 12.
FW12A, tape 700, 13:08:17-13:08:31
wet filament winding operation
FW12B, tape 02, 02:25:44-02:25:56
tilt, part created from prepreg material
FW12C, tape 29, 01:26:46-01:26:56
pan, filament winding mandrel during winding operation
FW12D, CGS: Mandrel

NARRATION (VO):

MATERIAL COST FOR FILAMENT WINDING IS LOW BECAUSE BOTH FIBER AND RESIN CAN TYPICALLY BE USED IN THEIR LOWEST-COST FORMS. FILAMENT WINDING ALSO ALLOWS FOR THE USE OF MORE EXPENSIVE PREPREG MATERIALS TO PRODUCE COMPONENTS. FILAMENT WINDING TOOLING COST IS LOW, TOO, BECAUSE ONLY ONE TOOL, THE MANDREL, IS REQUIRED.

SCENE 13.
FW13A, tape 12, 12:04:59-12:05:19
zoom out, filament winding of large tube
FW13B, tape 694, 10:10:24-10:10:39
zoom out, manual layup of large component
FW13C, tape 24, 22:06:16-22:06:31
tape layup operation

NARRATION (VO):

FURTHERMORE, NO PREFORMING IS TYPICALLY REQUIRED FOR FILAMENT WINDING AND THE NEED FOR LABOR IS USUALLY LOW. FOR LARGE COMPONENTS, THE COST OF FILAMENT WINDING IS LESS THAN ONE-FOURTH THAT OF MANUAL LAYUP...,
AND LESS THAN HALF THAT BY TAPE-LAYING MACHINES.

SCENE 14.
FW14A, tape 13, 13:22:36-13:22:59

NARRATION (VO):

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large storage container removed from mandrel

ON THE OTHER HAND, FILAMENT WOUND PART SHAPES MUST PERMIT MANDREL REMOVAL, AND CONCAVE SURFACE REGIONS CANNOT BE PRODUCED EASILY USING FILAMENT WINDING.

--- TOUCH BLACK ---

SCENE 15.
FW15A, CGS: Glass
FW15B, tape 700, 13:23:16-13:23:36
pan from fibers to filament winding operation
FW15C, tape 02, 02:23:45-02:23:59
filament winding using carbon fiber
FW15D, CGS: Polyethylene
Aramid
Carbon/Graphite

NARRATION (VO):

GLASS FIBERS ARE THE MOST COMMONLY USED FILAMENT WOUND REINFORCEMENT MATERIALS BECAUSE OF THEIR GOOD STRENGTH, MODULUS OR RIGIDITY AND TOUGHNESS, DIMENSIONAL STABILITY, LOW COST AND EASE OF HANDLING. OTHER FILAMENT WOUND REINFORCEMENT MATERIALS INCLUDE POLYETHYLENE, ARAMID AND CARBON OR GRAPHITE FIBERS.

SCENE 16.
FW16A, tape 29, 01:13:31-01:13:40
filament winding operation emphasizing resin
FW16B, CGS: Thermosets
FW16C, tape 12, 12:19:32-12:19:46
zoom in, filament winding using vinyl ester
FW16D, tape 695, 11:07:27-11:07:42
filament winding using epoxy

NARRATION (VO):

MATRIX MATERIALS FOR FILAMENT WINDING ARE MOSTLY THERMOSETS, WITH THE PRIMARY TYPES INCLUDING:

THE POLYESTERS AND VINYL-ESTERS WHICH ARE MOST COMMONLY USED COMMERCIALLY BECAUSE OF THEIR LOWER COST AND ADEQUATE OVERALL PROPERTIES, AND EPOXY RESINS WHICH ARE USED FOR MILITARY AND STRENGTH-CRITICAL APPLICATIONS.

--- TOUCH BLACK ---

SCENE 17.
FW17A, tape 703, 17:00:54-17:01:20
hoop winding mandrel in filament winding operation

NARRATION (VO):

THE FILAMENT WINDING MANDREL DEFINES THE INTERNAL SHAPE OF THE COMPONENT BEING WOUND.

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SCENE 18.
FW18A, tape 695, 11:10:03-11:10:11
simple mandrel being used in filament winding operation
FW18B, tape 02, 02:25:16-02:25:39
zoom out, complex mandrel
FW18C, CGS: Steel
Aluminum
Copper
Plaster
Ceramic
Plastic

NARRATION (VO):

MANDRELS RANGE FROM SIMPLE...,

TO COMPLEX IN DESIGN, AND ARE PRODUCED FROM

VARIOUS MATERIALS RANGING FROM STEEL,

ALUMINUM, COPPER, OR NONMETALLICS, SUCH AS

PLASTER, CERAMIC AND PLASTIC.

SCENE 19.
FW19A, tape 29, 01:20:05-01:20:30
zoom out, filament winding operation
FW19B, CGS: Durability
Thermal Expansion
Conductivity
Tolerances
Weight
FW19C, CGS: Deflection
Heat Resistance
Part Removal
Cost

NARRATION (VO):

IN CHOOSING A MANDREL MATERIAL, CONSIDERATION

MUST BE GIVEN TO DURABILITY, THERMAL EXPANSION

AND CONDUCTIVITY, TOLERANCES, WEIGHT,

DEFLECTION, HEAT RESISTANCE, PART REMOVAL AND

COST.

--- TOUCH BLACK ---

SCENE 20.
FW20A, tape 29, 01:17:04-01:17:26
wide, filament winding operation
FW20B, tape 30, 02:01:55-02:02:05
zoom out, headstock
FW20C, tape 30, 02:02:24-02:02:32
zoom out, tailstock
FW20D, tape 29, 01:28:15-01:28:28
tilt, filament winding operation

NARRATION (VO):

FILAMENT WINDING MACHINES TYPICALLY ARE

COMPUTER-NUMERICALLY-CONTROLLED AND HAVE

BETWEEN TWO-TO-SEVEN-AXES OF MOTION. THE

MANDREL IS USUALLY SUSPENDED HORIZONTALLY

BETWEEN A HEADSTOCK,

AND TAILSTOCK.

A CARRIAGE TRAVELS LENGTHWISE AT SPEEDS

SYNCHRONIZED WITH MANDREL ROTATION, DELIVERING

THE TOW FROM A WIND EYE AT A SELECTED ANGLE.

SCENE 21.
FW21A, tape 29, 01:04:02-01:04:18
strands of tow pulled through winding comb
FW21B, tape 29, 01:26:02-01:26:21
c.u. tow applied wet
FW21C, tape 02, 02:24:53-02:25:00

NARRATION (VO):

A WINDING COMB OR A SERIES OF ROLLERS

COLLIMATES SEVERAL STRANDS OF TOW INTO ONE

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zoom in, tow applied dry

BAND WIDTH FOR PLACEMENT ON THE MANDREL.

THIS TOW IS APPLIED EITHER WET...,

OR DRY.

SCENE 22.
FW22A, CGS: Wet Winding
FW22B, tape 700, 13:25:32-13:25:50
filament winding, filaments running through resin bath, freeze frame as wet winding head lands in front of camera
FW22C, GRAPHICS: arrow, scroll arrow to show tensioner, resin bath, wiper blade, winding eye

NARRATION (VO):

IN WET WINDING, THE TOW PROCEEDS FROM A CREEL OR TENSIONER INTO THE RESIN BATH. FROM THERE, THE BAND USUALLY PASSES BENEATH A WIPER, OR DOCTOR, BLADE TO REMOVE EXCESS RESIN, THEN PROCEEDS TO THE WINDING EYE FOR DEPOSITION.

SCENE 23.
FW23A, tape 12, 12:09:27-12:09:39
hand held, c.u. resin bath area of wet filament winding operation

NARRATION (VO):

LOW RESIN VISCOSITY IS REQUIRED FOR WET WINDING TO COMPLETELY WET-OUT THE WOUND MATERIAL AND TO REMOVE TRAPPED AIR.

SCENE 24.
FW24A, tape 700, 13:12:38-13:12:54
zoom out, wet filament winding operation
FW24B, tape 12, 12:23:13-12:23:28
zoom in, wet filament winding operation

NARRATION (VO):

WET WINDING IS THE LEAST EXPENSIVE METHOD OF FILAMENT WINDING, BUT SYSTEMS MUST BE LOW IN VOLATILES TO PREVENT OUTGASSING OF THE WOUND COMPONENT. ADDITIONALLY, ACCURATE CONTROL OF RESIN-REINFORCEMENT RATIO NECESSITATES ADJUSTING WINDING TENSION AS COMPONENT DIAMETER INCREASES.

SCENE 25.
FW25A, CGS: Dry Winding
FW25B, tape 02, 02:22:38-02:22:58
zoom in, dry winding using carbon fiber material

NARRATION (VO):

DRY WINDING REFERS TO WINDING PARTIALLY CURED PREPREG FILAMENTS OR WINDING DRY TOW AND THEN SUBSEQUENTLY APPLYING THE RESIN ON THE WOUND COMPONENT BY BRUSHING OR IMPREGNATION UNDER VACUUM OR PRESSURE.

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SCENE 26.
FW26A, tape 02, 02:19:16-02:19:45
filament winding using carbon fiber prepreg

NARRATION (VO):

DRY WINDING WITH PREPREG RAISES MATERIAL COST BUT ELIMINATES THE FORMULATING AND MAINTENANCE COSTS OF CONTROLLING THE MATERIAL RESIN-REINFORCEMENT RATIO, EASING QUALITY CONTROL. ALSO, USE OF HIGH-TACK PREPREG PERMITS WINDING ON STEEPER SLOPES.

--- TOUCH BLACK ---

SCENE 27.
FW27A, tape 700, 13:19:50-13:20:03
helical winding operation
FW27B, CGS: Helical Winding
FW27C, tape 696, 12:01:07-12:01:15
zoom out, hoop winding operation
FW27D, CGS: Hoop Winding

NARRATION (VO):

THERE ARE TWO PRIMARY WINDING METHODS FOR APPLYING FILAMENTS:

HELICAL WINDING...,

AND HOOP WINDING.

SCENE 28.
FW28A, CGS: Helical Winding
FW28B, tape 700, 13:27:20-13:28:15
helical winding operation

NARRATION (VO):

IN HELICAL, OR LONGITUDINAL, WINDING, MATERIAL IS DEPOSITED IN A HELICAL PATH IN ONE DIRECTION, THEN TURNS AROUND ON END AND RETURNS IN A HELICAL PATH IN THE OPPOSITE DIRECTION. THIS ROUTINE CONTINUES UNTIL DESIRED PART THICKNESS HAS BEEN BUILT UP. HELICAL WINDING ALLOWS FOR FILAMENT PLACEMENT AROUND CORNERS, OPENINGS, PINS OR LUGS.

SCENE 29.
FW29A, tape 700, 13:08:34-13:08:43
filament winding using horizontal mandrel

NARRATION (VO):

MANDREL ORIENTATION FOR HELICAL WINDING CAN BE HORIZONTAL OR VERTICAL.

SCENE 30.
FW30A, CGS: Hoop Winding
FW30B, tape 702, 16:21:14-16:21:29

NARRATION (VO):

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zoom out, hoop winding operation
FW30C, tape 702, 16:26:53-16:27:19
zoom in, hoop winding operation

HOOP, OR CIRCUMFERENTIAL, WINDING, IS A VARIATION OF HELICAL WINDING, WITH THE DIFFERENCE BEING THE DEGREE OF THE HELICAL ANGLE. IN HOOP WINDING THE FILAMENTS ARE WOUND AT ALMOST 90 DEGREES OR NEARLY PERPENDICULAR TO THE MANDREL AXIS. EACH MANDREL REVOLUTION ADVANCES THE DELIVERY CARRIAGE ONE BANDWIDTH, BUTTING THE EDGE OF ONE BAND NEXT TO THE PREVIOUS BAND.

--- TOUCH BLACK ---

SCENE 31.
FW31A, tape 695, 11:24:17-11:24:33
rotating part cured at room temperature
FW31B, tape 703, 17:16:00-17:16:08
oven doors opened

NARRATION (VO):

AFTER WINDING, THE COMPONENT IS CURED. CURING TYPICALLY TAKES PLACE AT ROOM TEMPERATURE, BUT DEPENDING ON THE RESIN SYSTEM USED MAY REQUIRE HEAT.

SCENE 32.
FW32A, still, zoom out, gas fired oven
FW32B, tape 15, 15:12:15-15:12:22
pan, autoclave

NARRATION (VO):

THE MOST COMMON HEATING EQUIPMENT FOR CURING OF FILAMENT WOUND COMPONENTS INCLUDE GAS-FIRED OR ELECTRIC OVENS...,

AND AUTOCLAVES.

--- FADE TO BLACK ---

SCENE 33.
FW33A, GRAPHIC: Review
white text on black
FW33B, peter carey narration
FW33C, review music

MUSIC UP AND UNDER

NARRATION (VO):

LET'S REVIEW THE MATERIAL CONTAINED IN THIS PROGRAM.

SCENE 34.
FW34A, tape 700, 13:08:46-13:09:06
wide, filament winding operation

NARRATION (VO):

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FILAMENT WINDING IS THE HIGH-SPEED, PRECISE DEPOSITION OF CONTINUOUS RESIN-IMPREGNATED FIBERS ALONG A PREDETERMINED PATH ON A MANDREL OF ALMOST ANY SHAPE.

SCENE 35.
FW35A, tape 696, 12:10:15-12:10:27
thick filament wound part being produced
FW35B, tape 695, 11:22:08-11:22:22
odd shaped filament wound part

NARRATION (VO):

FILAMENT WINDING PERMITS THE MANUFACTURE OF THE LARGEST AND THICKEST-WALL COMPOSITE SHAPES. ADDITIONALLY, THERE ARE ESSENTIALLY NO LIMITATIONS ON CONVEX CURVATURES THAT CAN BE PRODUCED.

--- TOUCH BLACK ---

SCENE 36.
FW36A, CGS: Glass
FW36B, tape 700, 13:23:16-13:23:36
pan from fibers to filament winding operation
FW36C, tape 02, 02:23:45-02:23:59
filament winding using carbon fiber
FW36D, CGS: Polyethylene
Aramid
Carbon/Graphite

NARRATION (VO):

GLASS FIBERS ARE THE MOST COMMONLY USED FILAMENT WOUND REINFORCEMENT MATERIALS BECAUSE OF THEIR GOOD STRENGTH, MODULUS OR RIGIDITY AND TOUGHNESS, DIMENSIONAL STABILITY, LOW COST AND EASE OF HANDLING. OTHER FILAMENT WOUND REINFORCEMENT MATERIALS INCLUDE POLYETHYLENE, ARAMID AND CARBON OR GRAPHITE FIBERS.

SCENE 37.
FW37A, tape 29, 01:13:31-01:13:40
filament winding operation emphasizing resin
FW37B, CGS: Thermosets
FW37C, tape 12, 12:19:32-12:19:46
zoom in, filament winding using vinyl ester
FW37D, tape 695, 11:07:27-11:07:42
filament winding using epoxy

NARRATION (VO):

MATRIX MATERIALS FOR FILAMENT WINDING ARE MOSTLY THERMOSETS, WITH THE PRIMARY TYPES INCLUDING:

THE POLYESTERS AND VINYL-ESTERS WHICH ARE MOST COMMONLY USED COMMERCIALLY BECAUSE OF THEIR LOWER COST AND ADEQUATE OVERALL PROPERTIES, AND EPOXY RESINS WHICH ARE USED FOR MILITARY

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AND STRENGTH-CRITICAL APPLICATIONS.

--- TOUCH BLACK ---

SCENE 38.
FW38A, tape 703, 17:00:54-17:01:20
hoop winding mandrel in filament winding operation

NARRATION (VO):

THE FILAMENT WINDING MANDREL DEFINES THE INTERNAL SHAPE OF THE COMPONENT BEING WOUND.

SCENE 39.
FW39A, tape 695, 11:10:03-11:10:11
simple mandrel being used in filament winding operation
FW39B, tape 02, 02:25:16-02:25:39
zoom out, complex mandrel
FW39C, CGS: Steel
Aluminum
Copper
Plaster
Ceramic
Plastic

NARRATION (VO):

MANDRELS RANGE FROM SIMPLE...,

TO COMPLEX IN DESIGN, AND ARE PRODUCED FROM VARIOUS MATERIALS RANGING FROM STEEL, ALUMINUM, COPPER, OR NONMETALLICS, SUCH AS PLASTER, CERAMIC AND PLASTIC.

--- FADE TO BLACK ---

SCENE 40.
FW40A, tape 29, 01:26:02-01:26:21
c.u. tow applied wet
FW40B, tape 02, 02:24:53-02:25:00
zoom in, tow applied dry

NARRATION (VO):

FILAMENT WINDING IS PERFORMED USING EITHER WET WINDING...,

OR DRY WINDING.

SCENE 41.
FW41A, CGS: Wet Winding
FW41B, tape 700, 13:25:32-13:25:50
filament winding, filaments running through resin bath, freeze frame as wet winding head lands in front of camera
FW41C, GRAPHICS: arrow, scroll arrow to show tensioner, resin bath, wiper blade, winding eye

NARRATION (VO):

IN WET WINDING, THE TOW PROCEEDS FROM A CREEL OR TENSIONER INTO THE RESIN BATH. FROM THERE, THE BAND USUALLY PASSES BENEATH A WIPER, OR DOCTOR, BLADE TO REMOVE EXCESS RESIN, THEN PROCEEDS TO THE WINDING EYE FOR DEPOSITION.

SCENE 42.
FW42A, CGS: Dry Winding
FW42B, tape 02, 02:22:38-02:22:58
zoom in, dry winding using carbon fiber material

NARRATION (VO):

DRY WINDING REFERS TO WINDING PARTIALLY CURED PREPREG FILAMENTS OR WINDING DRY TOW AND THEN SUBSEQUENTLY APPLYING THE RESIN ON THE WOUND

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COMPONENT BY BRUSHING OR IMPREGNATION UNDER VACUUM OR PRESSURE.

--- TOUCH BLACK ---

SCENE 43.
FW43A, tape 700, 13:19:50-13:20:03
helical winding operation
FW43B, CGS: Helical Winding
FW43C, tape 696, 12:01:07-12:01:15
zoom out, hoop winding operation
FW43D, CGS: Hoop Winding

NARRATION (VO):

THERE ARE TWO PRIMARY WINDING METHODS FOR APPLYING FILAMENTS:

HELICAL WINDING...,

AND HOOP WINDING.

SCENE 44.
FW44A, CGS: Helical Winding
FW44B, tape 700, 13:27:20-13:28:15
helical winding operation

NARRATION (VO):

IN HELICAL, OR LONGITUDINAL, WINDING, MATERIAL IS DEPOSITED IN A HELICAL PATH IN ONE DIRECTION, THEN TURNS AROUND ON END AND RETURNS IN A HELICAL PATH IN THE OPPOSITE DIRECTION. THIS ROUTINE CONTINUES UNTIL DESIRED PART THICKNESS HAS BEEN BUILT UP. HELICAL WINDING ALLOWS FOR FILAMENT PLACEMENT AROUND CORNERS, OPENINGS, PINS OR LUGS.

SCENE 45.
FW45A, CGS: Hoop Winding
FW45B, tape 702, 16:21:14-16:21:29
zoom out, hoop winding operation
FW45C, tape 702, 16:26:53-16:27:19
zoom in, hoop winding operation

NARRATION (VO):

HOOP, OR CIRCUMFERENTIAL, WINDING, IS A VARIATION OF HELICAL WINDING, WITH THE DIFFERENCE BEING THE DEGREE OF THE HELICAL ANGLE. IN HOOP WINDING THE FILAMENTS ARE WOUND AT ALMOST 90 DEGREES OR NEARLY PERPENDICULAR TO THE MANDREL AXIS. EACH MANDREL REVOLUTION ADVANCES THE DELIVERY CARRIAGE ONE BANDWIDTH, BUTTING THE EDGE OF ONE BAND NEXT TO THE PREVIOUS BAND.

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--- TOUCH BLACK ---

SCENE 46.
FW46A, tape 695, 11:24:17-11:24:33
rotating part cured at room temperature
FW46B, tape 703, 17:16:00-17:16:08
oven doors opened

NARRATION (VO):

AFTER WINDING, THE COMPONENT IS CURED. CURING TYPICALLY TAKES PLACE AT ROOM TEMPERATURE, BUT DEPENDING ON THE RESIN SYSTEM USED MAY REQUIRE HEAT.

SCENE 47.
FW47A, still, zoom out, gas fired oven
FW47B, tape 15, 15:12:15-15:12:22
pan, autoclave

NARRATION (VO):

THE MOST COMMON HEATING EQUIPMENT FOR CURING OF FILAMENT WOUND COMPONENTS INCLUDE GAS-FIRED OR ELECTRIC OVENS...,

AND AUTOCLAVES.

--- FADE TO BLACK ---

SCENE 48.
FW48A, CG, ROLL: credits
white text on black, fade up mid-screen

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SCENE 49.
FW49A, GRAPHIC: disclaimer
white text centered on black

Some machinery in this program had safety equipment removed to allow better recording of certain processes.
Always read the safety information provided in the manufacturers' manual before machine operation.

SCENE 50.
FW50A, SME logo open, with music