

## Specifications for an Electric Discharge Machining Facility

### Introduction

The Naval Research Laboratory (NRL) Vacuum Electronics Branch requires a high precision electric discharge machining (EDM) facility. EDM is a meso- to micro-scale fabrication technique which uses a small, controlled electrical spark to locally vaporize metal or other conductive material. By moving the discharge electrode relative to the material getting machined, very precise, non-contact machining of two-dimensional and three-dimensional patterns can be achieved. The EDM facility required by NRL shall consist of two separate machines with compatible operating systems, which are (item 1) a wire EDM machine, and (item 2) a sinker EDM machine. The two machines will be used in conjunction with each other by NRL staff for the fabrication of high precision millimeter-wave vacuum electronic devices, components, and electron beam source electrodes.

Wire EDM uses a very fine metal wire (down to 0.004 inch diameter), with a pulsed voltage applied between the work piece and the wire. The dielectric medium into which the work piece and the wire are immersed is highly pure water. During machining the discharge makes slot-like cuts through the material as the wire is moved relative to the work piece under computer control, as well as tapered cuts made possible by computer-controlled tilting between the work piece and the wire. In wire EDM, the wire does not make physical contact with the work piece, allowing very thin walls and septums to be created without distortion or collapsing the structures as with conventional metal cutting. Wire EDM can machine very hard refractory materials of interest to vacuum electronics such as tungsten, molybdenum, and conductive SiC, as well as standard materials like copper.

Sinker EDM uses a probe or die electrode that is sunk downward into the work piece and moved transversely relative to the work piece under computer control, to cut complex three-dimensional structures by using tools of various diameters and cross sections in conjunction with the trajectory control. By sinking the discharge electrode to various depths as a function of transverse position on the work piece, multiple level steps, cavities, and cuts can be made. Automatic changing between discharge electrode types and rotation of the electrode allow for great flexibility in the types of structures that can be made. Sinker EDM can machine very hard refractory materials such as tungsten, molybdenum, and conductive SiC, as well as standard materials like copper.

The detailed specifications for the Wire EDM machine (item 1 of the facility) are described in "Specifications for a Wire Electric Discharge Machine", and the detailed specifications for the Sinker EDM machine (item 2 of the facility) are described in "Specifications for a Sinker Electric Discharge Machine".

## Item 1 -- Specifications for a Wire Electric Discharge Machine

The Wire Electric Discharge Machine (Wire EDM) must (1) meet or exceed the following “Wire EDM Mechanical Performance Specifications” listed in Section 1.1; (2) must have an integral computer controller, control accessories, and control software that meets, exceeds, or is equivalent to the following “Computer Numerical Control Specifications for Wire EDM” listed in Section 1.2; (3) must have physical dimensions and weight that are less than or equal to the “Limits on Dimensions and Weight of Wire EDM” in Section 1.3; (4) must have required accessories and software that meet or exceed the specifications described in “Required Additional Accessories, Components, and Software for Wire EDM” in Section 1.4; (5) must be compatible with our utilities as listed in Section 1.5; (6) have a warranty as described in Section 1.6; (7) must include a visit by a factory representative to assist in the initial machine installation and provide on-site training as described in Section 1.7, and (8) must have documentation as listed in Section 1.8.

### Section 1.1) Wire EDM Mechanical Performance Specifications (must meet or exceed)

- 1.1.1 Overall construction of the Wire EDM frame shall be from stabilized fine-grained cast-iron blended with graphite, reinforced with ribs at the locations of greatest stress to prevent flexing and assure rigidity. Axes motion shall be on hardened steel ways.
- 1.1.2 Motion Travel Ranges for the Axes (when viewed from the front of the machine): 15.75 inch range for the X-axis (left-to-right motion) ; 11.8 inch range for the Y-axis (front-to-back motion) ; 9.85 inch range for the Z-axis (up and down vertical motion); 3.15 inch range for the U-axis (auxiliary left-to-right motion axis used for tapers); and 3.15 inch range for the V-axis (auxiliary front-to-back motion axis used for tapers).
- 1.1.3 Workpiece Size and Weight Capacity: The Wire EDM must be capable of accommodating a workpiece with an X dimension of 31.5 inches, a Y dimension of 27.6 inches, and a Z dimension of 9.85 inches. The Wire EDM must have a workpiece weight capacity of 2200 pounds.
- 1.1.4 Taper Cutting Capability: The Wire EDM must be capable of cutting an plus/minus 8.5 degree taper angle over a span of 9.85 inches. It must also be capable of cutting a plus/minus 30 degree taper angle over a span of 2.0 inches.
- 1.1.5 Type of Cutting Technology: The Wire EDM must use the submerged cutting method, in which the work piece and cutting wire are submerged in the dielectric fluid in a tank.
- 1.1.6 Wire Diameter Range: The Wire EDM must accommodate cutting wire diameters of 0.004 inches, 0.006 inches, 0.008 inches, 0.01 inches, and 0.012 inches, both coated and uncoated.
- 1.1.7 Type of dielectric fluid: The dielectric fluid must be high purity deionized water. An anti-electrolysis system is required to allow working with titanium and aluminum alloys.

## Attachment (a)

- 1.1.8 Workpiece Mounting: The clamping system must be fixed so that the weight of the workpiece rests directly on the machine frame (fixed bedframe), and so that the workpiece weight is not transmitted to the motion axes.
- 1.1.9 Axis Positioning: The X, Y, Z, U, and V axes must be capable of programmable independent, simultaneous control and movement. The Z axis must be capable of programmable movement of the upper guide assembly to allow cutting of workpieces of various heights and to ensure accurate taper cutting. Machine movement on all 5 axes must be accomplished with precision ball lead screws with recirculating ball bearings. The lead screws must have double nut construction that is supported on both ends to maintain rigidity. Each axis must be driven by computer-controlled servomotors with glass scale-based closed-loop position feedback, and each axis must be capable of a rapid positioning dry-run feed-rate of not less than 75 inches per minute, and a controllable cutting feed rate that can cover the entire range of 0.004 to 23 inches per minute.
- 1.1.10 Axis Control: Each of the axes (X, Y, Z, U, V) must individually exhibit a programmable and controllable positioning increment of 0.00004 inches (0.04 thousandths of an inch)
- 1.1.11 Cutting Straightness Specification: 5 micrometers per 9.85 inches of workpiece thickness, achieved with a single cut followed by a single trim-cut.
- 1.1.12 Wire Spool: The Wire EDM must have a spoolholder system that accommodates the industry-standard DIN 100, DIN 125, DIN 160, DIN 200, and DIN 355 wire spool sizes.
- 1.1.13 Wire Guiding Method: The Wire EDM shall utilize closed, high precision diamond guides.
- 1.1.14 Automatic Wire Threading: The Wire EDM must come equipped with an automatic wire threading system compatible with 0.004 to 0.012 inch diameter wire (both coated and uncoated) and be capable of threading through a 0.02 inch diameter hole. The wire threading system shall include automatic wire heating, stretching, and cutting of the threading tip. The threading process shall take place automatically by a command in the controlling program, or if the wire breaks during machining. If wire breakage occurs during machining, the machine must return to the start point of that opening, re-thread, and move through the program path back to the location where the break occurred, before resuming cutting. Failure to thread correctly must be sensed, with re-attempts at threading occurring automatically to a present limit.
- 1.1.15 Wire Chopper: The Wire EDM shall be equipped with a wire chopper to cut up the used wire into fragments and deposit them in a waste bins.
- 1.1.16 Dielectric Pumping and Filtration System: The Wire EDM must come with a dielectric fluid pumping system with a flow rate of at least 25 gallons per minute. The dielectric fluid system shall include a maintenance-free, mineral-based (or equivalent) dielectric filtration system to provide filtration down to 3 micrometers particle size or finer. The dielectric fluid system shall provide deionization using mixed bed resins.

## Attachment (a)

- 1.1.17 Dielectric Chiller: A dielectric chiller unit, to maintain repeatable dielectric temperature during machining, is required.
- 1.1.18 Enclosure: The Wire EDM must have a tank enclosing the dielectric fluid on the bottom and four sides and capable of accommodating the workpiece and submerging it in the dielectric fluid. The tank must have a window on the front surface to allow viewing of machining operations. Secondary enclosures to cover the lead screws, machine ways, the wire feeding and tensioning system, and power supplies are required to prevent debris from entering sensitive areas and to protect the operator.

Section 1.2) Computer Numerical Control (CNC) Specifications for Wire EDM (must meet, exceed, or be equivalent to)

- 1.2.1 Computer Controller-General: The dedicated computer numerical control (CNC) system must be capable of controlling all machine axes (X, Y, Z, U, V), the power supply that energizes the discharge between the wire and the workpiece, the wire feed and tensioning system, and the automatic wire threading functions. The controller must be a designed component of the Wire EDM system solely dedicated to CNC EDM operations and control of the internal functions of the machine, housed in a manner that is sufficiently rugged to withstand industrial machine shop conditions, including the presence of stray metal chips (i.e. attached standard office or home personal computers are NOT acceptable).
- 1.2.2 Computer Controller Memory: The Wire EDM must come with at least 2 MB factory installed memory capacity.
- 1.2.3 Operator Interfaces: The Wire EDM control system must have a color graphics screen, a dust-resistant membrane alpha-numeric keyboard with standard (Qwerty) layout, and a trackball.
- 1.2.4 Remote control: A handheld remote control unit, connected to the main computer controller with a cable, is required. The remote control must allow as a minimum the remote manual movement of each of the five axes, the remote execution of centering cycles, the remote setting of home position, the remote setting of wire feed, and the remote triggering of wire threading.
- 1.2.5 External Interface: The computer controller must have an Ethernet connection and an RS232 port to allow downloading and uploading of programs from/to an external computer network. The computer controller must also have a 3.5 inch floppy disk.
- 1.2.6 Computer Control Functions:
- a) Software to control (via a user-definable program) the machining operations of the Wire EDM must be supplied with the computer controller. The software must control the motions of all axes, the voltage/current of the discharge-energizing power supply, the wire feed, the wire tensioning and threading system, and the dielectric fluid system.

## Attachment (a)

- b) The software must be capable of simultaneous motion control of all 5 axes, with linear and circular interpolation functions in the XY and UV planes.
- c) The software must support taper cutting, including sharp corner cutting, constant corner taper cutting (ISOCONO), and constant radius taper cutting (ISORADIUS), as well as edge rounding and chamfer functions.
- d) The software must support ISO standard CNC programming language. It must also support the generation of simple programs or program segments automatically via on-screen templates and/or a simple fill-the-blanks questionnaire.
- e) The software must control the cutting process to optimize the erosive process, including intelligent selection of power supply parameters based on the material being cut and the wire diameter, modification of the automatic control of the programmed parameters of the power supply to ensure optimum cutting of different workpiece cross sections, and settings for rough and finish cutting.
- f) The software must allow wire diameter compensation, graphic program review/dry run, coordinate rotation and scaling, and programmed path graphic display with current working position, cutting speed, and profile length shown.
- g) The software must allow absolute and incremental modes of operation and have inches/metric full conversion.
- h) The software must allow for macros and subroutines within programs, with the capability of four nesting levels. The software must also allow conditional and non-conditional jumps within programs, with the capability of 10 control parameters.
- i) The software must include routines for workpiece edge searching with tolerance, centering within inner workpiece cavities (slots, holes), zero offsets, vertical position search, and vertical position return.
- j) The software must indicate the cutting length and cutting speed of the wire, and it must provide monitoring of consumables expenditure (wire, guides).
- k) The software must allow identification and explanation of any alarm indication to be displayed. The software must also allow the release of a short circuit if the wire and workpiece short out during operation. The software must allow the machine to automatically restart its cutting operation after a main power interruption.

### Section 1.3) Limits on Dimensions and Weight of the Wire EDM (must be less than or equal to)

- 1.3.1 Maximum Machine Weight: The total weight of the Wire EDM system must not exceed 7000 pounds, exclusive of a workpiece.

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1.3.2 Maximum Machine Height: The maximum height of the Wire EDM during operation must not exceed 89 inches. During on-site assembly procedures or during temporary maintenance operations, the height may not exceed 99 inches.

1.3.3 Machine Footprint: The floor surface dimensions (footprint) occupied by the machine body and supporting power supplies and dielectric fluid pumps and conditioners shall not exceed 114 by 98 inches, not counting door clearances and not counting any movable computer controller rack cabinet.

Section 1.4) Required Additional Accessories, Components, and Software for the Wire EDM (must include the following items and meet or exceed the specifications )

1.4.1 A complete set of diamond wire guides for 0.004, 0.006, 0.008, 0.010, and 0.012 inch diameter wire is required.

1.4.2 A Microsoft windows-based computer aided design-computer aided machining (CAD-CAM) software package that is compatible with wire EDM operations, such as “Esprit Solidwire” (sold by DP Technology, 1150 Avernida Acaso, Camarillo, CA, 93012, USA), or its equivalent, is required. The CAD-CAM software package must support machining of parts containing contoured surfaces including molds, dies, cores, cavities, and profiles. The CAD-CAM package must support the cutting of any number of straight and tapered cuts, as well as rough and skim cuts, while optimizing wire cutting paths. The CAD-CAM package must support 4 axis synchronized machining, no-core cutting of cavities (i.e. without creating a slug), alternating cylindrical constant radius corners with conical constant taper corners, and independent upper and lower radius control.

Section 1.5) Wire EDM Compatibility with Utilities

1.5.1 The Wire EDM must be compatible with our existing electric utilities:

208 V, 3-phase AC, 60 Hz, 12 kVA

Section 1.6) Warranty on the Wire EDM

1.6.1 As a minimum, a standard commercial warranty of six months including parts and labor is required.

Section 1.7) Setup of the Wire EDM and On-Site Training

## Attachment (a)

- 1.7.1 An initial on-site setup of the Wire EDM by a factory representative is required. (NRL will handle the rigging prior to this). A minimum of four (4) hours of on-site training by a factory representative, to occur at the time of installation, is also required.

## Section 1.8) Documentation for the Wire EDM

- 1.8.1 NRL requires one (1) copy of an operators manual for the complete Wire EDM. This operators manual must include essential maintenance instructions and maintenance schedules as well as operating instructions.

## Item 2 -- Specifications for a Sinker Electric Discharge Machine

The Sinker Electric Discharge Machine (Sinker EDM) must (1) meet or exceed the following "Sinker EDM Mechanical Performance Specifications" listed in Section 2.1; (2) must have an integral computer controller, control accessories, and control software that meets, exceeds, or is equivalent to the following "Computer Numerical Control Specifications for Sinker EDM" listed in Section 2.2; (3) must have physical dimensions and weight that are less than or equal to the "Limits on Dimensions and Weight of Sinker EDM" in Section 2.3; (4) must have required accessories and software that meet or exceed the specifications described in "Required Additional Accessories and Components for Sinker EDM" in Section 2.4; (5) must be compatible with our utilities as listed in Section 2.5; (6) have a warranty as described in Section 2.6; (7) must include a visit by a factory representative to assist in the initial machine installation and provide on-site training as described in Section 2.7, and (8) must have documentation as listed in Section 2.8.

### Section 2.1) Sinker EDM Mechanical Performance Specifications (must meet or exceed)

- 2.1.1 Overall construction of the Sinker EDM frame shall be from stabilized fine-grained cast-iron blended with graphite, reinforced with ribs at the locations of greatest stress to prevent flexing and assure rigidity. Axes motion shall be on hardened steel ways.
- 2.1.2 Motion Travel Ranges for the Axes (when viewed from the front of the machine): 15.75 inch range for the X-axis (left-to-right motion) ; 11.8 inch range for the Y-axis (front-to-back motion) ; 11.8 inch range for the Z-axis (up and down vertical motion); 360 angular degrees for the C-axis (electrode auxiliary angular rotation about the Z-axis).
- 2.1.3 Work Tank Internal Dimensions: The Sinker EDM work tank must have internal dimensions of at least 39 inches in the X dimension, 24 inches in the Y dimension, and 13.78 inches in the Z dimension. The work tank must accommodate a dielectric height of 12 inches.
- 2.1.4 Table Construction, Working Surface Dimensions, And Capacity: The table, which is the X-Y surface onto which the workpiece is mounted for EDM operations, must be constructed of stainless steel, and must have an X direction working dimension of at least 25 inches and a Y direction working dimension of at least 15.5 inches, and a weight capacity of 1650 pounds.

## Attachment (a)

- 2.1.5 Platen to Table Clearance: The combination of the maximal upward Z-axis vertical motion and the construction of the Sinker EDM worktable must allow the distance between the electrode holder platen and the table to achieve a vertical clearance of 18.5 inches, with the C-axis installed but without an electrode.
- 2.1.6 Electrode Weight Capacity of Platen: The Sinker EDM with the C-axis installed must accommodate an electrode mounted on the electrode holder platen weighing 110 pounds under static conditions. Under maximum speed dynamic conditions, an electrode weight capacity of 26 pounds is required.
- 2.1.7 Axis Positioning: The X, Y, Z, and C axes must be capable of programmable independent, simultaneous control and movement. Machine movement on all 3 linear axes (X, Y, Z) must be accomplished with precision ball lead screws with recirculating ball bearings. The lead screws must have double nut construction that is supported on both ends to maintain rigidity. Each axis (X, Y, Z, and C) must be driven by computer-controlled servomotors with closed-loop position feedback
- 2.1.8 Axis Control: Each of the linear axes (X, Y, Z) must individually exhibit a programmable and controllable positioning increment of 0.00004 inches (0.04 thousandths of an inch), and the rotary C-axis must exhibit a programmable and controllable angular positioning increment of 0.001 degrees.
- 2.1.9 Type of Cutting Technology: The Sinker EDM must use high speed pulse technology, which is based on fast vertical head motion under servomotor control, to permit deep grooves and cavities to be machined without the use of side dielectric flushing lances and malformations caused by dielectric flow.
- 2.1.10 Surface Finish Specification: A VDI 0 surface finish (Ra 0.1 micron) must be achievable in fine finish mode on a 0.5 square centimeter surface, while a VDI 22 (Ra 1.26 micron) surface finish must be achievable on a 225 square centimeter surface.
- 2.1.11 Average Machining Current: The Sinker EDM must be capable of reaching a 60 A average machining current.
- 2.1.12 Dielectric Filtration System: The Sinker EDM must come with a dielectric fluid filtration system with long life filtering elements (10,000 working hours) that provide filtration down to 1 micrometers particle size, with automatic cleaning and sludge extraction.
- 2.1.13 Enclosure: The Sinker EDM must have a tank enclosing the working area on the bottom and four sides that is capable of accommodating the workpiece as described in Section 2.1.3. Secondary enclosures to cover the lead screws, machine ways, and power supplies are required to prevent debris from entering sensitive areas and to protect the operator.

Section 2.2) Computer Numerical Control (CNC) Specifications for Sinker EDM  
(must meet, exceed, or be equivalent to)

## Attachment (a)

- 2.2.1 Computer Controller-General: The dedicated computer numerical control (CNC) system must be capable of controlling all machine axes (X, Y, Z, C), the power supply that energizes the discharge between the electrode and the workpiece, an electrode changer, and the dielectric flushing/filtration system. The controller must be a designed component of the Sinker EDM system solely dedicated to CNC EDM operations and control of the internal functions of the machine, housed in a manner that is sufficiently rugged to withstand industrial machine shop conditions, including the presence of stray metal chips (i.e. attached standard office or home personal computers are NOT acceptable).
- 2.2.2 Computer Controller Memory: The Sinker EDM must come with at least 2 MB factory installed memory capacity.
- 2.2.3 Operator Interfaces: The Sinker EDM control system must have a color graphics screen and a dust-resistant membrane alpha-numeric keyboard with standard (Qwerty) layout.
- 2.2.4 Remote control: A handheld remote control unit, connected to the main computer controller with a cable, is required. The remote control must allow as a minimum the remote manual movement of each of the four axes.
- 2.2.5 External Interface: The computer controller must have an RS232 port to allow communication with an external computer network, and a 3.5 inch floppy disk drive.
- 2.2.6 Computer Control Functions:
- a) Software to control (via a user-definable program) the machining operations of the Sinker EDM must be supplied with the computer controller. The software must control the motions of all axes, the voltage/current of the discharge-energizing power supply, the electrode changer, and the dielectric fluid system.
  - b) The software must be capable of simultaneous motion control of all 4 axes (X, Y, Z, and C), allowing full contouring with linear, circular and helical interpolation functions. The ability to continuously rotate the C axis is also required.
  - c) The software must have canned cycles for orbital machining (circular and square), three-dimensional orbital machining, taper machining, spherical machining, conical machining, helical machining (internal and external), and vector machining.
  - d) The software must support ISO standard CNC programming language. It must also support the generation of simple programs or program segments automatically via on-screen templates and/or a simple fill-the-blanks questionnaire.
  - e) The software must control the cutting process to optimize the erosive process, including intelligent selection of power supply parameters based on the material being cut and the electrode size, modification of the automatic control of the programmed parameters of the power supply to ensure optimum cutting and surface finish of different workpiece cut depths and surface areas, and settings for rough and finish cutting.

## Attachment (a)

- f) The software must allow electrode diameter compensation, graphic program review/dry run, coordinate rotation and scaling, programmed path graphic display with current working position.
- g) The software must allow absolute and incremental modes of operation and have inches/metric full conversion.
- h) The software must allow for macros and subroutines within programs, with the capability of four nesting levels. The software must allow for variables within programs and subroutines. The software must also allow conditional and non-conditional jumps within programs, with the capability of 10 control parameters.
- i) The software must include routines for automatic edge positioning, internal and external centering in any plane, machine reference search in all axes, zero offsets in all axes, electrode center deviation error compensation, and vertical and horizontal gap compensation.
- j) The software must allow identification and explanation of any alarm indication to be displayed.

### Section 2.3) Limits on Dimensions and Weight of the Sinker EDM (must be less than or equal to)

- 2.3.1 Maximum Machine Weight: The total weight of the Sinker EDM system must not exceed 5400 pounds, exclusive of a workpiece and electrodes.
- 2.3.2 Maximum Machine Height: The maximum height of the Sinker EDM during operation must not exceed 99 inches.
- 2.3.3 Machine Footprint: The floor surface dimensions (footprint) occupied by the machine body and supporting power supplies and dielectric fluid pumps and conditioners shall not exceed 118 by 71 inches, not counting door clearances.

### Section 2.4) Required Additional Accessories and Components for the Sinker EDM (must include the following items and meet or exceed the specifications )

- 2.4.1 A factory-installed C axis, contained within the head of the electrode holder, is required. The C-axis must allow computer-controlled tool rotation about the vertical electrode axis, full contouring, and helicoidal capabilities. The mechanical design of the electrode holder on the end of the C axis must be compatible with the following industry-standard EDM tooling systems and tool mounting configurations: Erowa (EROWA Technology Inc., 2535 South Clearbrook Drive, Arlington Heights, IL 60005, USA), Hirschmann (Hirschmann Automation LLC, 1760 Britannia Drive, Suite #1, Elgin, IL 60123, USA), and System 3R (System 3R USA, Inc. 915 Busse Rd, Elk Grove Village IL 60007, USA).

## Attachment (a)

- 2.4.2 A dielectric chiller unit, to maintain repeatable dielectric temperature during machining, is required.
- 2.4.3 An electrode changer, with capacity for 5 or more electrodes, is required. The electrode changer must be compatible with the CNC computer controller. The electrode changer under CNC control must allow automated exchanges of electrodes, in any order, during machining. The electrode changer must allow for a combined electrode weight of 80 pounds and a unit electrode weight of 22 pounds.

### Section 2.5) Sinker EDM Compatibility with Utilities

- 2.5.1 The Sinker EDM must be compatible with our existing electric utilities:

208 V, 3-phase AC, 60 Hz, 12 kVA

### Section 2.6) Warranty on the Sinker EDM

- 2.6.1 As a minimum, a standard commercial warranty of six months including parts and labor is required.

### Section 2.7) Setup of the Sinker EDM and On-Site Training

- 2.7.1 An initial on-site setup of the Sinker EDM by a factory representative is required. (NRL will handle the rigging prior to this). A minimum of four (4) hours of on-site training by a factory representative, to occur at the time of installation, is also required.

### Section 2.8) Documentation for the Sinker EDM

- 2.8.1 NRL requires one (1) copy of an operators manual for the complete Sinker EDM. This operators manual must include essential maintenance instructions and maintenance schedules as well as operating instructions.