B R O O K H A V E N   N A T I O N A L   L A B O R A T O R Y

MAGNET DIVISION NOTES

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Computer Aided Cross section Measurement and Analysis

Ramesh Gupta

In this note we propose a method for a computer aided cross section measurement and analysis. Presently the cross section, wire position in a coil cross section to be particular, is measured using the old bubble chamber machines and technology. Only a few of these machines are available and they are practically non-portable and painful to use. Moreover, those machines are very old with life time unknown. Even if they do not retire in near future, these machines may not be easily accessible to industry.

Here we recommend a new method for doing above measurements based on modern technology. In addition to measurements one can also do a useful physical analysis of a cross section with the proposed system since it uses CAD – a powerful software for such applications. It requires the following hardware and software which are commercially available and most of them are present in many laboratories anyway.

- Hardware HP ScanJet Plus[1]
- Software PC Paintbrush[2]
- Software AUTOCAD[3]
- Software CAD Overlay GS[4]

First a photograph or directly the object is scanned on ScanJet so that the image is digitized and stored electronically. This kind of job is typically done for storing a picture for publication using various commercially available wordprocessors. Next the picture is processed and the optimized image is saved in to a file with Paintbrush. This picture can be seen on the screen at this moment. Paintbrush also has the capability of zooming the picture and one can very clearly see the individual strand in the cable. Though the cursor position is displayed on the screen and one can note the position of superconducting wires, the Paintbrush does not have a capability of writing the coordinates of them directly in to a file. However, recently a software "*CAD Overlay GS*" has come out in the market which converts the paintbrush files in TIFF format to files in IGES format, which can be read by AutoCAD. The format conversion maintains the gray scales which is very crucial for image interpretation. Moreover the software allows AutoCAD to work on this image. To get the coordinates of the center of the wire one would simply click the mouse at the desired locations and in the end one would save the output file containing the information where the mouse was clicked. This would create an ASCII file containing the center of the wires. The file can be post-processed by other programs to compute the field harmonics or whatever else is desired.

At this stage we have already done whatever was being done with the bubble chamber technology. In addition one can re-visit the picture to see where the center position of a wire was chosen by the user to analyse and correct any discrepancy etc., since a mark was left at that position. One can also see, for example, whether all the wires were included in the analysis or not, because those wires which were not included would not have that mark. These kind of things were simply not possible in the case of bubble chamber technology. One can also zoom the image, to any desired magnification to get a reasonable accuracy in finding the wire center or to see visually any type of distortion in the magnet geometry.

The linearity of a photograph is basically maintained during the process of scanning the photograph with ScanJet and in doing any further analysis. We used a 600 dots per inch resolution to test it (maximum available 1500 DPI) – with each pixel representing 1.67 mil. A typical deviation at any point was 1 or 2 pixel with the maximum anywhere being 3 pixel. However, these errors may have been there in the scale itself and may also have occurred in the observation due to a poor quality image used in this calibration. Moreover, if one is really concern about the accuracy at this level and if the errors mentioned here are real, one can photograph the picture with a high precision grid overlayed on it and use a table created by measuring that grid to correct those errors in wire position with an external computer program. Therefore, this method should be acceptable for this type of analysis. When the picture is printed on a laser printer a 1:1 ratio is maintained unless changed.

As mentioned earlier, once the image is in AutoCAD, one can do a variety of analysis right there. For example, one can get pole angle, size and location of wedges, location of turns, etc. can be easily obtained from AutoCAD. One can overlay the design cross section (already available as AutoCAD file) on the measured one to visually see (at a proper magnification) what is happening, for example to the turn positions, in the process of manufacturing the coil as compare to what was expected.

Presently the position of a turn is determined from the position of several wires (23, 30 or 36) in a cable. In this AutoCAD based analysis, one can directly get the position of cable using a straight line or box fit to the cable surfaces (which has a clear contrast to the insulation wrapped on the cable). If this comes out to be reliable and accurate method, there may not be a need to obtain the center position of a large number of wires in a cable for most purpose. This would bring a great saving in time.

In figure 1, we have given a copy of the photograph of a cross section. In fig 2 and fig 3 we have shown what a user would see on a computer screen, at two different resolutions during this analysis.

One can also measure the collar, spacer, yoke etc. by directly putting those objects on the ScanJet. By taking a picture of them before and after the magnet is assembled one can obtain the deformation at various places which could possibly be useful in checking the mechanical analysis computations. In figure 4, we have printed the computer screen after scanning the two SSC collars interleaved to each other. In figure 5, we have shown the scan of a pair of the RHIC yoke laminations.

We also studied the image of a coil cross section by putting a cookie (cut out from a magnet) directly on to the scanner. This was to avoid a step of taking the photograph which invariably introduces a magnification. Though we could identify the individual cable, the quality of image was not good enough to identify the individual wires (strands) separately. If measuring the cable approach, as discussed earlier, is found to be satisfactory, one may like to follow through on this. We also recommend investigating the approach in which the image of an object is directly digitized. This is already being done elsewhere for storing the picture of persons on computer. In this case the need of scanning (or rather re-scanning) a photograph would be eliminated.

In conclusion, the computer aided image scanning and analysis has been found to be adequate for the mechanical measurement of the cross section. It should take us a step further from what is being done presently.

Discussion and help from B. Gottschalk, S. Khan, R. Hogue, K. Power and others is appreciated in bringing the above method to reality.

References

1. HP ScanJet Plus is a registered Trademark of Hewlett Packard Corp.

1. HP Paintbrush is a registered Trademark of Hewlett Packard Corp. Scan Gallery version 5 has been used here.

3. AutoCAD is a registered Trademark of Autodesk, Inc.

4. CAD Overlay GS is a registered Trademark of Image System Technology.

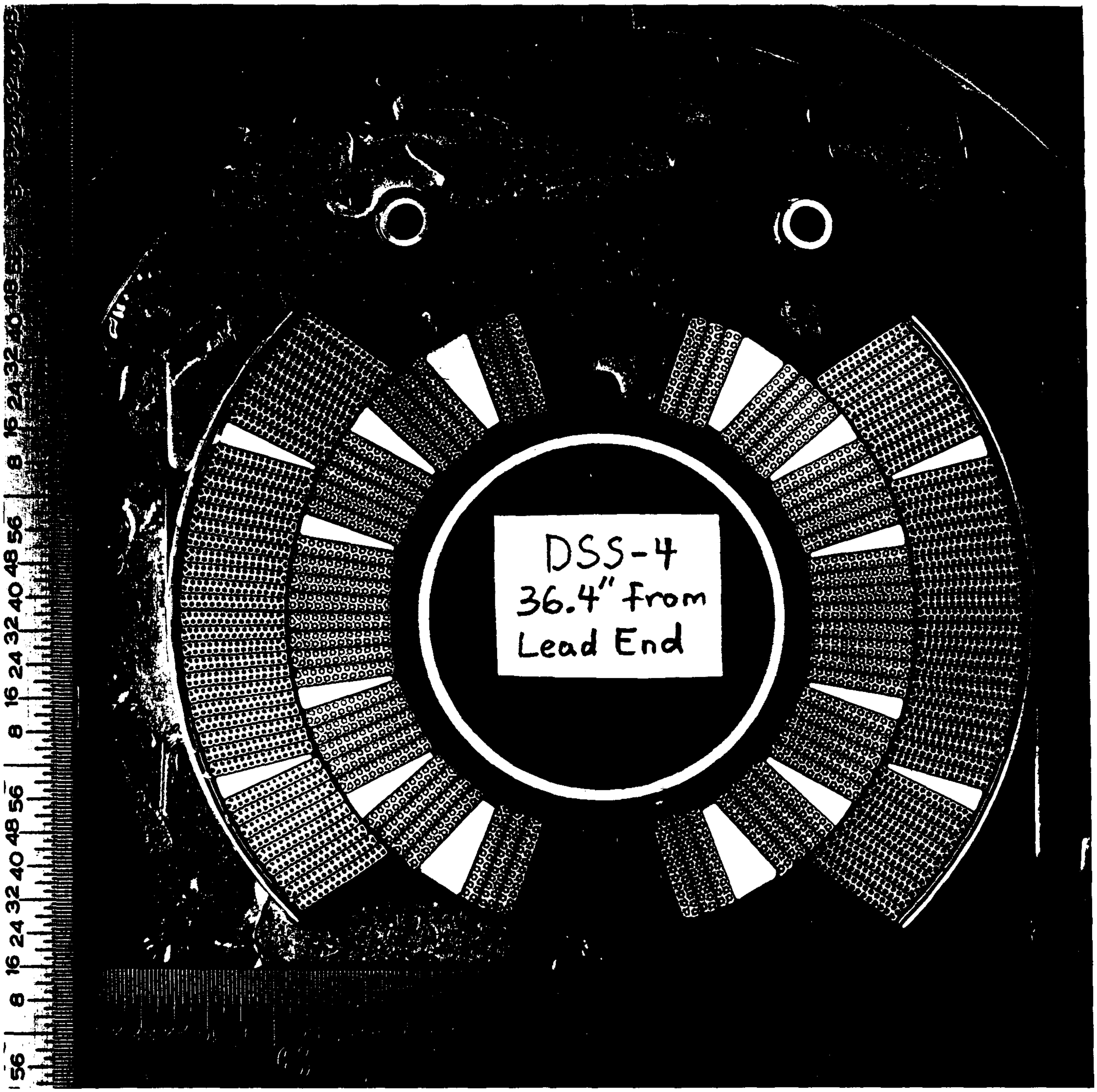

Figure 1: Photograph of a coil cross section, obtained after cutting a magnet.

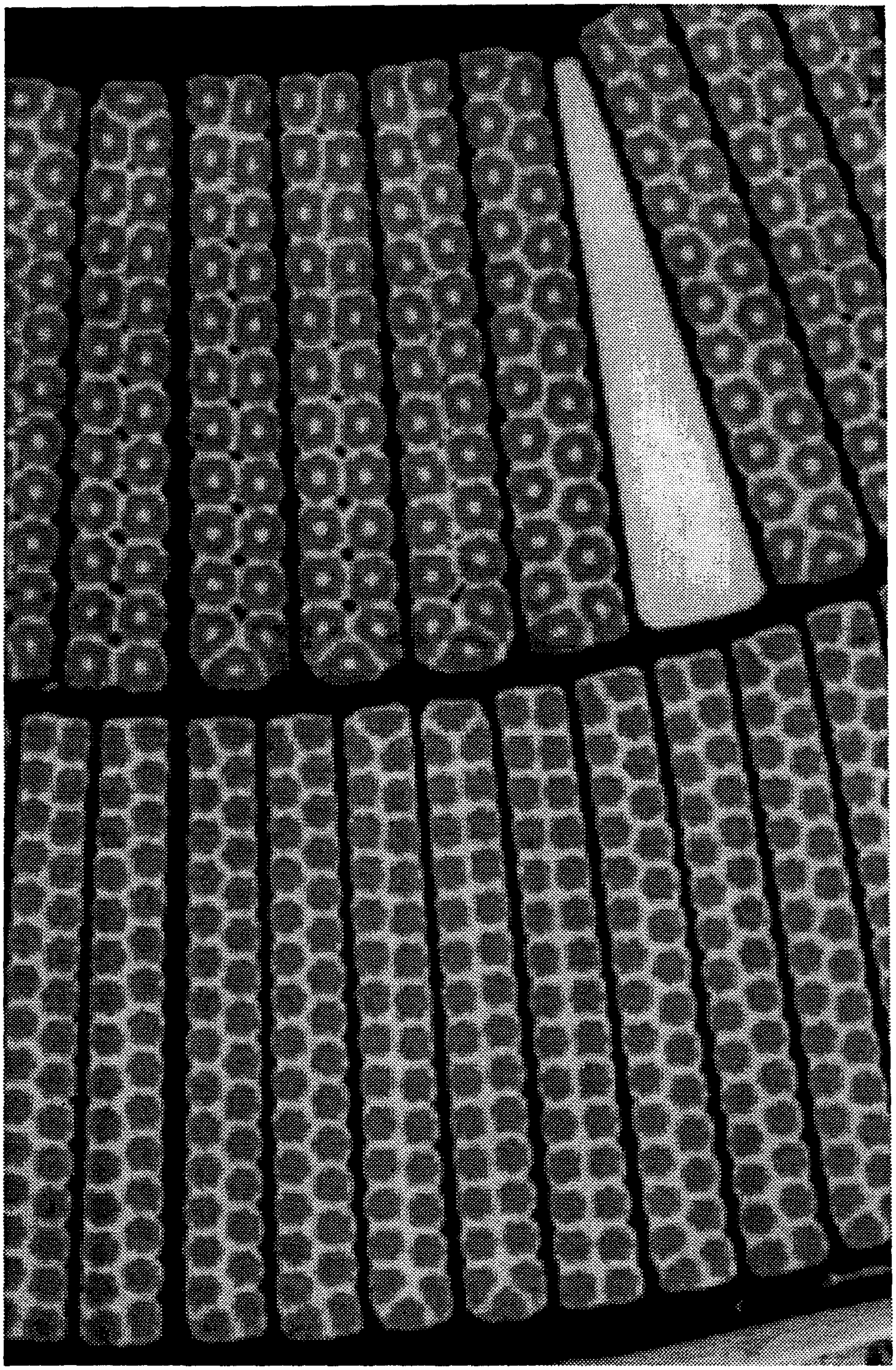

Figure 2: Coil cross section of figure 1, as seen on a computer screen, at a medium magnification.

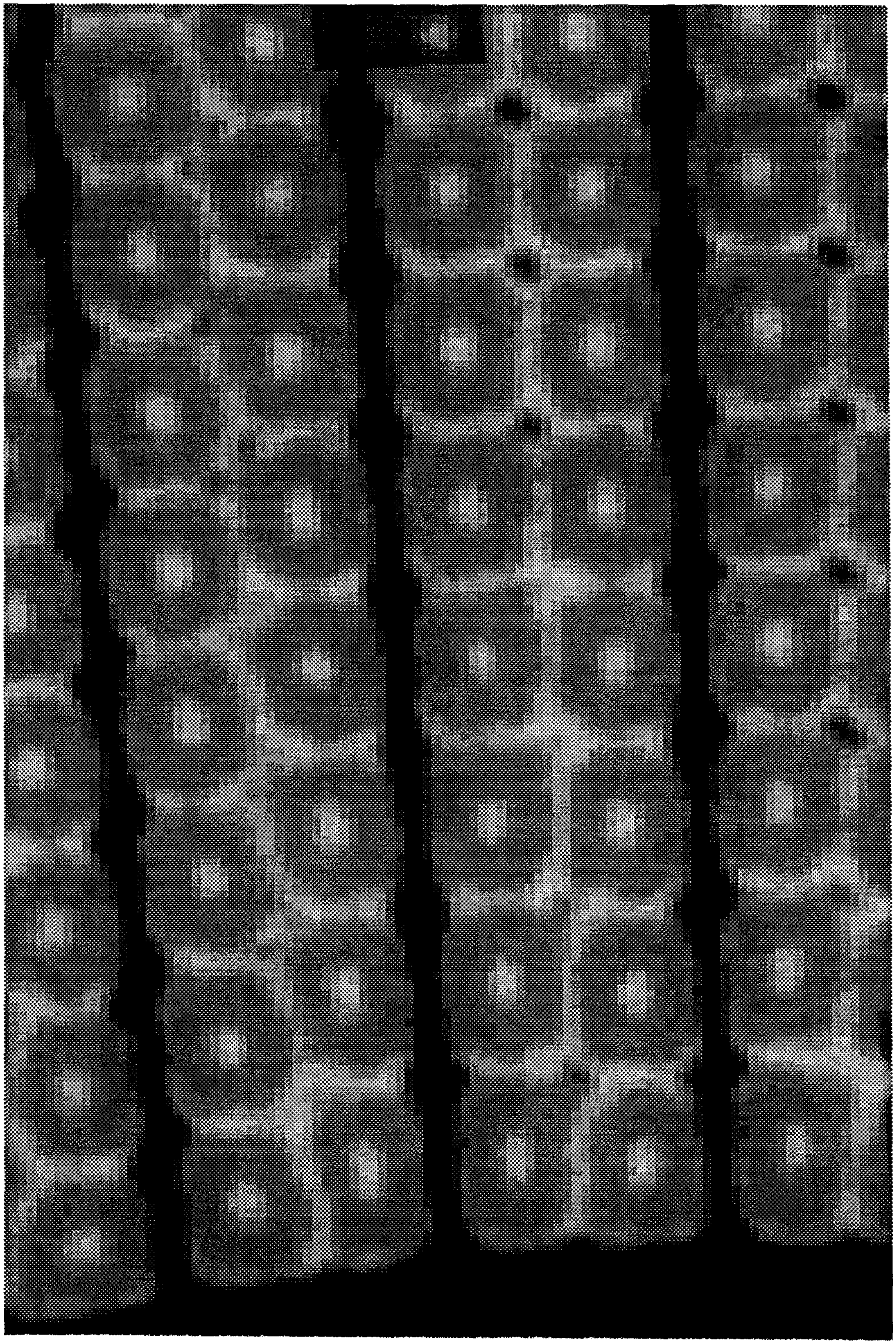

Figure 3: Coil cross section of figure 1, as seen on a computer screen, at a high magnification.

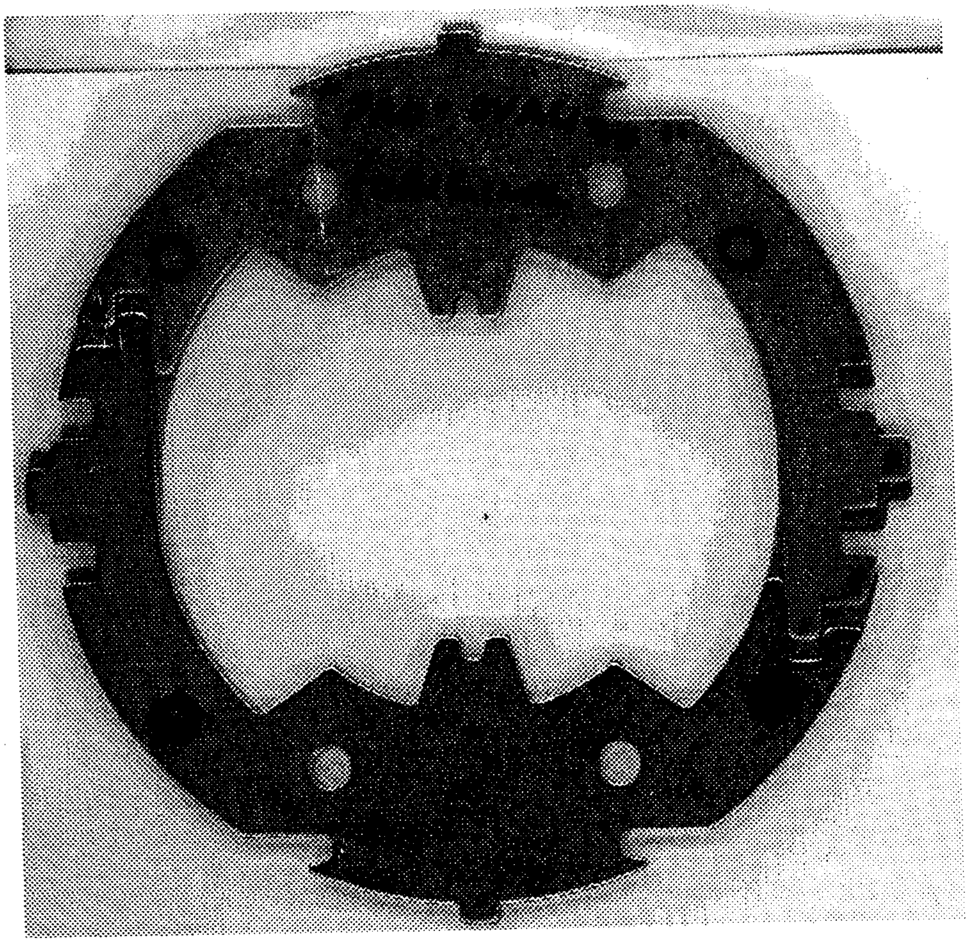

Figure 4: Image of the SSC collars, obtained by directly putting them on the scanner.

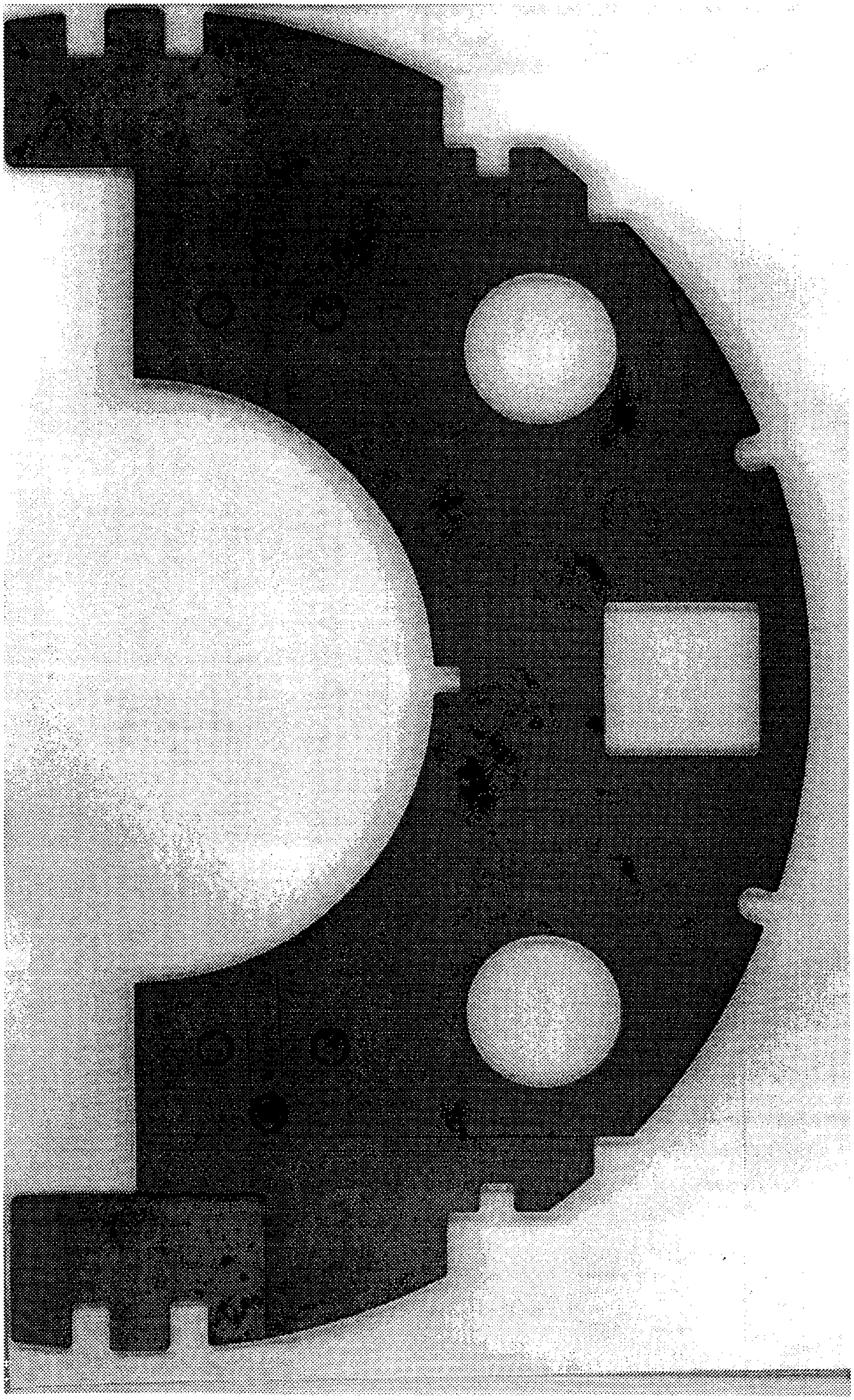

Figure 5: Image of the RHIC yoke, obtained by directly putting it on the scanner.