FINAL REPORT

Engineering Design, Construction, Operation, and Maintenance of the 7-Ohm Line and Relativistic Klystron Facilities
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### Title and Subtitle

Engineering Design, Construction, Operation, and Maintenance for the 7-Ohm Line and Relativistic Klystron Facilities

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### Abstract (Maximum 200 words)

SFA designed, built, installed, operated, and maintained special-purpose equipment and fixtures in support of experimental research in high-power RF radiation and particle acceleration. Specifically, SFA personnel designed and fabricated hardware for experimental application of the 7-Ohm line generator; modulated intense relativistic electron beams (IREBs); constructed magnetic field coils and low-voltage, high-energy capacitor banks; upgraded the relativistic klystron facility; and designed and fabricated a relativistic klystron amplifier.

### Subject Terms

Unclassified

### Security Classification of Report

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### Security Classification of This Page

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### Security Classification of Abstract

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### Limitation of Abstract

Unlimited
Under contract N00014-89-C-2042, SFA designed, built, installed, operated, and maintained special-purpose equipment and fixtures in support of experimental research in high-power RF radiation and particle acceleration. Specifically, SFA personnel worked on the following tasks:

- Design and Fabrication of Hardware for Experimental Application of the 7-Ohm Line Generator
- Modulation of Intense Relativistic Electron Beams (IREBs)
- Construction of Magnetic Field Coils and Low-Voltage, High-Energy Capacitor Banks
- Upgrade of the Relativistic Klystron Facility
- Design and Fabrication of Relativistic Klystron Amplifier

**Design and Fabrication of Hardware for Experimental Application of the 7-Ohm Line Generator**

SFA designed and built new hardware to apply the 7-ohm line generator to different experiments. This generator is a high-voltage machine constructed out of a 700 kV Marx generator, a pulse-forming line, and a high-voltage diode. The generator is constantly changed to match different experimental requirements. SFA personnel performed mechanical tasks related to the preparation, maintenance, and operation of this high-voltage machine. SFA planned, installed, and removed the scientific devices used as support equipment in the experimental area, and assisted in the assembly, rigging, and repair of devices used in the various experiments. SFA personnel maintained the vacuum pumps and oil and water systems. SFA also performed general maintenance on the 700 kV Marx generator, which included periodically cleaning the Marx column and triggering system. Other duties included routinely cleaning the high-voltage diode and pulse line, maintaining the vacuum system, and fabricating carbon cathodes and stainless steel cathode stocks.

**Modulation of Intense Relativistic Electron Beams**

To modulate the intense relativistic electron beams (IREBs), SFA designed and built structures consisting of coaxial cavities, which were pumped to a pressure of $10^{-5}$ Torr and maintained in close tolerance. The structures were machined out of stainless steel, and the surfaces of the cavities were lined with a 1-millimeter layer of either copper or silver. The mechanical design of these structures required familiarity with microwave circuit design. SFA fabricated, assembled, and installed the coaxial cavities; solved problems within the system; and applied leak detection techniques. SFA personnel also performed calibration checks and adjustments on vacuum systems, and aligned the cavities.

**Construction of Magnetic Field Coils and Low-Voltage, High-Energy Capacitor Banks**

SFA personnel constructed magnetic field coils and low-voltage, high-energy capacitor banks. This work included making forms, made of a non-conducting material, on which magnetic wires were wound as a long or short solenoid. The magnetic field coil withstood a minimum magnetic force of $10 \, \text{kg/cm}^2$ during a minimum operation of 100 ms. The coil was energized by a 20 kV capacitor bank operated by ignitrons. SFA's responsibilities included layout, materials flow and handling, assembly, cost reduction, problem solving, fabrication, and quality control. SFA also ensured that proper grounding techniques and safety methods for high-voltage equipment were followed.
Upgrade of the Relativistic Klystron Facility

SFA personnel upgraded the relativistic klystron facility. SFA’s responsibilities for this project included planning, construction, alteration, maintenance, setup, operation, and repair services for the facility’s reconstruction. SFA managed the rigging subcontractor in the relocation of experimental components. In addition, SFA designed and installed acoustical partitions to buffer this high-noise facility from administrative support personnel. SFA installed capacitor banks, a Marx column, and a triggering system in the new Marx tank. SFA personnel constructed the pulse line and high-voltage diodes; installed the capacitor bank for low-voltage, high-energy magnetic-field coils; and installed a circulating water system and control panel for the pulse line and magnetic field coil. SFA also rewired the screen room for electronic equipment and installed a vacuum system for the high-voltage diode.

Design and Fabrication of Relativistic Klystron Amplifier

SFA designed and built a high-power relativistic klystron amplifier with a complete vacuum system (see Appendix). SFA personnel provided the engineering design and fabrication drawings for the coaxial high-voltage generator facility. SFA provided the layout of the floor plan for the new facility. SFA personnel laid out and installed 250 energy storage capacitors connected together with resistors, contact switches, and grounding systems. SFA personnel designed and prepared fabrication drawings of an oil tank and a high-voltage parallel transmission line to be connected to the existing 7-ohm Blumlein and Marx generator. SFA also designed and prepared fabrication drawings of the diode sub-assembly with a double insulator. Fabrication drawings were designed and prepared for a pumping ports housing with two ports connected to a diffusion pump, cold trap, and a mechanical gate valve through a pump adapter, with a third port connected to a large mechanical booster pump to increase vacuum pumping speed. SFA provided fabrication drawings for a viewing port housing with six rectangular ports, used for diagnostic testings and for access to the double insulator to clean carbon residue. SFA prepared fabrication drawings of the cathode sub-assembly and designed an end cover plate with test probes. Outer and inner magnetic field coils were designed. SFA personnel designed and prepared fabrication drawings for the cart to support the outer magnetic field coil. This cart can adjust the coil to its required height and position, and may move toward or away from the diode using dual roundway bearings that sit on tracks in the floor. SFA personnel performed the layout of the L-band waveguide transmission line to connect an existing magnetron located in an adjacent laboratory to the new facility. An L-band splitter was designed; the splitter, a waveguide switch, three isolators, and two bi-directional couplers were installed in the L-band waveguide transmission line. Radio frequency and microwave leak tests were performed on all joints after the system was installed.
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High-voltage parallel transmission line, extension
Coaxial high-voltage generator diode sub-assembly
Pumping ports housing
Cathode sub-assembly
Outer inductive coil (large)
1. SQUARE INSULATED MAGNET WIRE, SATE #8, 0.1285" X 0.1285" BARE WIRE, INSULATION CAPABLE TO WITHSTAND TEMPERATURES IN EXCESS OF 100 DEG. CENTRIPEDAL AND HOLD OFF VOLTAGES OF 20 VOLTS BETWEEN ADJACENT TURNS.

2. MAGNET WIRE SHALL BE WOUND ON A NON-METALLIC TUBE, CAPABLE TO WITHSTAND THE WEIGHT OF THE WIRE. THE INSIDE AND OUTSIDE DIAMETERS OF THE TUBE SHALL BE CONCENTRIC TO WITHIN ±0.005".

3. LENGTH OF 1.00" OF INSULATING AND NON-METALLIC MATERIAL.

4. LENGTH OF 2.00" OF INSULATING AND NON-METALLIC MATERIAL.

5. EACH LAYER OF WIRE SHALL BE CONCENTRIC WITH DATUM A TO WITHIN ±0.005" ALONG THE ENTIRE LENGTH OF THE COIL. AFTER BEING WOUND, EACH LAYER OF MAGNET WIRE WILL BE METAL W/EPoxy and COVERED WITH INSULATING PAPER, THE PAPER WILL EXTEND AXILY 0.5" BEYOND THE MAGNET WIRE LAYER (TO PREVENT SURFACE FLASHOVER), AND IT WILL OVERLAP ON ITSELF BY AT LEAST 1.0". SUBSEQUENTLY, THE PAPER WILL BE COVERED BY STRAND S FIBERGLASS WET-LAY-\n
6. INSULATING AND NON-METALLIC MATERIAL.

7. ALL LAYERS OF THE MAGNET WIRE SHALL BE WOUND IN THE SAME DIRECTION. FOR EXAMPLE, IF STARTED CLOCKWISE, ALL LAYERS WILL BE CLOCKWISE. THE HELIX OF THE WINDINGS SHALL BE OPPOSITE FROM LAYER TO LAYER. ALL WIRE CONNECTIONS SHALL BE IN SERIES, CONNECTING AN END OF ONE LAYER TO THE BEGINNING OF THE NEXT ONE.

8. MAGNET WIRE USED IN EACH LAYER SHALL BE CONTINUOUS, NO JOINTS PERMISSIBLE. CONNECTIONS BETWEEN LAYERS WILL BE DONE BY BRAZING.

9. INSIDE DIAMETER TOLERANCE ±0.005", OUTSIDE DIAMETER TOLERANCE ±0.005".

10. THE ENDS OF THE COIL SHALL BE VACUUM IMPREGNATED WITH EPOXY IN SUCH A WAY THAT THE EPOXY COMPLETELY FILLS THE Voids CREATED BY THE INSULATING PAPER EXTENDING BETWEEN THE WIRE LAYERS.

SPECIFICATIONS AND REQUIREMENTS :

1. OPERATING VOLTAGE OF 15 KV ON TERMINALS.
2. PULSE DURATION - 200 MICROSECONDS OR LONGER.
3. MECHANICALLY ABLE TO WITHSTAND MAGNETIC FIELDS OF UP TO 15 GAUSS.
4. MINIMUM LIFETIME OF 100,000 SHOTS, AS PER CONDITIONS STATED IN 1, 2, & 3. ONE SHOT EVERY 6 MINUTES, AND NOT MORE THAN 50 SHOTS PER DAY.

OUTER INDUCTIVE COIL (LARGE)
1. Square insulated magnet wire, gage #10, 0.107" x 0.019", bare wire, insulation capable to withstand temperatures in excess of 100 deg. centigrade and hold off voltages of 20 volts between adjacent turns.

2. Magnet wire shall be wound on a non-metallic tube, capable to withstand the weight of the wire, the inside and outside diameters of the tube shall be concentric to within 0.001".

3. Length of 1.00" of insulating and non-metallic material.

4. Length of 2.00" of insulating and non-metallic material.

5. Each layer of wire shall be concentric with datum A to within 0.005" along the entire length of the coil. After being wound, each layer of magnet wire will be wetted with epoxy and covered with insulating paper. The paper will extend axially 0.5" beyond the magnet wire layer (to prevent surface flashovers), and it will overlap on itself by at least 1.0. Subsequently, the paper will be covered by stranded fiberglass wet-laid with epoxy. After being cured and machined the fiberglass insulation shall be machined so that the total insulation thickness between layers is 0.050" and the machined surface is concentric with datum A to within 0.005" along the entire length of the coil.

6. Insulating and non-metallic material.

7. All layers of the magnet wire shall be wound in the same direction. For example, if started clockwise, all layers will be clockwise. The ends of the windings shall be opposite from layer to layer. All wire connections shall be in series, connecting an end of one layer to the beginning of the next one.

8. Magnet wire used in each layer shall be continuous, no joint is permissible. Connections between layers will be done by brazing.

9. Inside diameter tolerance 0.000", outside diameter tolerance 0.004".

10. The ends of the coil shall be vacuum impregnated with epoxy in such a way that the epoxy completely fills the voids created by the insulating paper extending between the wire layers.

Specifications and requirements:
1. Operating voltage of 15 kV on terminals.
2. Pulse duration = 200 milliseconds or larger.
3. Insulation capable to withstand magnetic fields of up to 15 kGauss.
4. Minimum lifetime of 10,000 shots, as per conditions stated in 1, 2, 3. One shot every 6 minutes, and not more than 50 shots per day.

Inner inductive coil (small)

91-0050
Inner inductive coil (small)
NOTES:
1. "SNIP OFF ALL SHARP EDGES AND CORNERS.
2. ALL PARTS SHALL BE FREE OF DRY AND DRIED."
3. PRE-ASSEMBLE ALL PARTS TO BE SURE THAT IT FITS ACCORDING TO THE SPECIFICATIONS SHOWN.
4. PROVIDE THE FOLLOWING:
A. ALL SCREWS AND NUTS BOLTED OUT ON THE FIELD OF THE DRAWING.
B. ROBERT A. RANKIN CART IRON WHEELS
CART ROLLING CARTS
D. LOAD CAPACITY
FIRM: TRANSPORTCO.
QUANTITY: 3 REPOS
SHIPPING: 2320 11TH STREET
TOLL: 908-329-3200

Cart for inductive coil