# The Exel Imaging System.
# 2004

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# EIS-500 Imaging Head
# Exel Imaging System

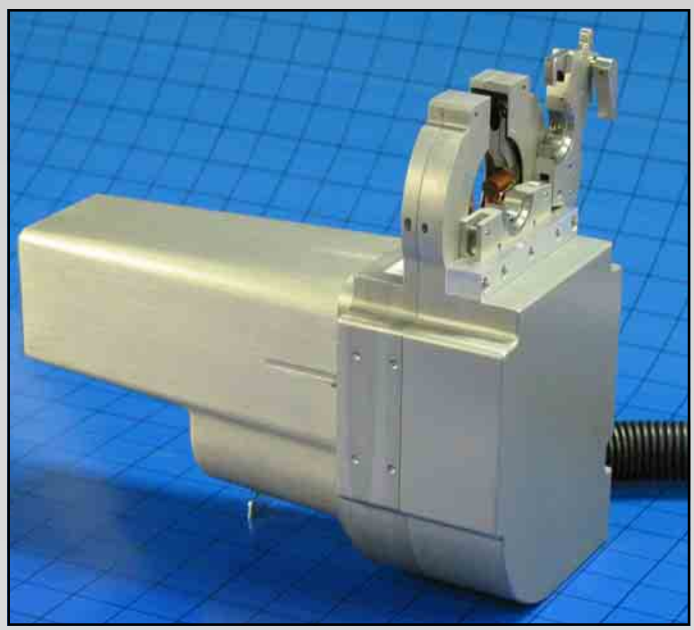
The **EIS-500 Exel Imaging System** is a revolutionary technology for imaging orbital tube welds. As an alternative to X-Ray and dye penetrant the EIS-500 can image a weld and inspect for pores, inclusions, cracks and other anomalies in just a few minutes. Because the EIS-500 uses a hybridized eddy current probe it emits no radiation and no precautions need to be taken during operation. The EIS-500 is small and can be used insitu meaning the manufacturing process no longer needs to be interrupted to allow inspection to take place. This provides for a LEAN streamlined manufacturing process.

Operation is easy and very little special training is required. A 3D image of the weld is produced by the computer with the aid of special algorithms that quickly show flaws. Flaws can be highlighted in red while good welds can be shaded green for go, no go evaluation.

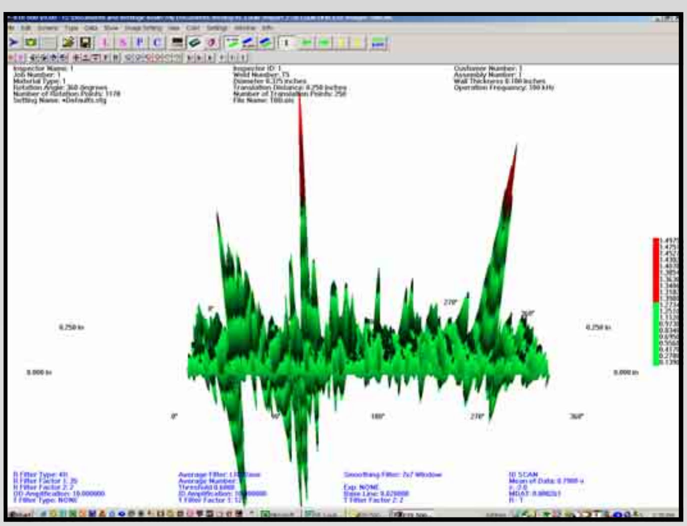
The EIS-500 is the worlds first imaging system designed to operate with Exel's orbital welding process. Images can be made while orbital welding is being performed in close proximity. Imaging can be performed in roughly the same time as a weld adding to the streamlining effect on productivity.

The EIS-500 can also be used with a combination weld/ image fixture for Integrated Weld and Inspect (IWI). An orbital weld can be made in a fixture, when the orbital head is removed the imaging head can be inserted in the same fixture and an image made. Because there is no additional handling of the work piece production is even further streamlined.


EIS-500-A Imaging Head with Pedestal , Fixture and Controller.

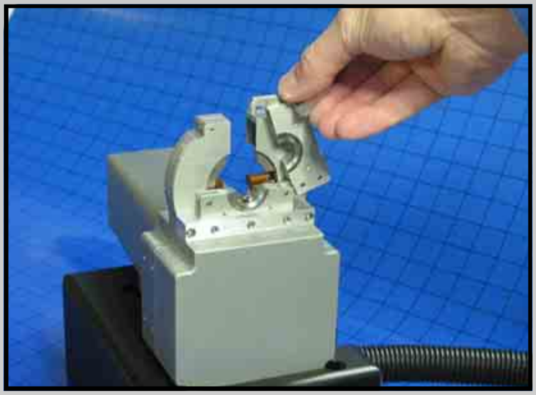


EIS-500-A Imaging Head and Fixture

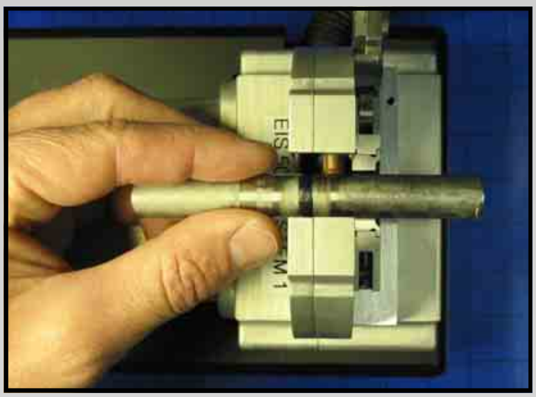


3D Image of an Orbital Weld with 2 Pores in Red

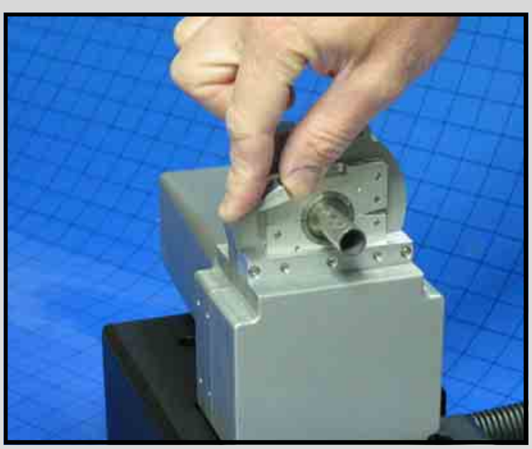
# EIS-500 Imaging Head
# Operation, 5 Easy Steps



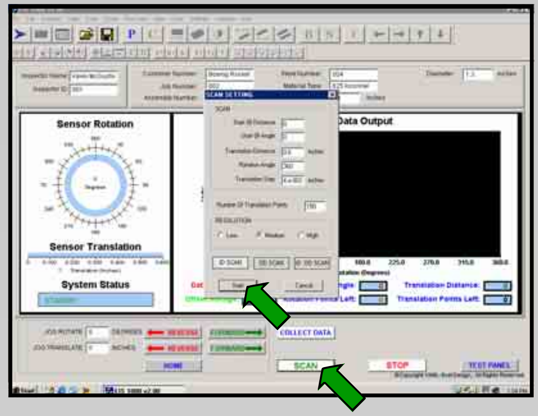
**Step 1**, Open the fixture on the imaging head.



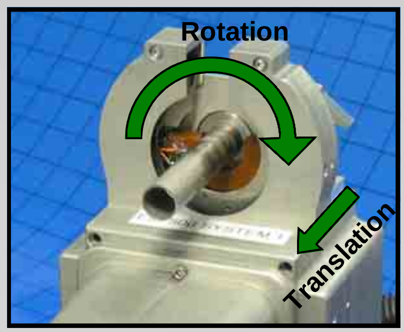
**Step 2**, Insert the orbital weld assembly or joint in the imaging head and align the weld bead to the left of the sensor.



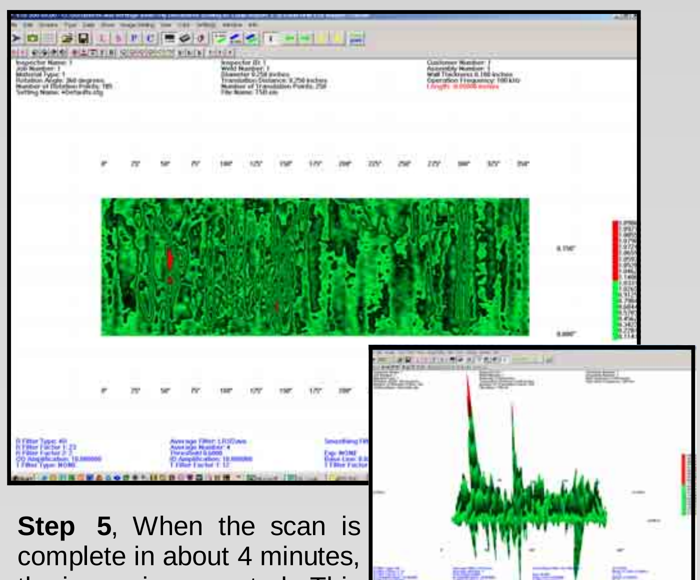
**Step 3**, Clamp the assembly in the imaging head.




**Step 4**, Click Scan and the scanning parameters will be shown, then click Start.



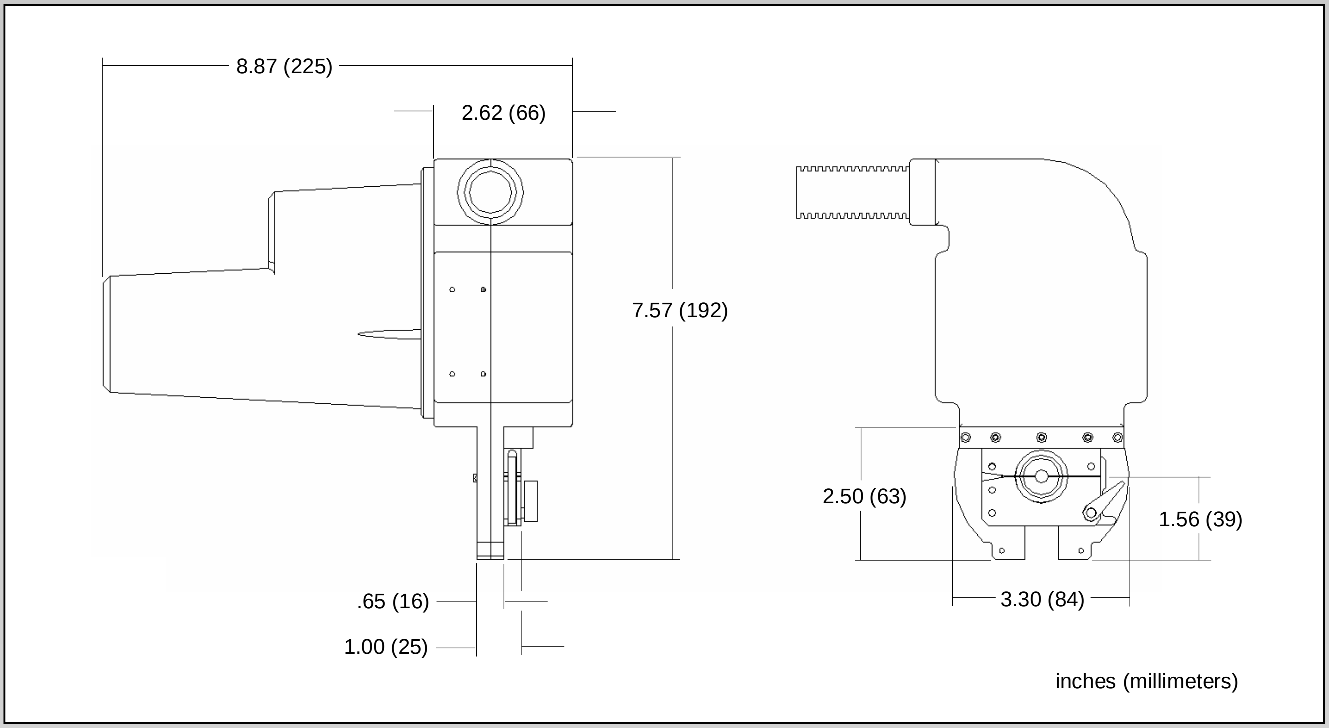

During scanning the sensor rotates around the tube and translates across the weld bead to generate a topographical image of the weld internally and externally.



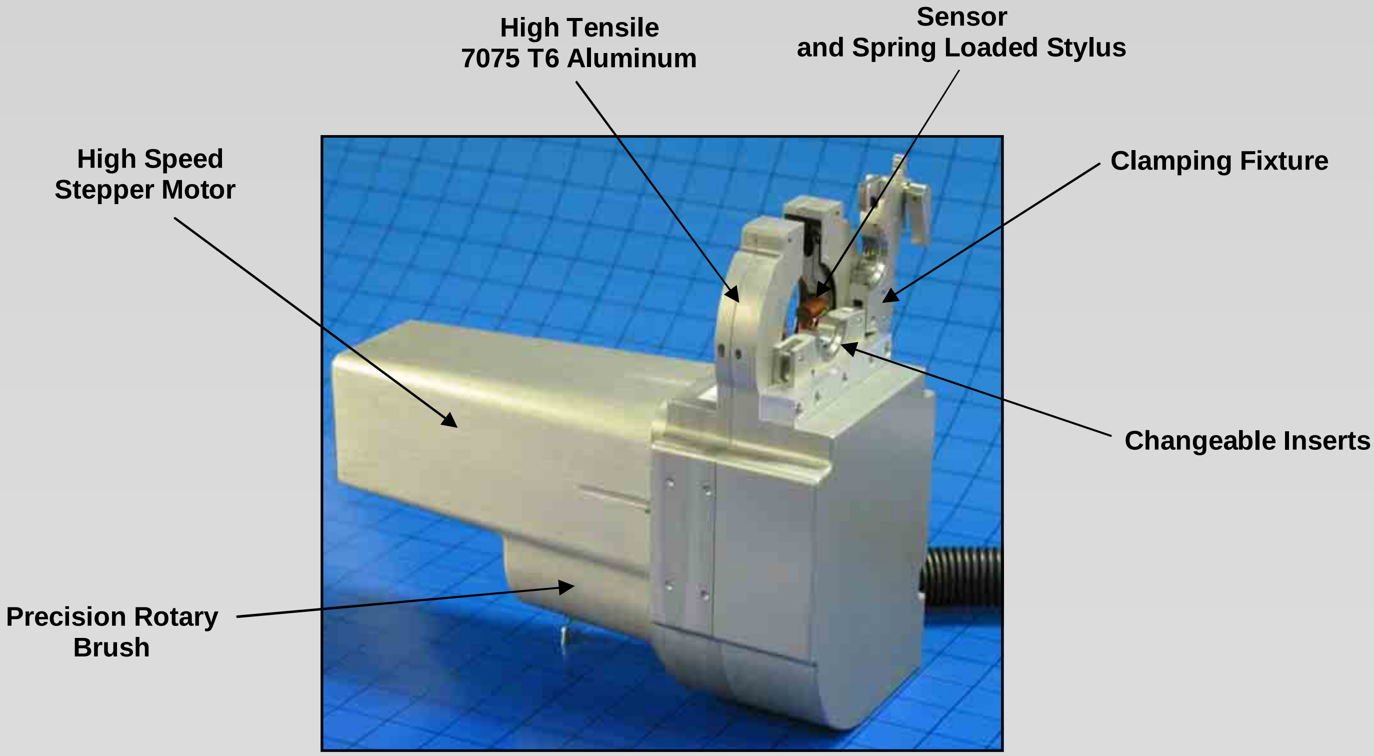
**Step 5**, When the scan is complete in about 4 minutes, the image is presented. This image may be viewed in many formats. Shown is the C-Scan View and the Isometric View. Several pores can be seen in this image.

# EIS-500 Imaging Head
# Technical Information




Drawing shown with integrated fixture




EIS-500-A Imaging Head

# EIS-500 Imaging Head
# Ordering Information

| Part Number | Description |
|---|---|
| EIS-500-A | Imaging Head, 3/16” to 5/8” Diameter Capability |
| INS-5-3 | Tube Insert for 3/16” Diameter |
| INS-5-4 | Tube Insert for 1/4” Diameter |
| INS-5-6 | Tube Insert for 3/8” Diameter |
| INS-5-8 | Tube Insert for 1/2” Diameter |
| IES-5-PED | Pedestal |

Note: Custom and metric inserts are available upon request.

# EIS-3000 Imaging Head
## Exel Imaging System


Connects to EIS-CONT Controller

EIS-3000-A Imaging Head

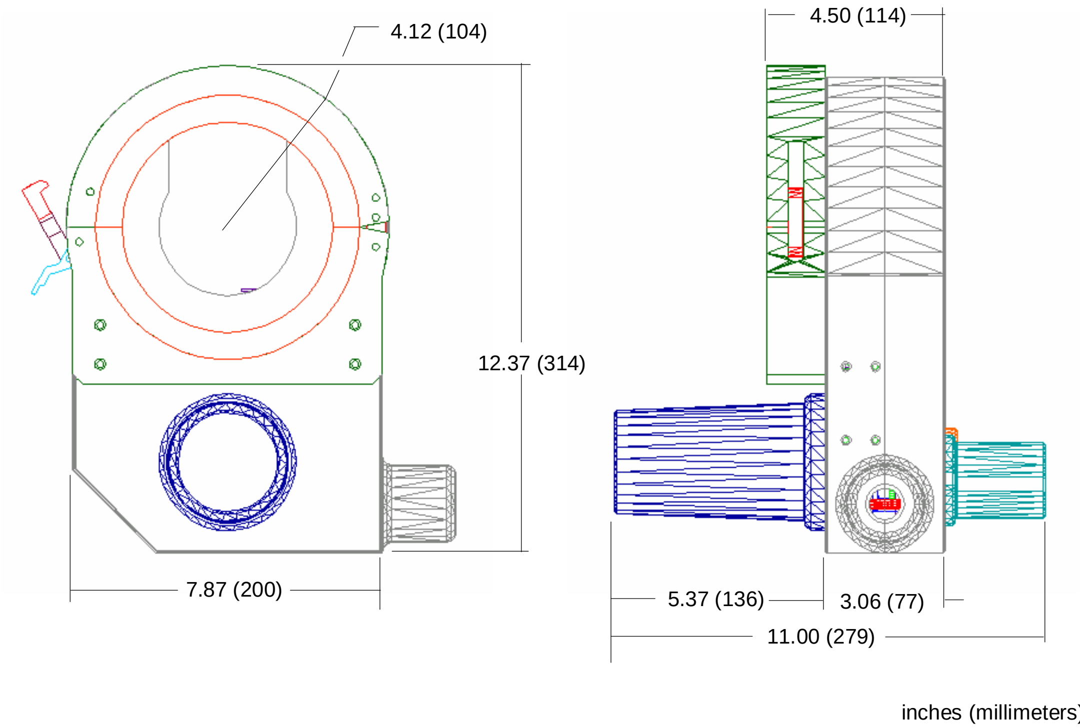
The **EIS-3000-A Exel Imaging Head** is capable of imaging up to 3 1/2” diameter components. Like the EIS-500 this imaging head incorporates new technology that allows it to image orbital welds which can be performed by Exel’s orbital welding equipment.

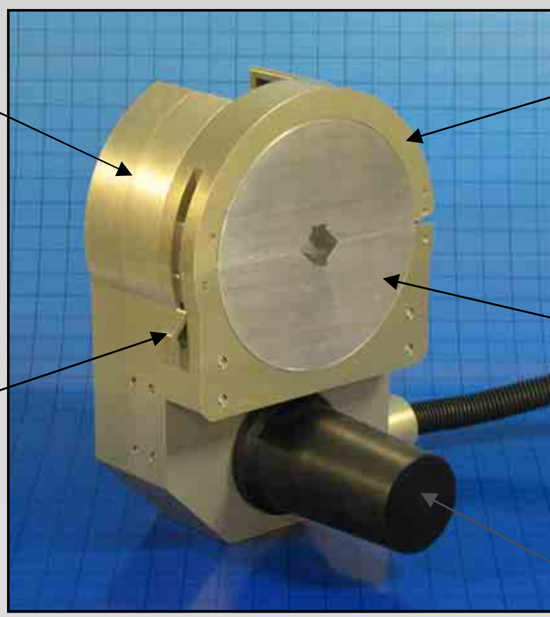
The EIS-3000-A was originally developed to meet the needs of Boeing’s RS-68 Rocket Engine Program. This engine was developed to power the Delta 4 Rocket into space. Its advanced all composite nozzle made it the most powerful engine in the world. Motivated by Boeing’s Lean Manufacturing Initiative, a more seamless and definitive method of inspection was sought. Boeing asked Exel to develop the EIS-3000-A so that high pressure fuel and oxidizer lines on the engine could be quickly certified, crack and pore free. It was projected by Boeing that up to 80% of the cost of quality assurance for fuel lines on the RS-68 would be saved by implementing the EIS-3000-A.

Exel and Boeing rigorously tested the Exel Imaging System to verify that it could detect defects with the same reliability as X-ray or RTR (Real Time Radiography). This testing was completed in the form of a 90/95 POD/CL Analysis. This stands for 90% Probability Of Detection and 95% Confidence Level. These statistics were calculated in two different formats, one on software provided by the U.S. Air Force and the other provided by Boeing Statisticians. Both indicate that the EIS-3000-A performed at least as well as methods currently being used including RTR and X-Ray. Below is the cover of the final report summarizing that success. A full version of this report is available on Exel’s web site at exelorbital.com.


90/95 POD/CL Final Report

# EIS-3000 Imaging Head
## Technical Information



EIS-3000-A Imaging Head

# EIS-3000 Imaging Head
# Ordering Information

| Part Number | Description |
|---|---|
| EIS-3000-A | Imaging Head, 1/2” to 3-1/2” Diameter Capability |
| INS-30-8 | Tube Insert for 1/2” Diameter |
| INS-30-12 | Tube Insert for 3/4” Diameter |
| INS-30-16 | Tube Insert for 1” Diameter |
| INS-30-24 | Tube Insert for 1-1/2”Diameter |
| INS-30-32 | Tube Insert for 2” Diameter |
| INS-30-40 | Tube Insert for 2-1/2” Diameter |
| INS-30-48 | Tube Insert for 3” Diameter |
| INS-30-56 | Tube Insert for 3-1/2” Diameter |

Note: Custom and metric inserts are available upon request.

# EIS-CONT Controller
## Hardware

EIS-CONT Imaging System Controller

The **EIS-CONT, Exel Imaging System Controller** is an integrated controller with graphical user interface that allows presentation and manipulation of images scanned by Exel's Imaging Heads. This compact yet powerful controller incorporates all the necessary equipment to operate and perform self diagnostics on the imaging head as well as store and track images scanned.

The platform is a laptop computer that operates in the Windows environment. Exel has developed the software to be intuitive and versatile so that the time required to become proficient in operation is minimized. Images can be saved either locally or at remote locations via a network and those images can be tracked for easy correlation to welds that have been imaged.

Imaging is fast and easy and a low resolution scan can be made in as little as 3 minutes. There is very little special training required to operate the Exel Imaging System. The same personnel that perform orbital welds can also operate the imaging system so that the manufacturing process can be LEANed out. The added advantage of giving the welder near real time feedback concerning the quality of the weld is invaluable. Near real time corrections can be made to the welding process when using the Exel Imaging System as a tool for production.

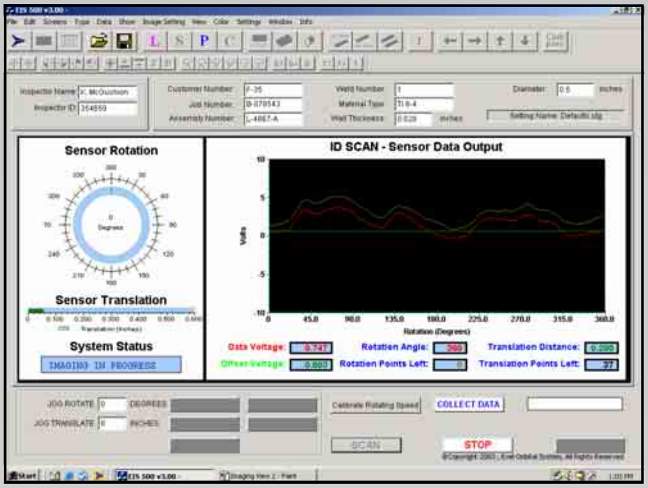
Imaging does not disrupt the production flow as the scanning process is autonomous, once the scan has been started and additional welding can be performed simultaneously and adjacent to the imaging system.

Since the EIS-CONT Imaging System Controller can operate any imaging head it is not necessary to buy multiple controllers. Because the imaging system uses a standard laptop, networking, file sharing, printing and management of data becomes seamless.


EIS-3000 Imaging Head

EIS-500 Imaging Head with Controller

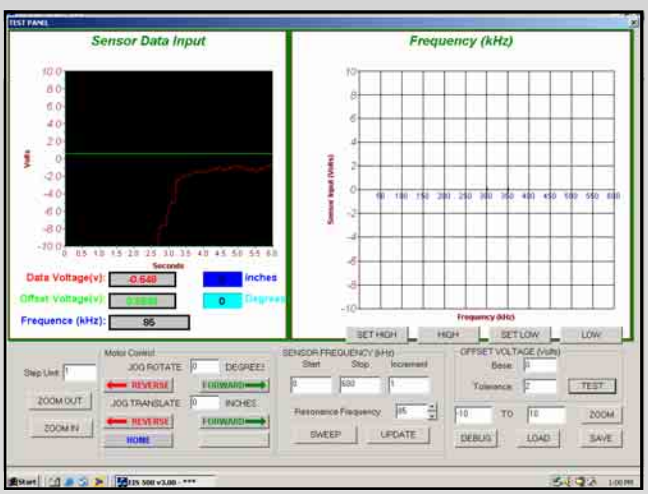
# EIS-CONT Software




Real Time Operating Screen

## Real Time Operating Screen

When imaging, all relevant data is displayed on the Real Time Operating screen. In the main, center window the Sensor Data Output is displayed showing the operator the raw output of the sensor relative to angular position of the scan. Likewise both the rotational and translational position are displayed in the Sensor Rotation and Translation window. Tracking of imaging data is made easier by entering all data pertaining to both the operator and the weld being imaged.

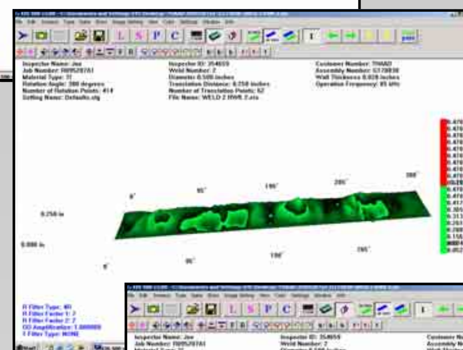



Sensor Diagnostics Screen

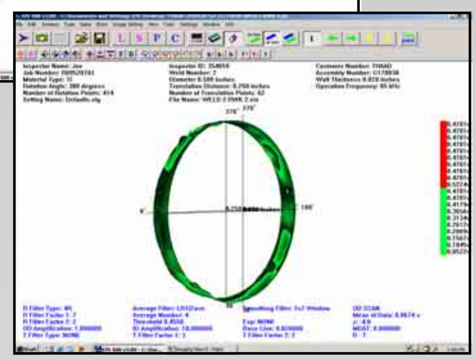
## Sensor Diagnostic Screen

The status of the sensor may be verified at any time by accessing the Sensor Diagnostic Screen. Troubleshooting and repair are made easier with this tool.

C-Scan



3-D

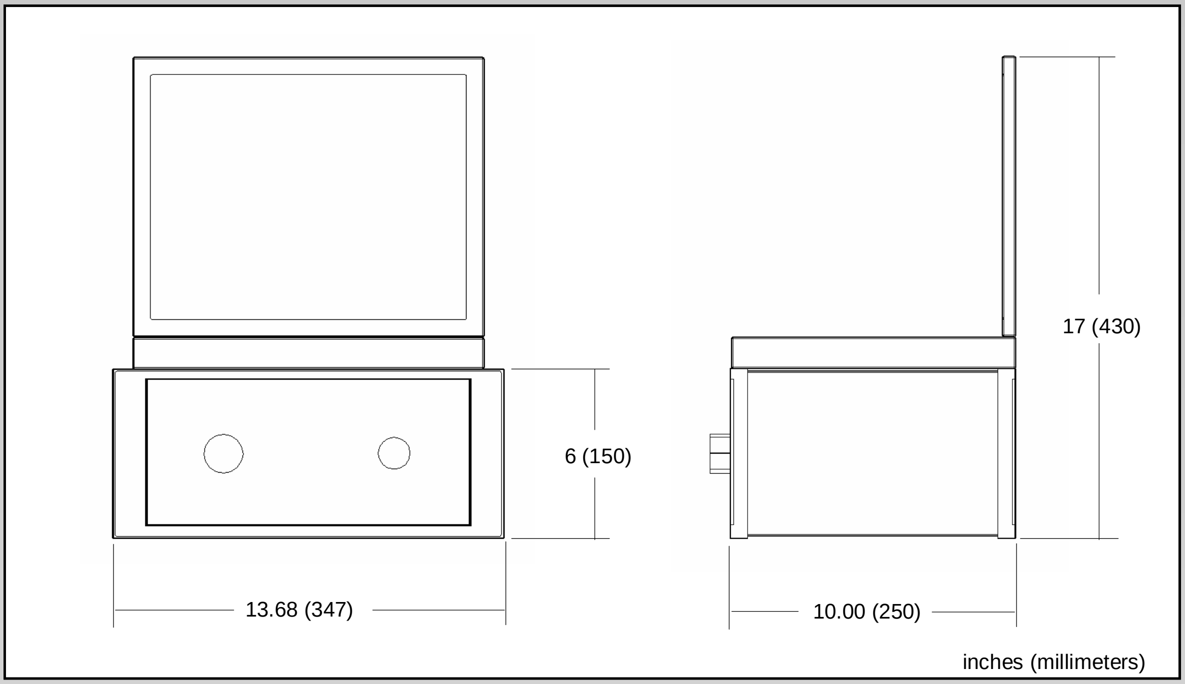


Polar

## Three Viewing Modes

Three viewing modes can be used for ease of inspection. The first mode and most basic is the **C-Scan** mode which depicts the data collected in flat planar view as seen from directly above. The **3-D** view adds dimension to the data as the height of peeks are revealed for relative flaw size. The **Polar** view allows the operator to view the weld as it appears in the imaging fixture. This view works well to locate angular position of a flaw. The 3-D and Polar views have the added advantage of being articulated by clicking and dragging the mouse. This helps the operator view the image from any angle. With the zoom in and zoom out feature areas of interest can be studied up close.

# EIS-CONT
# Technical Information




Drawing shown with integrated laptop

**Windows Based Intuitive Software**

**Integrated Laptop Computer**


**Sensor Connector**

EIS-CONT Controller Front View

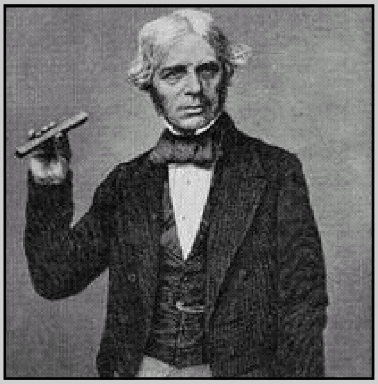
**Motor Connector**


EIS-CONT Controller Back View

**Power Input**
**47-63 kHz**
**85-265 volts**

# How It Works
# Eddy Current Detection

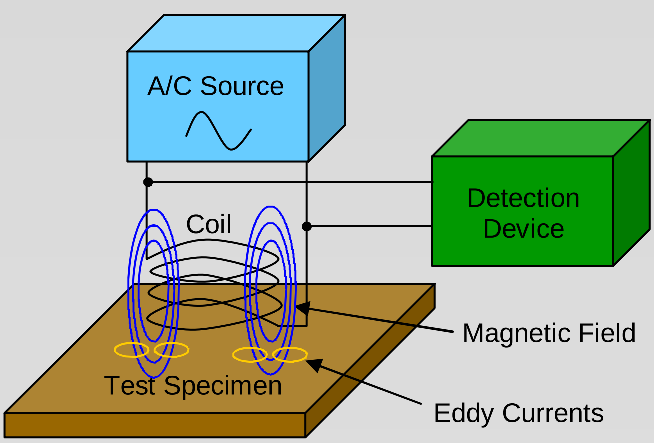
Eddy current inspection has been around since the 1940's however the phenomena of eddy currents was first discovered by Michael Faraday during his research into electromagnetic induction. It was only later however that the significance of conductivity and magnetic permeability was discovered. This revelation made possible the eddy current detection systems we know today which are able to detect minute changes in material properties ranging from the presence of cracks to chemical composition and metallurgical conditions of metal.


Michael Faraday 1791-1867

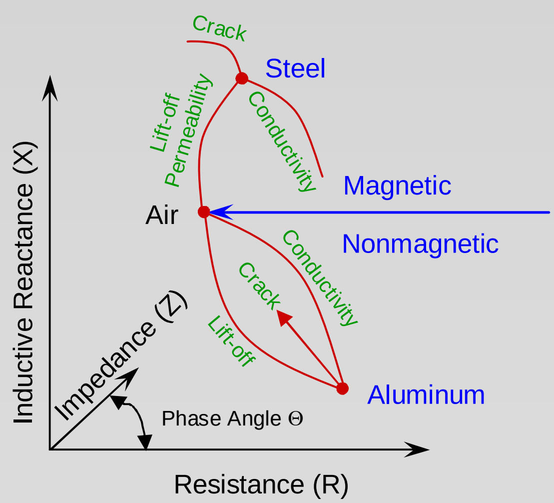
An eddy current detection system is comprised of four basic components they are:

1. A/C Source
2. Coil
3. Test Specimen
4. Detection Device

The A/C Source is a source of alternating current with which to drive the Coil. The Coil produces an alternating magnetic field coincident with the A/C Source. The magnetic field from the Coil extends through the Test Specimen and the specimen becomes part of the total electrical circuit. The Magnetic Field produces circular electrical currents in the specimen known as eddy currents. As the characteristics of the Test Specimen change so to do the characteristics of the eddy currents and of the circuit as a whole. That circuit change is measured by a Detection Device. This device can be something as simple as a volt meter or as complex as an impedance meter.




An impedance meter measures two components of the circuit one on each axis of its display. The first or horizontal axis is resistance (R) of the circuit and the second or vertical axis is inductive reactance (X), which is the resistance associated with the inductance of the Coil. The resulting trace or Impedance (Z) is shown for several conditions that may exist on a test specimen. As an example, as lift-off decreases over Aluminum resistance increases while inductive reactance decreases but while lift-off decreases over steel both resistance and inductive reactance increase. Cracks also form unique patterns depending on the type of metal which are discernibly different from lift-off. These patterns formed on an impedance display are often called Lissajou Patterns



# How It Works
# Eddy Current Testing

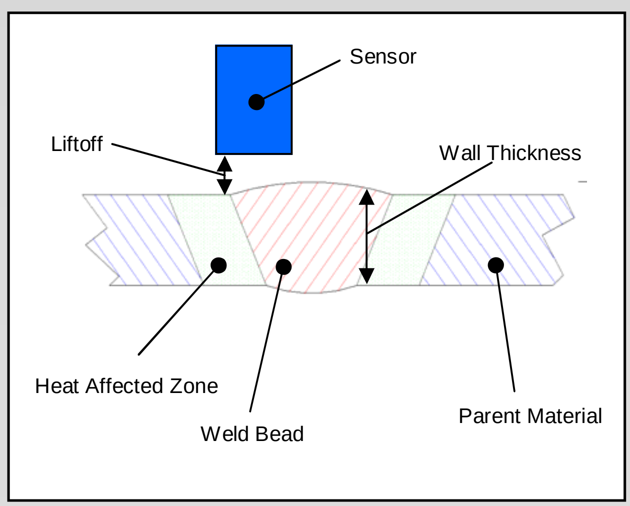
Eddy current testing is in use in many industries from building aircraft and spacecraft to building nuclear power plants and ships. All of these industries have at least on thing in common the need to guarantee the quality of the metal structures and components in them. Eddy current testing has been used in both the manufacture and maintenance of systems in these industries because of its flexibility, portability and effectiveness.

Eddy current testing can be used to test anything from cracking due to stress to change in metallurgy. There has however been a distinct series of limitations with eddy current testing due to either the subjective nature of the impendence plane output or its inability to scan a specimen where multiple variables are changing at once. One such area of limitation has been welds.

As seen in the classic impedance plane display on the previous page, data relating to material type, lift off, conductivity, presence of cracking and phase angle all change simultaneously. It is therefore almost impossible to isolate a single characteristic when all of these variables change at once as it does in a weld. Below is a drawing showing the variables that change at once in a weld bead from lift off to wall thickness to material changes while traveling from parent material to the weld bead. All of these conditions cause an impedance plane change and to this point no defect has been sought.

Photo of Boeing 737's being assembled

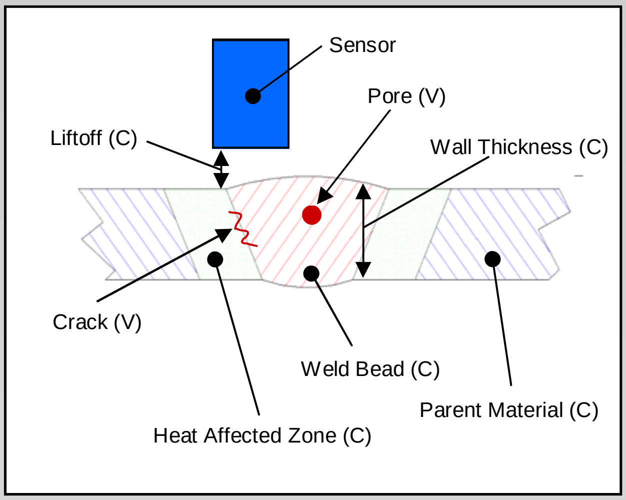
Photo of the core of a nuclear reactor




Components of a Weld

# How It Works
## The Exel Imaging System

The Exel Imaging System works by holding certain variables constant through a series of computer algorithms developed by Exel. An example of how this can work (in the weld below) is if one were to be interested in only the effect of say a crack or a pore while scanning the weld bead, the affects of lift off, wall thickness and material type must be held constant, denoted with a 'C'. In this case only the effects of the pore and crack are apparent to the imaging system. It is the use of this revolutionary technique that makes imaging something as potentially complex as a weld bead possible.




Variables and Constants of a Weld

# How It Works
# System Validation

The Exel Imaging System has been rigorously tested and validated to insure that it is reliable when testing for defects in automatic welds. Below are two examples of that analysis, the first of which is a titanium hydraulic line with a fitting connection made with an orbital weld. This X-ray shows a series of pores or a pore cluster. That pore cluster is directly correlated to the Exel Image to the right.

Second, is an analysis of a 3” diameter, 625 Inconnel fuel line and orbital weld. During this analysis an EDM notch was sought however other flaw indications were revealed. Upon further analysis they were identified as linear tailed pores constituting cracks. These cracks were not visible on X-ray.

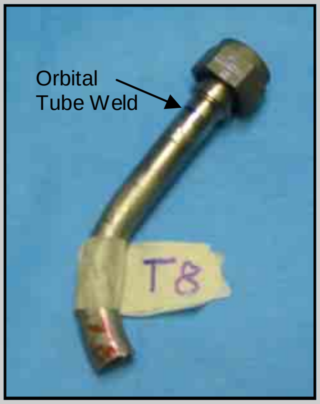
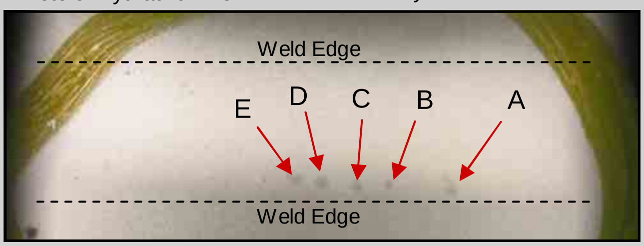
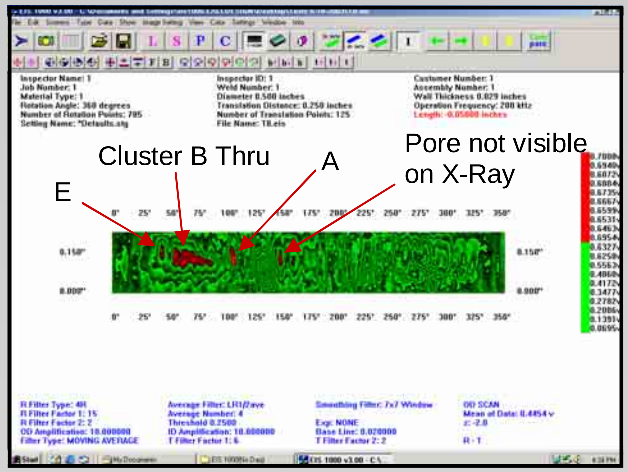



Photo of Hydraulic Line


X-ray Pore Diameter Scale




X-ray of Hydraulic Line Showing Porosity




Exel Imaging System Image of Titanium Hydraulic Line Weld

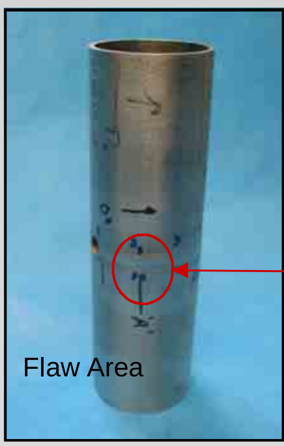
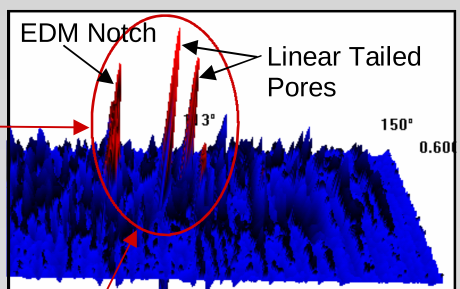
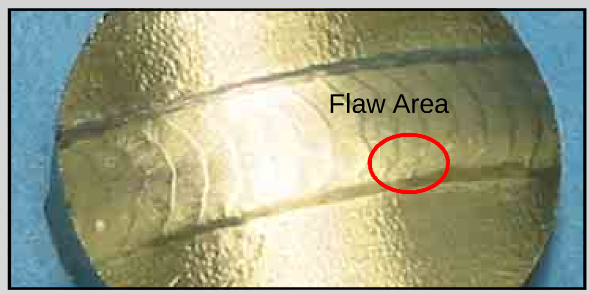


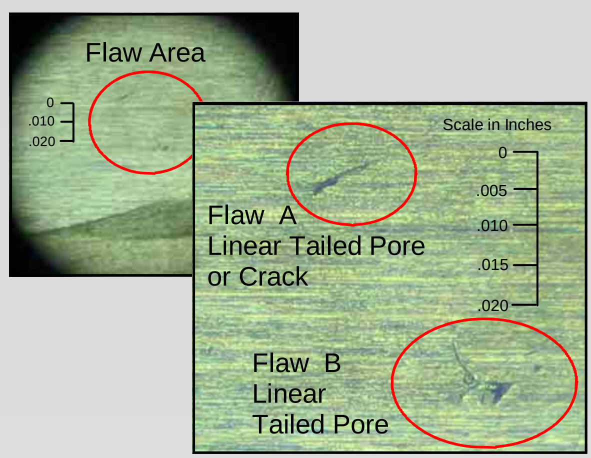

Photo of Fuel Line

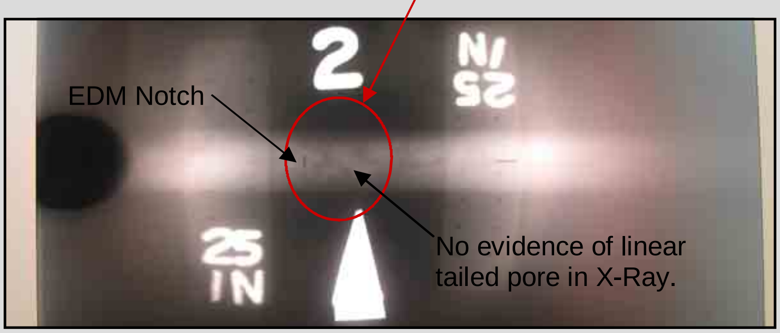



Exel Imaging System Isometric View




Flaw Area Cut Out




X-ray of Fuel Line Weld

Flaw Area After Grinding

# Requirements

## Material Properties and Flaw Detection

Some materials that have been imaged include:

1. Stainless Steels
    a. S316L
    b. 304L
2. Titanium
    a. 6-4
    b. 3-2.5
3. Inconnel
    a. 625
    b. 718
4. Graphite Composite
    a. IM7/977
    b. IM7/977 with High Attenuation Weave
    c. MMS 5024

Flaws that have been reliably imaged include:

For Metals (Using Orbital Imaging Head):

1. Pores
2. Pore Clusters
3. Linear Tailed Pores
4. Inclusions
5. Cracks
6. Lack of Fusion
7. Suck Back
8. EDM Notches (Artificial)
9. Holes Both Through and Blind (Artificial)

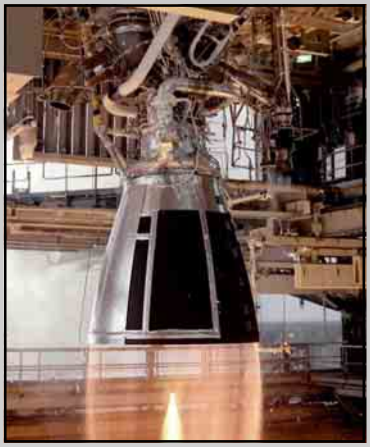
For Graphite Composite (Using Linear Imaging System)

1. Delamination
2. Voids
3. Teflon Disks (Artificial)

The above lists of materials and flaws that have been tested does not necessarily exclude other materials and flaws that have not been tested. Please contact us if you have an application that you think may be scanned by the Exel Imaging System. We can usually conduct a quick test of a sample provide by you for evaluation.

# Current Programs
# Exel Imaging Systems In Use

The Exel Imaging Systems is currently being either used or evaluated by several customers they are:



RS-68 Rocket Engine Test

**Company:** Boeing Rocketdyne (Canoga Park Facility)

**Program:** RS-68 Rocket Engine

**Material:** 625 Inconel 1.25" thru 3.50" diameter x .100" wall.

**System:** EIS-3000

THAAD Missile Test

**Company:** Boeing Rocketdyne (Desoto Facility)

**Program:** THAAD (Theater High Altitude Area Defense) Missile

**Material:** 3-2.5 Titanium, 1/4" thru 5/8" diameter x .028 wall.

**System:** EIS-500

Delta 4 Rocket Launch

**Company:** Boeing (Huntington Beach Facility)

**Program:** Delta 4 Rocket

**Material:** 625 Inconel 1/4" thru 1/2" diameter.

**System:** EIS-500

F-18 Fighter

**Company:** Boeing (St. Louis Facility)

**Program:** F-18 Fighter

**Material:** 6-4 Titanium 1/4" thru 1/2" diameter .028 wall.

**System:** EIS-500

F-35 Fighter

**Company:** Northrop Grumman (El Segundo Facility)

**Program:** F-35 Joint Strike Fighter

**Material:** Graphite Composite Structures

**System:** Modified system for large surface imaging.