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CABLE FABRICATION AND ENCAPSULATION
PROCESS IMPROVEMENTS, FY73-3

PDO 6984792, Quarterly Report

T. J. Husby, Project Leader

Project Team:
G. S. Darner
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**Kansas City
Division**

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Department 862

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Quarterly Report

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CABLE FABRICATION AND ENCAPSULATION PROCESS IMPROVEMENTS,
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July 1973.

Prepared by T. J. Husby, D/862.

Methods were developed to apply solder sleeves to five common types of cable terminations. Studies revealed that TFE Teflon, RTV630, and Sylgard 186 molding materials can be used with EN-4 polyurethane. Significant cost savings can be realized through use of the Cable Identification Device.

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KANSAS CITY DIVISION

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A prime contractor for the
Atomic Energy Commission

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SUMMARY

Work to improve cable fabrication and encapsulation processes was begun in October 1971. Development during this quarter included the following:

- Continued evaluation of solder sleeves and application equipment;
- Time studies of a cable identification device (CID) versus a buzzbox;
- The design, development, and fabrication of a set of universal moldmaster tools;
- A mold material study to be used with EN-4 (polyurethane) encapsulation material;
- Design of a universal cable-length control tool; and
- Design of a machine to facilitate twisting the wires of cable assemblies.

The use of solder sleeves was evaluated for multiple termination, cotermination, bus wire, coaxial wire, and axial-lead components. An acceptable method was developed for each type of application. Time studies reveal that a CID saves more time than a buzzbox for wire identification.

Because of the increasing cost of hard tooling and increasing tool-procurement lead time, a set of universal mold masters was developed. With these mold masters low-cost silicon rubber molds can be made in 1 day. This set of molds was designed to fit all standard rack-and-panel connectors with multiple wire bundle break-out options.

EN-4 polyurethane samples cast in three different molding materials (TFE Teflon, RTV630, and Sylgard 186) display good dimensional consistency. The mold materials release well with no apparent mold degradation after ten parts.

The design for a universal cable length-control fixture has been completed, and a tool for evaluation has been ordered. The tool incorporates connector vises, clamps, and an adjustable scale to enable the fixture to be used on cables of different lengths.

The present method of hand-twisting cable wires is time-consuming since it requires twisting and untwisting numerous times to produce one twisted cable. Therefore, a motorized machine was designed to twist the cable while the operator controls only the wire dress.

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DISCUSSION

SCOPE AND PURPOSE

The continuing objective of this project is to establish improved fabrication processes and techniques needed to support present and future cable production. The areas of investigation include sealing techniques, tooling, process variables, new fabrication equipment, and improved production methods.

PRIOR WORK

Previous project work¹⁻⁴ included evaluation and development of the following processes and equipment:

- Single-stage and two-stage open-pour encapsulation to reduce encapsulant wicking in multiconductor cable ends potted to connectors;
- Evaluation of Lockfoam as a material for sealing cables to be potted under a vacuum;
- A special wire-identification device (CID) capable of meeting Bendix needs at a cost less than that of commercially available verifiers;
- A machine to pull tight uniform knots on string ties used in sealing cables;
- Wire-stripping devices capable of stripping insulation from multistrand wires without fraying or damaging conductors;
- Tinning methods to maintain the original diameter of multistrand wire for convenient insertion into closely-spaced connector cups; and
- Solder sleeves (short lengths of heat-shrinkable tubing with precise amounts of solder and flux) for use in terminating wires to connector solder cups with the Raychem AA400 Super Heater.

ACTIVITY

Solder Sleeves

Special techniques are needed to adapt solder sleeves to some applications. The following configurations may be encountered in the preparation of cable assemblies:

- Straight single wires to solder cups;
- Buswire terminations;
- Multiple-wire termination;
- Coaxial-wire terminations; and
- Axial-lead components.

Straight entrance of single wires was investigated during the previous work. With some limitations processing capability for this configuration has been established. All wires must be the same diameter if the infrared heater is to be used. Heat absorptions vary with mass and cause uneven heating across a row of wires if the diameters are not equal. Wires of differing colors cannot be soldered in the same set up with the infrared heater because darker pigments absorb more heat and solder more rapidly than light-colored wires. Both different gages and various colors can be soldered with the AA4400 Superheater.

Attempts to solder bus wires were ineffective with both the superheater and the infrared heater. The wire heats faster than the joint area, drawing the solder along the wire away from the joint area. Teflon-insulated single-strand wire appears to be a satisfactory replacement for bus wire.

Splicing operations are required in multiple terminations when using either the hand-solder or the solder-sleeve method. Figure 1 illustrates a typical hand-soldering technique for multiple terminations. Bus wire is used primarily for multiple terminations. Figure 2 shows a solder-sleeve bundle which can be used for this application, as it allows use of a desired combination of wire and insulation. When the wires are inserted into the splicing sleeve and heated, the sleeve shrinks, the splice is soldered, and the ends of the sleeve are sealed with a self-contained adhesive. Terminations at the solder cups are then treated as straight-entrance single wires.

Two methods of terminating coaxial cable were developed. The first (Figure 3) uses a splice sleeve containing two preset leads. Two bands of solder and two bands of adhesive are contained in the sleeve. The solder bands terminate the center conductor and the shield to appropriate leads, while the two adhesive rings separate the two portions and seal the sleeve end. Smaller shielded wires are terminated directly to the solder cup (Figure 4).

By placing Teflon sleeving over leads on components, the leads can be treated as insulated wires. Components can be shielded sufficiently to prevent heat damage. In general, any application can be handled if the termination problem can be reduced to the insulated-wire configuration, but the effects of heating must be considered.

Figure 1. Typical Hand-Solder 6-Pin Termination

Figure 2. Typical Solder-Sleeve 6-Pin Termination

Figure 3. Solder-Sleeve Application to Small-Diameter Coaxial Cable

Figure 4. Adaptor Splice-Sleeve for Large-Diameter Coaxial Cable

Numerous equipment failures occurred during solder sleeve application studies. Two voltage regulators failed; one had a defective diode, and the other had a circuit fuse which was not the proper rating. Proper voltage output was obtained after defective components were replaced. The timer in some infrared equipment was found to be miswired. Failures were encountered in the AA400 Superheater equipment. Two heating elements burned out, and the plastic barrel housings melted or cracked. These failures occurred well below the life rating specified by the equipment manufacturer.

One of the manufacturing departments prepared samples to be used for an intensive solder-sleeve testing program. Hand-solder, Superheater, and infrared techniques were used. All of these samples were made with AWG 24 wire. A number of different tests will be performed on these samples.

Cable Identification Device

Several operators were timed while identifying and sorting the wires of a high-density cable to compare use of the CID with a buzzbox. The test was set up to evaluate the times for many different bundle sizes (numbers of wires). The results were averaged and recorded as shown in Figure 5. The graph for the buzzbox shows a curved portion to about 35 wires, indicating that the number of wires in the bundle affected the time per wire. Above 35 wires the graph tends to become a straight line, indicating that beyond this point increasing the bundle size linearly increases the time required to identify the wires. The graph for the CID shows that the time required to identify each wire is the same, regardless of the number of wires in the bundle. The CID graph also shows that the amount of time needed to identify the wire is substantially less than the time needed to identify the wires by buzzing. The time savings for any given bundle size is the distance between the two curves. For 50 wires the time is 12.6 minutes minus 1.6 minutes, or 11 minutes saved.

Universal Mold Masters

Because of the cost of metal molds and tool procurement lead time, a set of universal mold masters was developed. A mold master is a machined metal part which resembles the final encapsulated part. From the mold master a silicone rubber room-temperature-vulcanizing (RTV) mold is made by pouring RTV around the master in a metal box. After curing the RTV, the master is removed, leaving a mold cavity for the production part (Figure 6). These masters are based on standardized outside dimensions of rack-and-panel (RP) connector encapsulations. For a given RP connector the width and depth dimensions are held constant, and the height dimension can be varied by adding spacers between the connector master and the top potting master. The wire breakout can be varied by screwing a sleeve dowel of the proper size into either the top or the end of the master. These molds can be left open

Figure 5. Time Savings Achieved With Cable Identification Device

on top to facilitate off-center breakouts, angle breakouts, or multiple-bundle breakouts. If desired, this mold can be used as a connector pre-pot mold (Figure 7). An RTV mold costs approximately \$15, compared to approximately \$600 for a metal mold.

Procurement time for the RTV mold is only one day, as compared to approximately eight weeks for metal molds. This technique is ideal for short-order or low-production use. These mold masters have been used five times, resulting in a cost saving of approximately \$2,700.00 during the first two months of use.

Figure 6. Mold Master, Molded Part, and RTV Mold

Figure 7. RTV Molds Used for Various Wire Bundle Breakout Options

EN-4 Mold Material

Three molding materials, TFE Teflon, RTV630 and Sylgard 186 (described in the preceding quarterly report) were chosen for the EN-4 encapsulation investigation. All molds were of the same design. Ten samples potted in each mold were made and serialized to study possible mold deterioration. After these samples were potted with EN-4, they were studied for adherence to mold materials, detrimental effects on the molds, dimensional consistency, and potting quality. All three materials displayed good mold release characteristics and showed no detrimental effects on the molds after ten units. Dimensional data demonstrated that all ten samples potted in each material were within 0.2 percent of being identical. Potting quality remained consistent throughout the study.

Universal Length-Control Tool

A design for a universal length-control fixture to be used in soldering operations has been completed. The fixture (Figure 8) features interchangeable cable-adapter details, one which is fixed at a zero reference point on a scale, and another which slides to any length on the scale. Details provided with

Figure 8. Universal Length-Control Fixture

the tool include two connector vises, a toggle clamp block for locating a cable junction, and grooved blocks to hold the cable at a proper height to maintain the cable centerline. Special locating details for specific connectors can be fabricated to interchange with the standard connector vises, thus saving the cost of new soldering and/or assembly fixtures for every part. A length-control tool has been ordered for evaluation.

Wire Twisting Machine

A machine to twist wires in a cable assembly before sleeving is installed has been designed and is being fabricated. The concept of the machine is exactly opposite to the hand method presently used, where the connector is stationary and a block patterned with wire holes is twisted. This method requires the time-consuming operating of unsnarling the wires that are tangled behind the twist block. With the wire-twist machine the connector is clamped on a motorized plate, the drilled wire blocks are placed over the wires, and the motor twists the connector instead of the wire block. The operator slowly pulls the wire block away from the connector at a rate which provides the required wire lay ratio (Figure 9). No wire snarling occurs. This machine was designed to handle a variety of connectors and any wire bundle size.

Figure 9. Wire-Twisting Machine

ACCOMPLISHMENTS

Methods have been developed to apply solder sleeves to common termination problems. Samples have been prepared for a thorough solder sleeve testing program.

Time studies demonstrated a significant cost effectiveness potential in using the CID instead of the buzzbox wire identification method.

A set of universal mold masters developed to replace hard metal molds reduced both tooling cost and lead time.

Three molding materials (TFE Teflon, RTV630 and Sylgard 186) evaluated for use with EN-4 polyurethane proved satisfactory and easily processed.

Designs for a universal cable length-control tool and a wire-twisting machine have been completed.

FUTURE WORK

Solder sleeve evaluation will be continued, with extensive environmental, resistance, cross-section, and X-ray testing. Final evaluation of a special-design solder cup will be completed.

The length-control tool will be evaluated under manufacturing conditions when this tool is received.

A prototype wire-twist machine will be fabricated at Bendix and then evaluated for production use.