



Nelson
RF/AC Magnetic Field and
Eddy-current analysis

Field Precision
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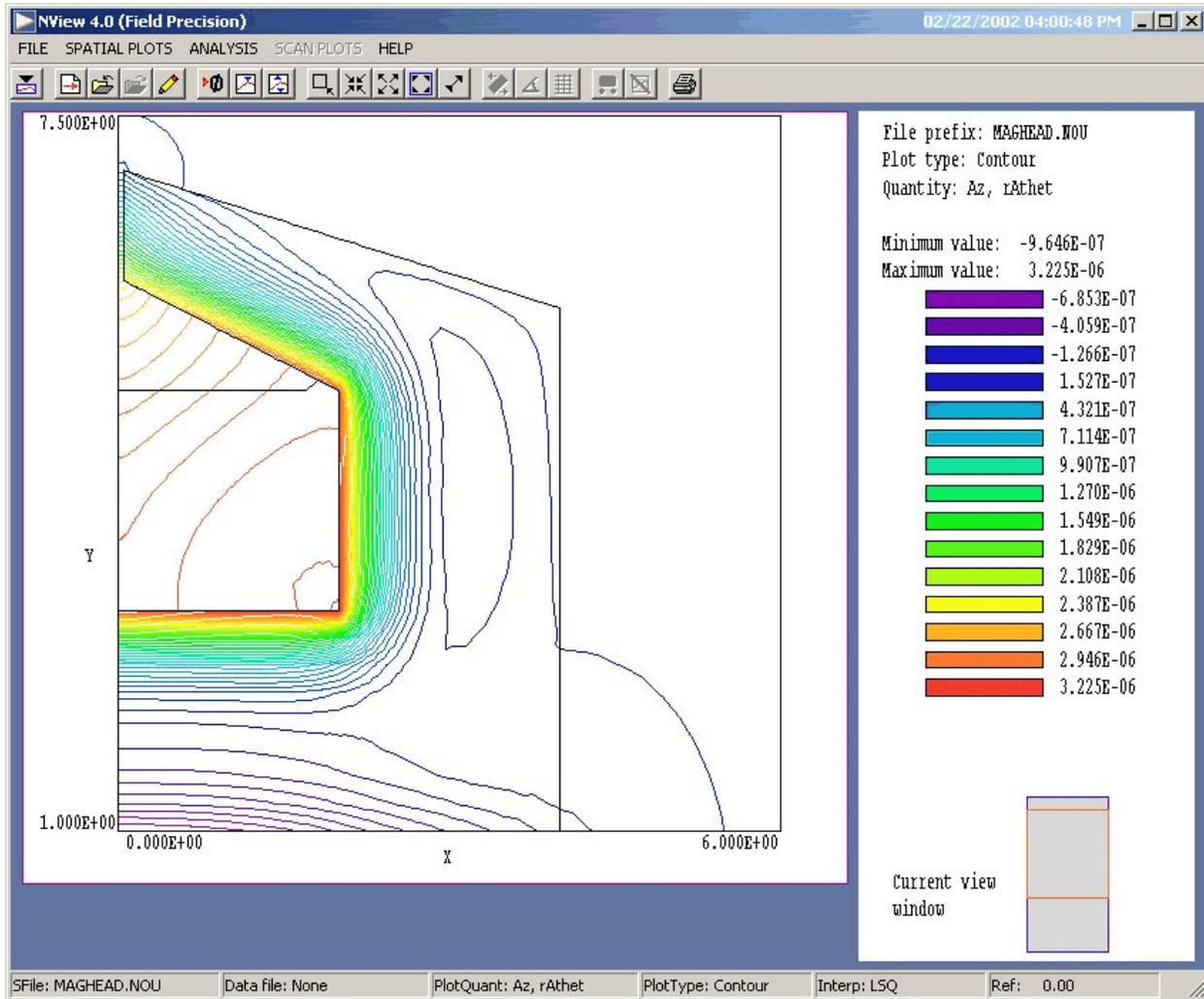


Figure 1. NView post-processor work environment

1. Program function

Nelson is a versatile numerical tool to calculate RF and AC magnetic fields in conductive media for complex cylindrical or rectangular geometries. The program applies finite-element methods on a variable-resolution conformal triangular mesh. You can define up to 127 regions to represent coils or different materials. The amplitude and phase of the harmonic coil currents or vector potential on surfaces can be set individually. Conductive materials are characterized by values of the volume resistivity and relative magnetic permeability. **NView**, an interactive graphics analysis program provides full information on the amplitude and phase of the magnetic field and other derived quantities throughout the solution regions. The program makes screen and hardcopy plots of magnetic field lines, electric field amplitude and resistive energy deposition.

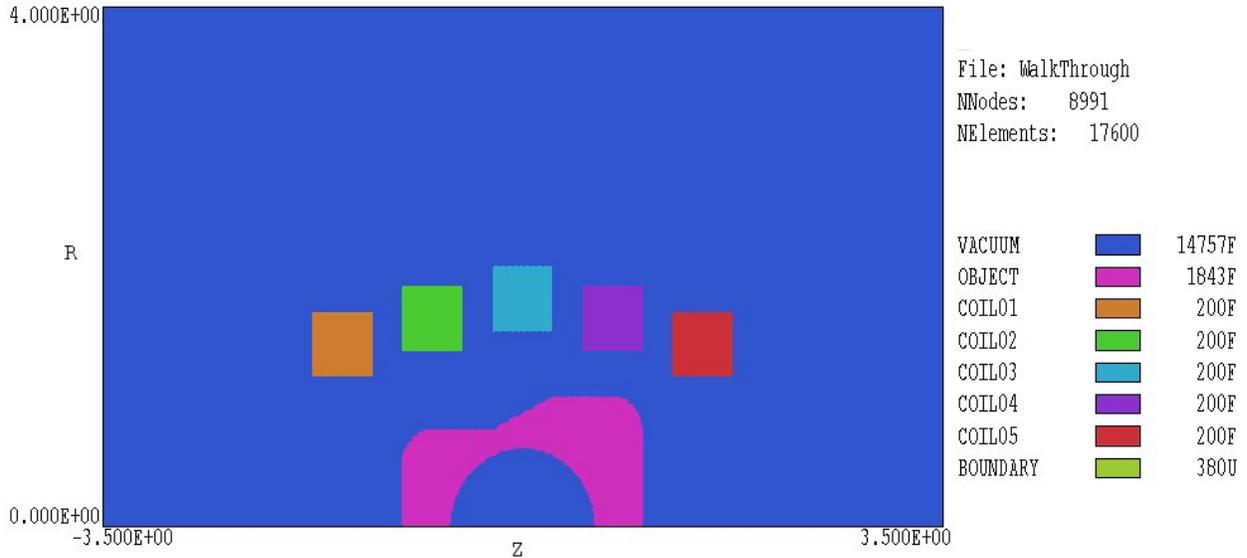


Figure 2. Region divisions for the WALKTHROUGH example.

The frequency-domain solutions of **Nelson** are limited to linear materials and excitation at a single frequency. The Field Precision time-domain **Pulse** code calculates magnetic fields for non-linear magnetic materials with arbitrary drive current waveforms. The theory of finite-element solutions for magnetic fields in the eddy current limit is reviewed in Sect. ##.

2. Walkthrough example

We shall consider the *WALKTHROUGH* example included in the **Nelson** library to illustrate a complete solution. The simulation addresses induction heating of a large metal object by a shaped coil. Figure 2 shows the geometry (with dimensions in feet). The system has cylindrical symmetry about the z axis (abscissa). The five coils create a solenoid magnetic field at 60 Hz frequency. All coils are in phase and each coil carries a peak current of 500 A. The hollow metal piece has relative magnetic permeability $\mu_r = 3.0$ and volume resistivity $\rho = 120 \mu\Omega\text{-cm}$. In a finite-element solution, a condition must be specified along the boundaries of the solution volume. In this case, we use the condition $rA_\theta = 0.0$, equivalent to perfectly-conducting walls. The extra space around the assembly ensures that the boundary condition has a small effect on fields near the work piece. The goal of the calculation is to determine the distribution of electric and magnetic fields and the total volumetric resistive heating.

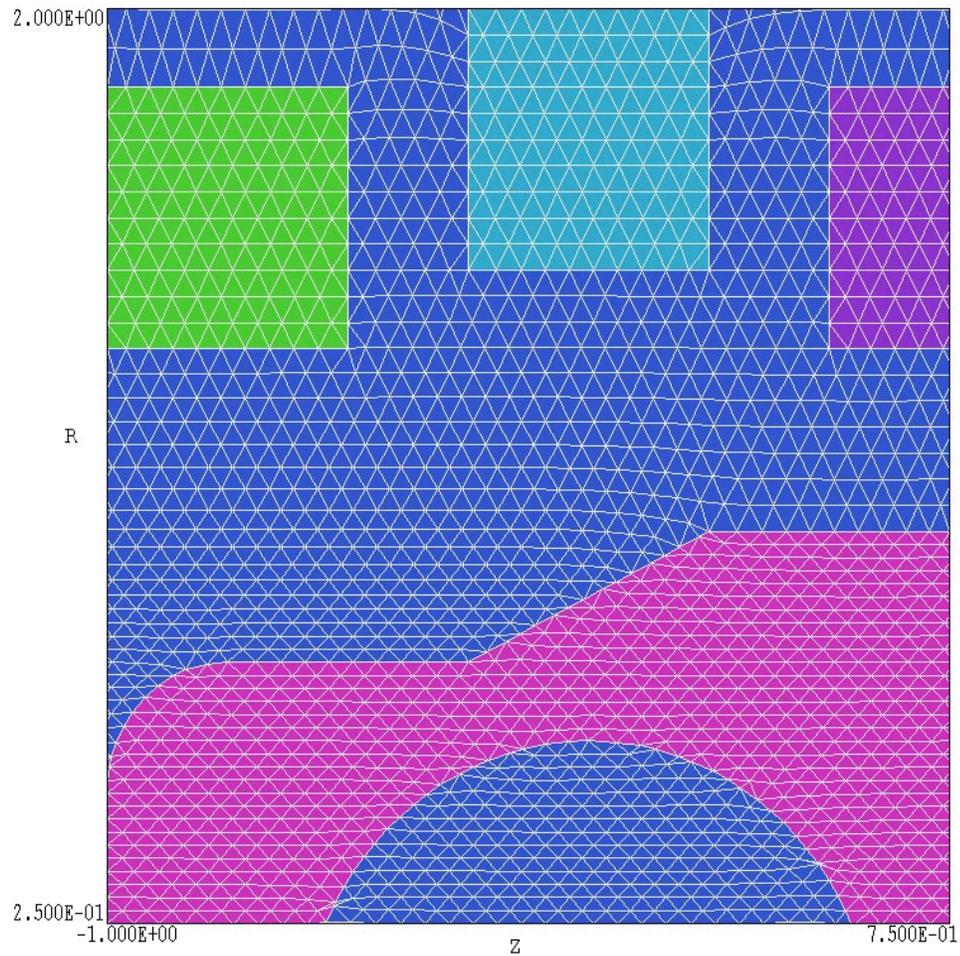


Figure 3. Mesh detail for the WALKTHROUGH example.

Copy the files WALKTHROUGH.MIN, WALKTHROUGH.NIN, and WALKTHROUGH.SCR to a convenient working directory (*i.e.*, \TRICOMP\BUFFER). The first step is to generate a file of geometric information, a required input for **Nelson**. Make sure the data directory in the **TC** program launcher is set to your working directory, and then run the **Mesh** program from **TC**. Click on *Load script (MIN)*, pick WALKTHROUGH.MIN in the dialog, and click *OK*. The **Mesh** manual describes the format of the file. It contains specifications for the foundation mesh (*XMesh* and *YMesh* commands) and sets of vectors that define the shapes in Figure 2. Click on the *Process* command. When mesh generation is complete, click on *Save mesh (MOU)* to create the file WALKTHROUGH.MOU. Click on *Plot type* and choose the *Region style*. Choose *View/Zoom window* and narrow the view to the region near the work piece (Fig. 3). Note how the size of the elements varies for good resolution of skin-depth effects on the surface of the work piece.

The next step is to run **Nelson** from **TC**. The second required input is the control script `WALKTHROUGH.NIN`. Click on *Edit input files* in the *File* menu and choose `WALKTHROUGH.NIN` to show the following content:

```
* WALKTHROUGH.NIN

Set Freq 60.0
Set ResTarget 2.0E-7
Set Omega 1.25
Set DUnit 3.281
Set MaxCycle 2500
Set Geometry Cylin

Region 1 Material 1.0
Region 2 Material 3.0 120.0E-8
Region 3 Current 500.0
Region 4 Current 500.0
Region 5 Current 500.0
Region 6 Current 500.0
Region 7 Current 500.0
Region 8 Potential 0.0

EndFile
```

The first group of commands beginning with the keyword *SET* controls the solution process. For example, `SET DUNIT 3.281` specifies that dimensions in the **Mesh** file are given in feet. Section ## describes the *SET* commands in detail. The second group of commands beginning with the word *REGION* defines material properties associated with solution regions. The air and coil regions has default fixed values of $\mu_r = 1.0$ and $\rho = \infty$. Each coil region has a total current amplitude 500 A. The current density is distribution uniformly over the cross-section of the region. Region 8 (a line around the outside of the solution volume) has the condition $rA_\theta = 0.0$.

Exit the editor and click the *Start run* command in the *Run* menu. Pick the file `WALKTHROUGH.NIN` and click *OK* to start the solution. **Nelson** employs an iterative relaxation technique to solve the complex-number finite-element equations. The solution takes a few seconds on a high-performance personal computer. When the solution is complete, the program creates the file `WALKTHROUGH.NOU` which contains information on the locations of nodes and the associated values of vector potential or stream function.

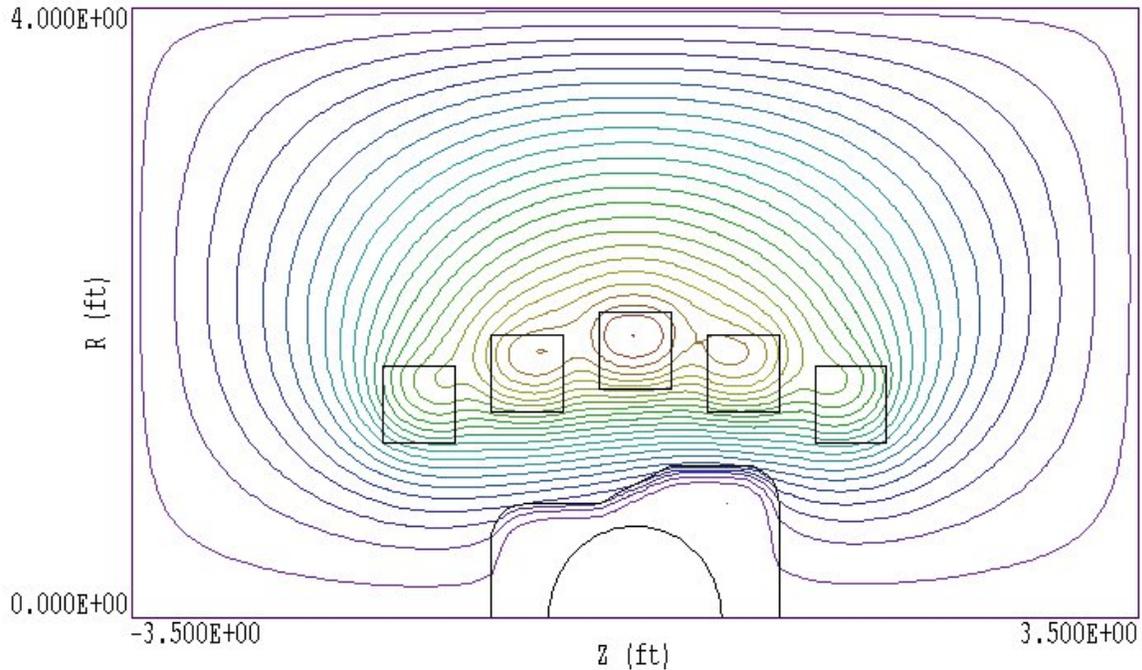


Figure 4. Magnetic field lines in the WALKTHROUGH example.

Run **NView** from **TC** to analyze the solution. Click the *Load solution* command in the *File* menu and pick WALKTHROUGH .NOU. The program creates the default plot of Fig. 4 showing contours of rA_θ . In a two-dimensional solution the contours lie along lines of \mathbf{B} (magnetic flux density). Because the lines are separated by equal intervals of magnetic flux, the spacing looks larger near the axis of a cylindrical solution. In the *Spatial plot* menu click on *Plot type* and choose *Element*. The program issues a message that plots of rA_θ contours are not supported in the plot type. Click on *Ploted quantity* and choose $|E|$, the amplitude of toroidal electric field. You should see the plot of Fig. 5 which shows electric field penetration into the work piece.

To conclude we shall perform some analysis using the control script feature of **NView**. Click on *File/Run script* and choose WALKTHROUGH .SCR. The file has the content:

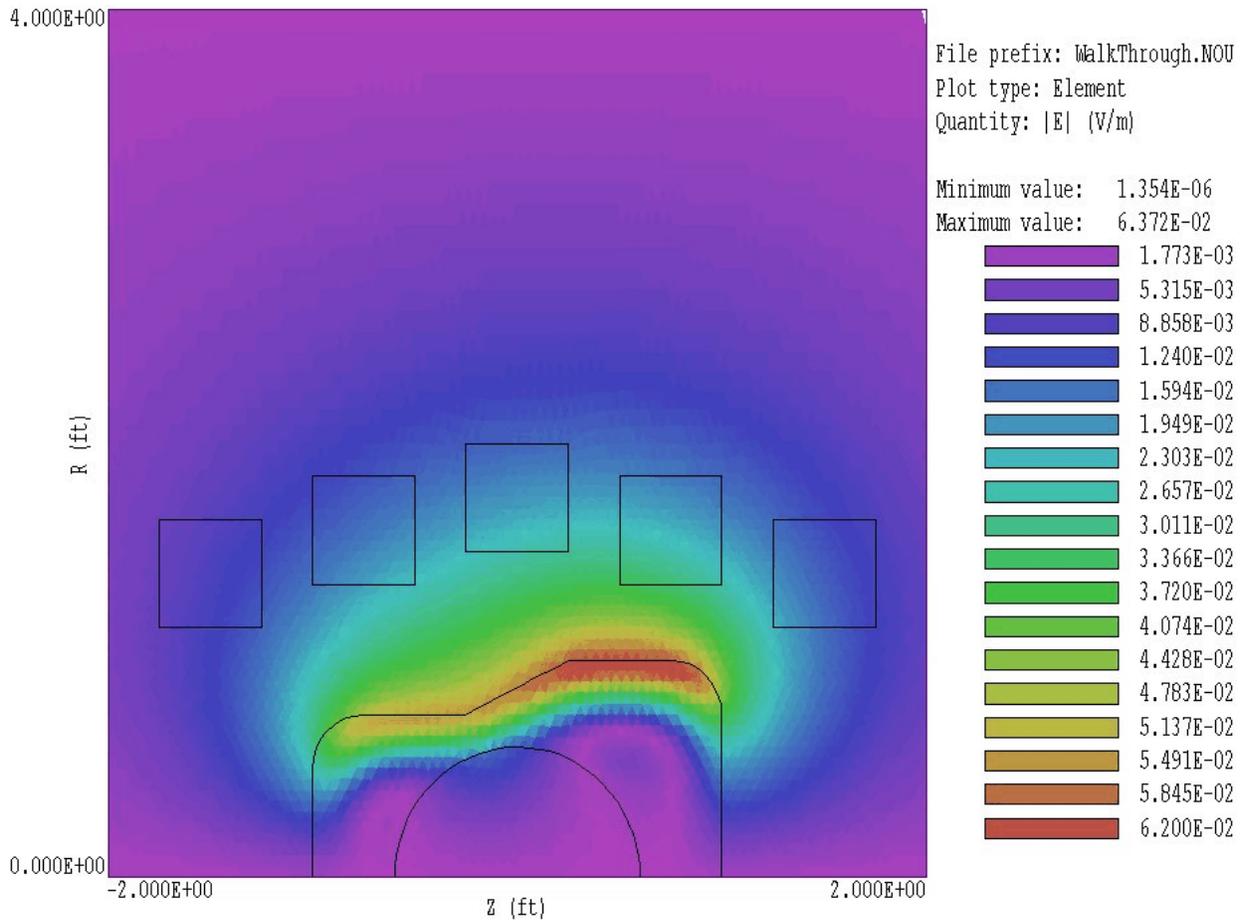


Figure 5. Amplitude of E_0 in the WALKTHROUGH example.

```

* File WALKTHROUGH.SCR
INPUT WalkThrough.NOU
OUTPUT WalkThrough
NSCAN 100
SCAN 0.0 0.0 0.0 1.5
REGION 2
ENDFILE

```

In response, **NView** loads the solution file and opens a text file WALKTHROUGH.DAT for output. The program sets the number of scan point to 100 and takes a scan of values at $z = 0.0$ ft from $r = 0.0$ ft to $r = 1.5$ ft. Finally, **NView** does an analysis of region 2 (the work piece) and closes the output file. It is easy to capture the values in the text file and transfer them to other software. The plot of $|E_0|$ in Fig. 6 was created with PsiPlot. **NView** also has internal plot capabilities with digital oscilloscope features. The *Region* command initiates a volume integral and produces the listing:

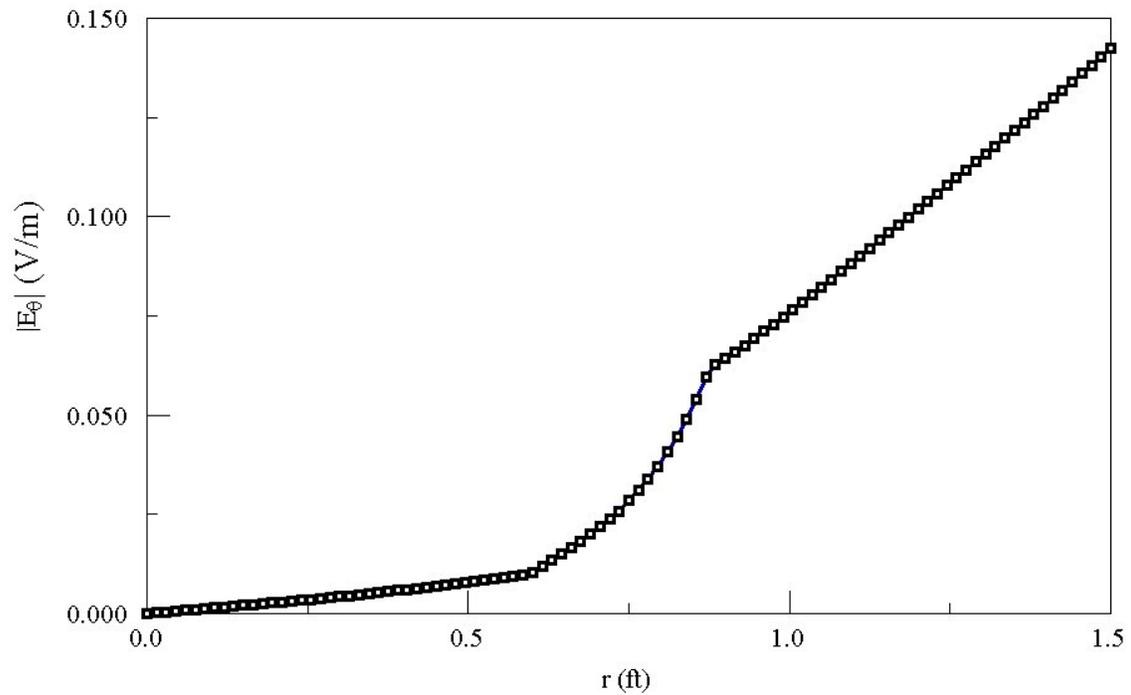


Figure 6. Variation of $|E_{\theta}|$ with radius at $z = 0.0$. Data created by **NView**, plot created with **PsiPlot**.

```

--- Region Information ---
Region No: 2
Volume: 1.090E-01 m3
Energy: 1.563E-12 J
Power: 2.417E+04 W
BPeak: 6.488E-03 tesla
ZPeak: 6.350E-01
RPeak: 9.917E-01

```

The resistive power dissipation is 24.17 kW.