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Digital Processing of Breast Thermograms

by

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The Artificial Intelligence Center of SRI has pioneered the development of pattern-classification and scene-analysis techniques[*] for more than a decade. In an effort to apply such disciplines to medical problems, the Institute has digitized and processed a series of breast thermograms of positive patients.[**]To improve the medical value of such imagery for the radiologist, several off-the-shelf algorithms have been applied to the digitized images. Figure 1 contains a half-tone reproduction of a digitized thermogram. (The inverted horizontal line is an intentional artifact of the IR scanner.) Figure 2 is a centered and enlarged (zoomed) version of the Figure 1 image. Note the appearance of additional detail resulting from the zooming operation.

Figures 3 and 4 represent attempts to enhance the visibility of the thermographic imagery. In particular, Figure 3 was generated by enhancing the contrast of Figure 2. The imagery was enhanced by passing the picture through a fictitious photographic process with a high-contrast (high-gamma) film. The process results in darker blacks, lighter whites, and more distinguished grays; contrast enhancement thus makes better use of the dynamic range of the human eye. Similarly, Figure 4 was produced by crispening Figure 3. The imagery was crispened by first decomposing the picture into its Fourier components, then boosting the high spatial frequencies, and finally recomposing the picture to form the crispened image. The crispening process thus tends to reduce the strength of the large uniform areas and increase the strength of the small detailed ones. Edge crispening thus improves the visibility of fine image structure.

[*] R. Duda and P.Hart; Pattern Classification and Scene Analysis
    (Wiley - Interscience, New York, 1973)
[**]The breast thermograms were taken by Solon Finkelstein, M.D., of
   Palo Alto Medical Clinic with a Spectrotherm camera.

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Figures 5 through 8 demonstrate the use of pseudo-color techniques
with breast thermograms. Pseudo-color displays provide a powerful
technique for overcoming the limited contrast sensitivity of the human
eye. As a rule, the human eye can distinguish about fifty brightness
levels relative to the ambient. In other words, a breast lesion must
be about 2% brighter than its immediate surroundings to be seen by the
human eye. On the other hand, the human eye can distinguish thousands
of color hues at a given brightness level. To take advantage of this
better color sensitivity, one can convert the brightness levels of a
monochrome picture to corresponding hues for a color display. In
particular, low-brightness regions (Figure 5) can be converted to blue,
medium-brightness ones, (Figure 6) to green, and high-brightness ones,
(Figure 7) to red. When displayed simultaneously, one obtains a
pseudo-color image (Figure 8). Since small brightness differences be-
come large color differences, the detectability of lesions is markedly
improved.

Besides improving the visibility of the breast thermograms, the
digital computer can also analyze the breast thermogram for unusual
thermal features. Figure 9, for example, contains crosses marking
the hottest and coldest points of the thermogram. Further processing
might enlarge on this algorithm and locate the hottest areas of the
picture, with the size, topology, and location of the area controlled.
For example, the computer might look for hot spots and signal their
presence to the attending physician. The same procedure could also
detect periareolar heating or engorged venous systems. From an image-
processing viewpoint, such tasks represent quite reasonable under-
takings.

Profiles and histograms represent another approach to the analysis
of breast thermograms. Figure 10, for example, contains a vertical
profile of the Figure 2 image. (The vertical profile was obtained by
simply averaging the picture elements in each horizontal row of the

thermogram.) The sharp spike corresponds to the inverted line discussed earlier, and the broad hump on the right represents the inframammary fold. Generally speaking, the profile looks normal. Figure 11 contains a horizontal profile of Figure 2. The broad hump in the center corresponds to the cleft between the two breasts. The right side of the curve is obviously hotter than the left, an anomalous condition. Such inbalance suggests that further examination--e.g., mammography and palpation--of the patient is warranted.

Temperature histograms also signal differences between the right and left breasts. Figure 12, for example, contains a histogram of the temperatures found in Figure 2. The main bump represents the basic distribution of breast temperatures; the smaller hump on the right probably represents the inframammary fold and interbreast cleft. Figures 13 and 14 contain, respectively, the temperature histograms for the left and right sides of Figure 2. Note that the right side features higher temperatures than the left, another suspicious indicator of breast cancer. Detailed inspection of Figure 2 suggests a problem in the superior region of the right breast. In particular, the heat band running from the interbreast cleft to above the right nipple is definitely anomalous, and indicates the patient should receive follow-up examination.
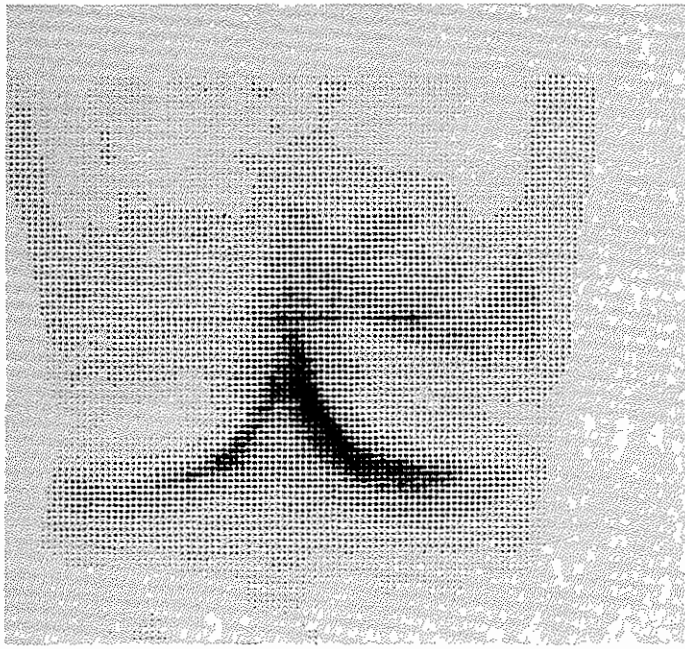
TA-740583-14
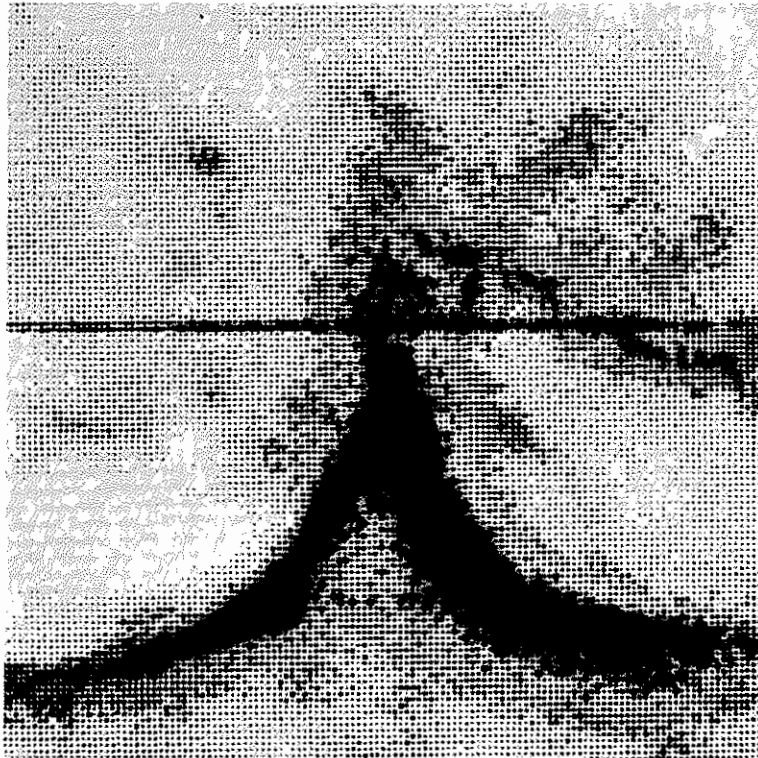
FIGURE 1   DIGITIZED BREAST THERMOGRAM

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FIGURE 2   ZOOMED AND CENTERED THERMOGRAM

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FIGURE 3   THERMOGRAM WITH CONTRAST ENHANCEMENT
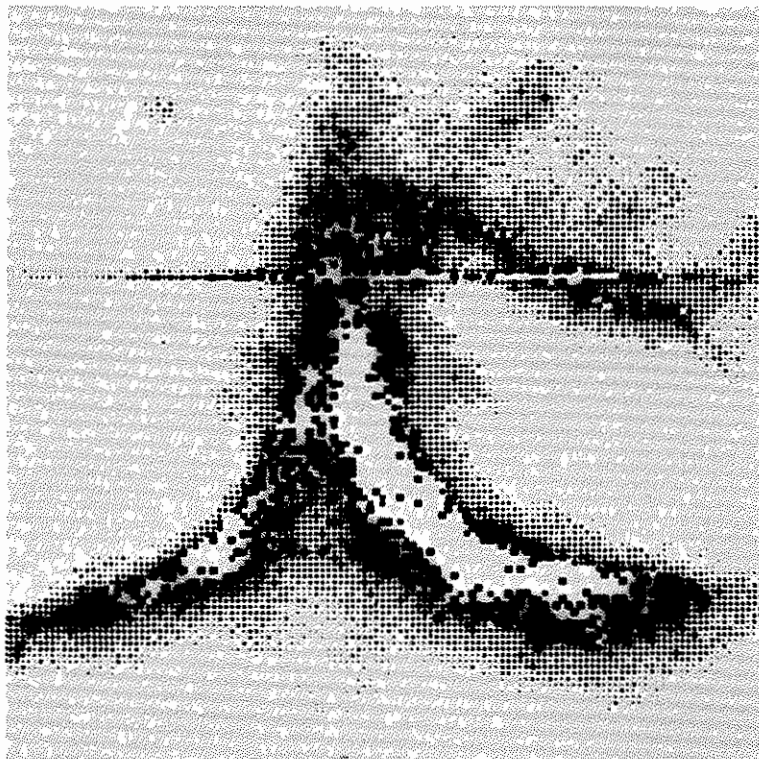
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FIGURE 4   THERMOGRAM WITH CONTRAST ENHANCEMENT
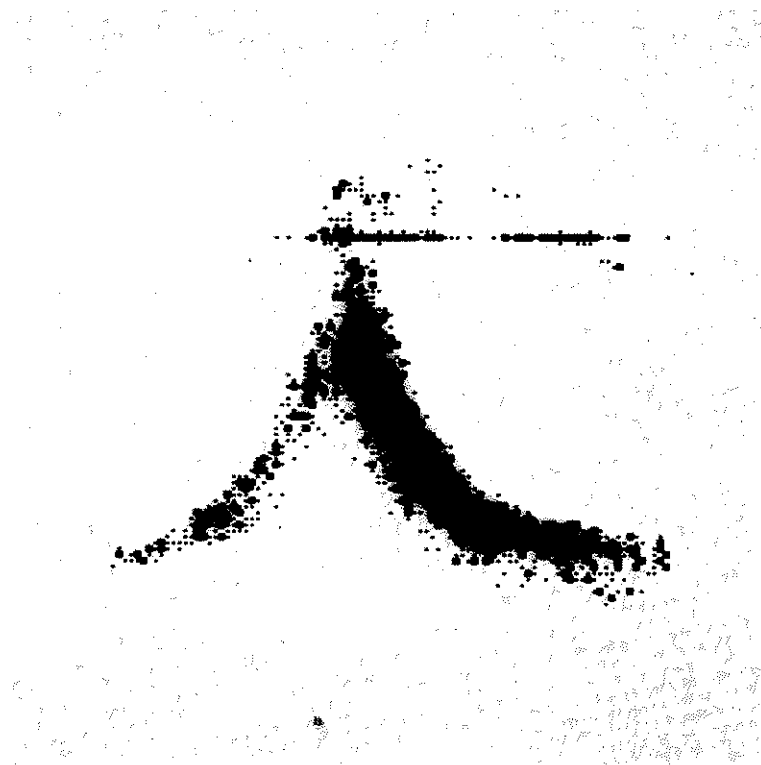   AND EDGE CRISPENING

TA-740583-18
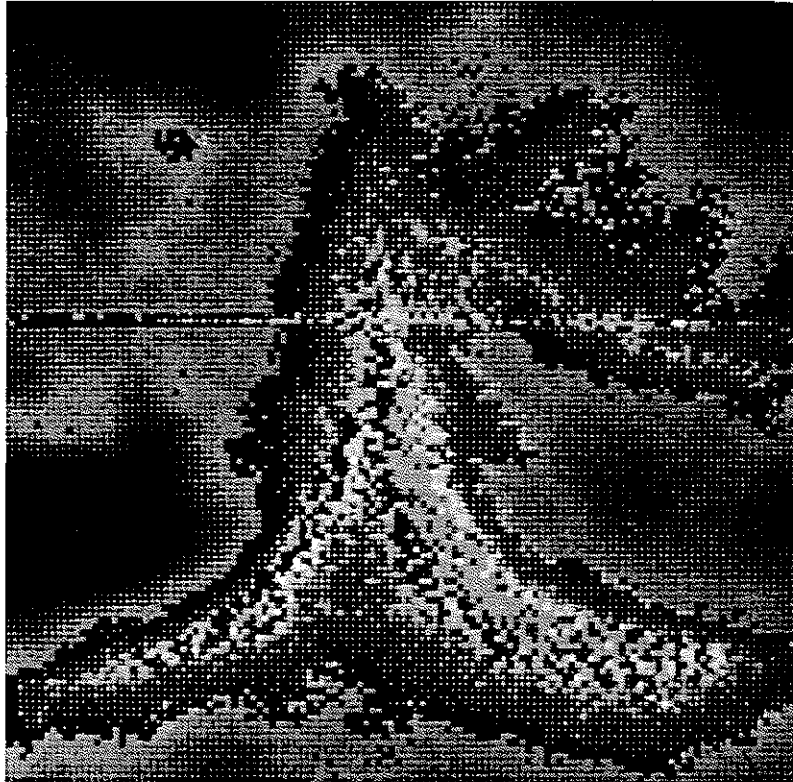
FIGURE 5   COLD PORTION OF THERMOGRAM (BLUE)

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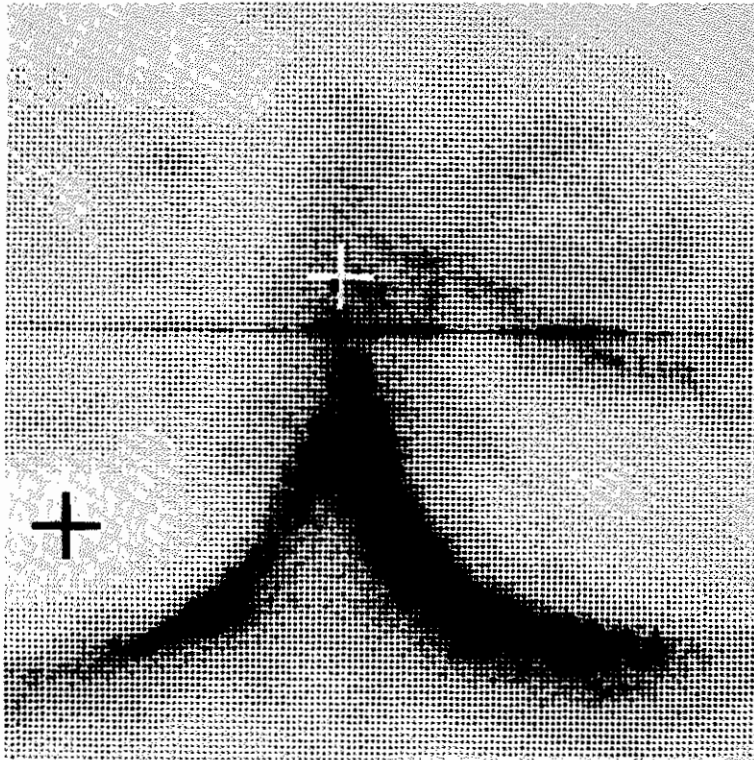
FIGURE 6   WARM PORTION OF THERMOGRAM (GREEN)

TA-740583-20
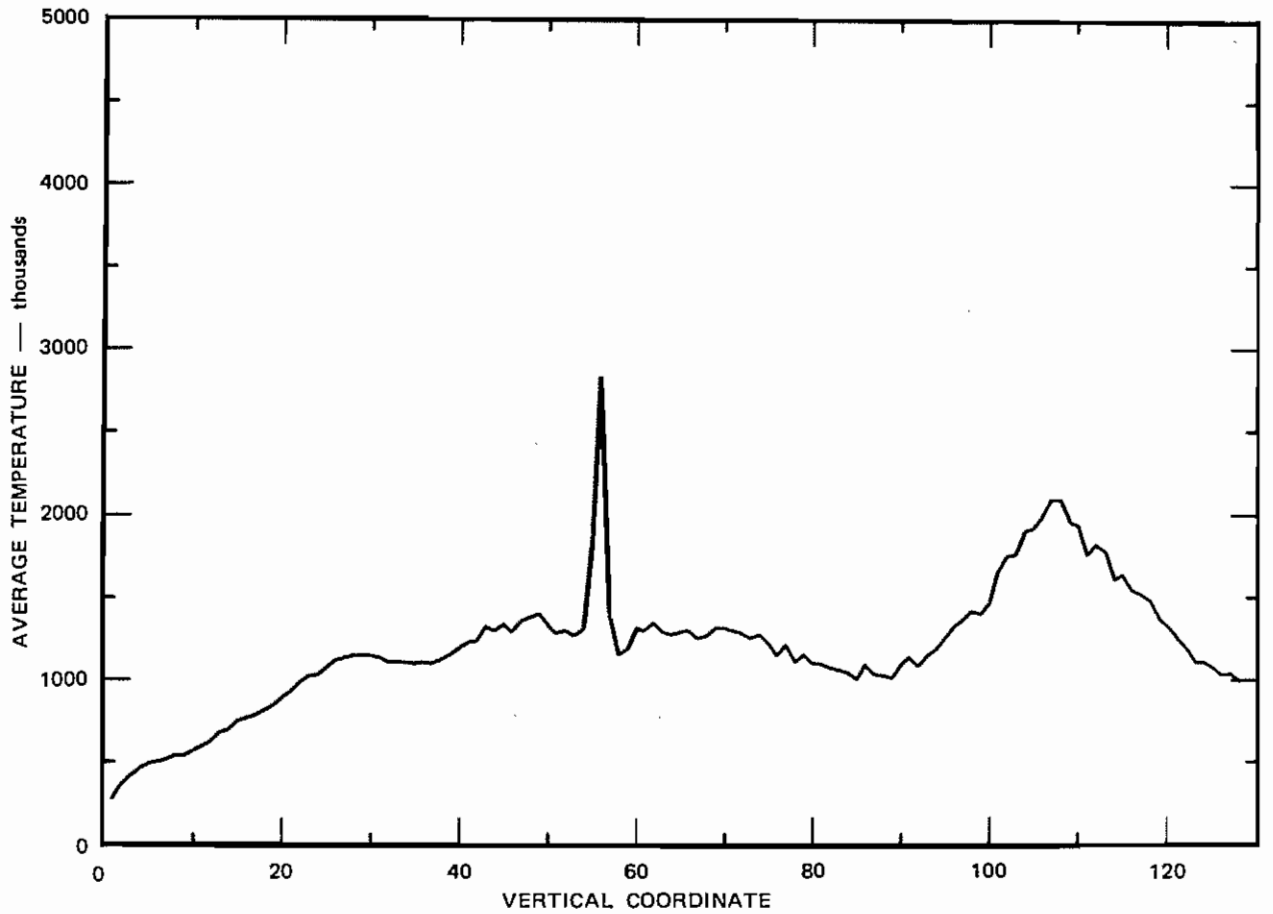
FIGURE 7   HOT PORTION OF THERMOGRAM (RED)

TA-740583-21
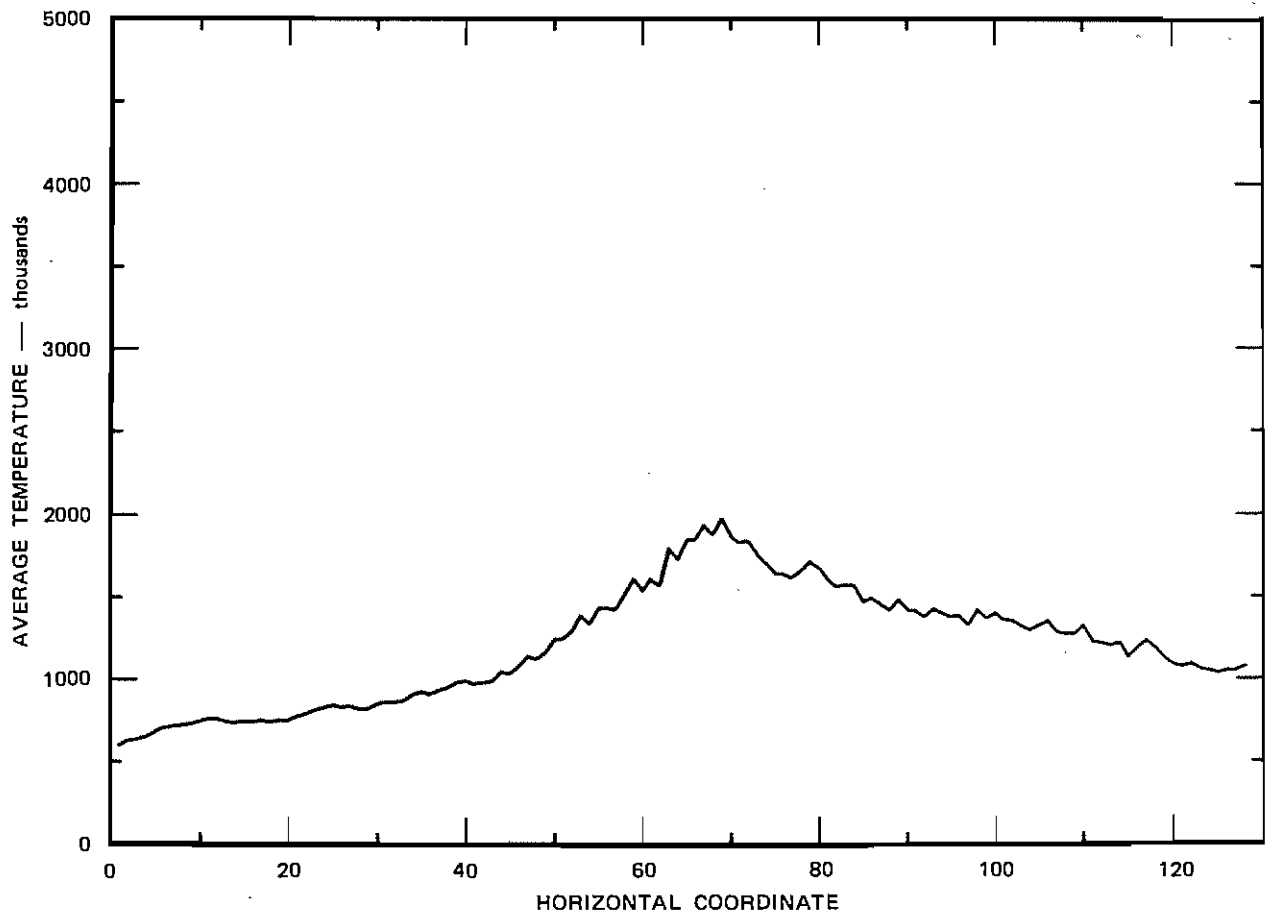
FIGURE 8   PSEUDO-COLOR BREAST THERMOGRAM
(MONOCHROME)

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FIGURE 9   HOTTEST (WHITE CROSS) AND COLDEST (BLACK CROSS) POINTS OF THERMOGRAM

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FIGURE 10   VERTICAL TEMPERATURE PROJECTION
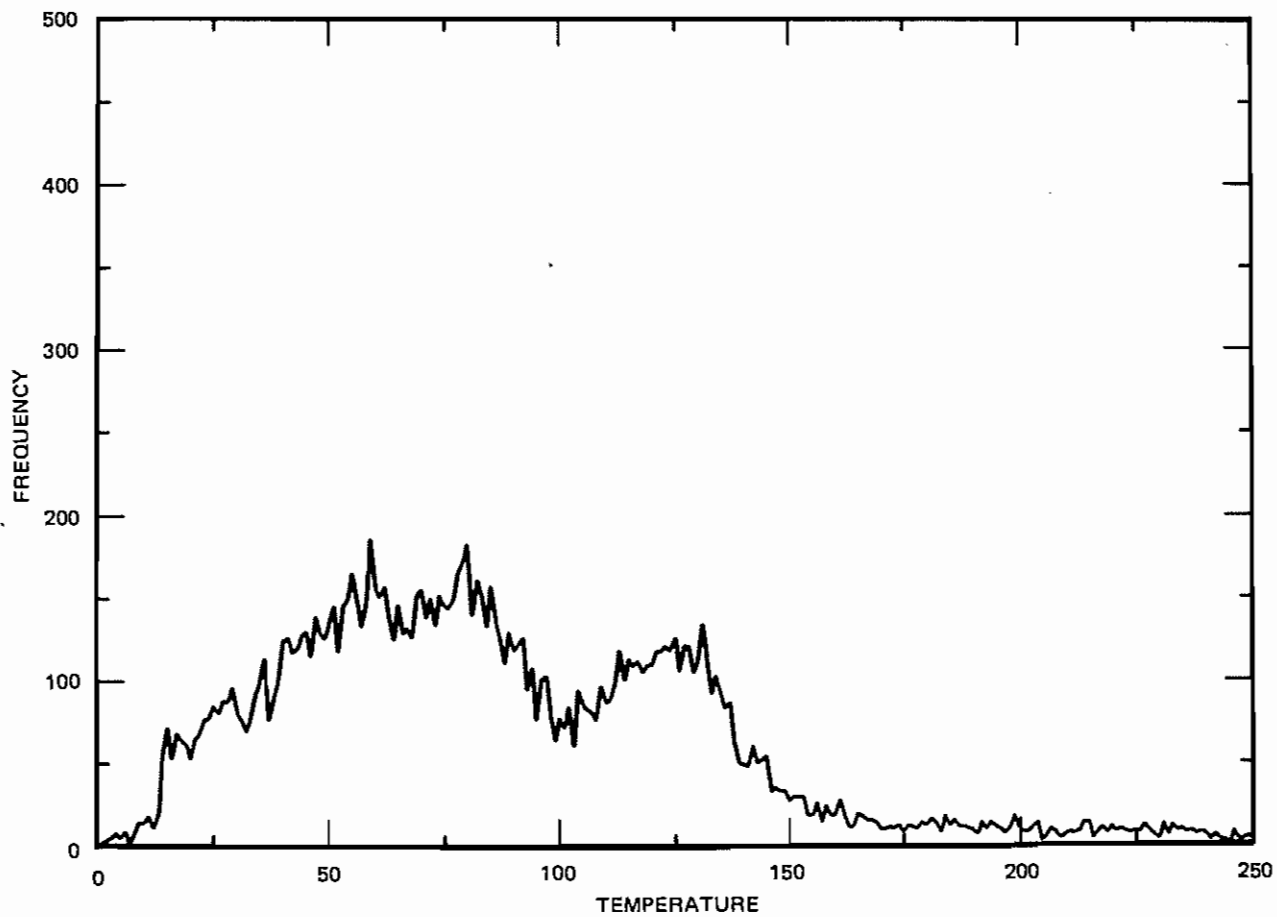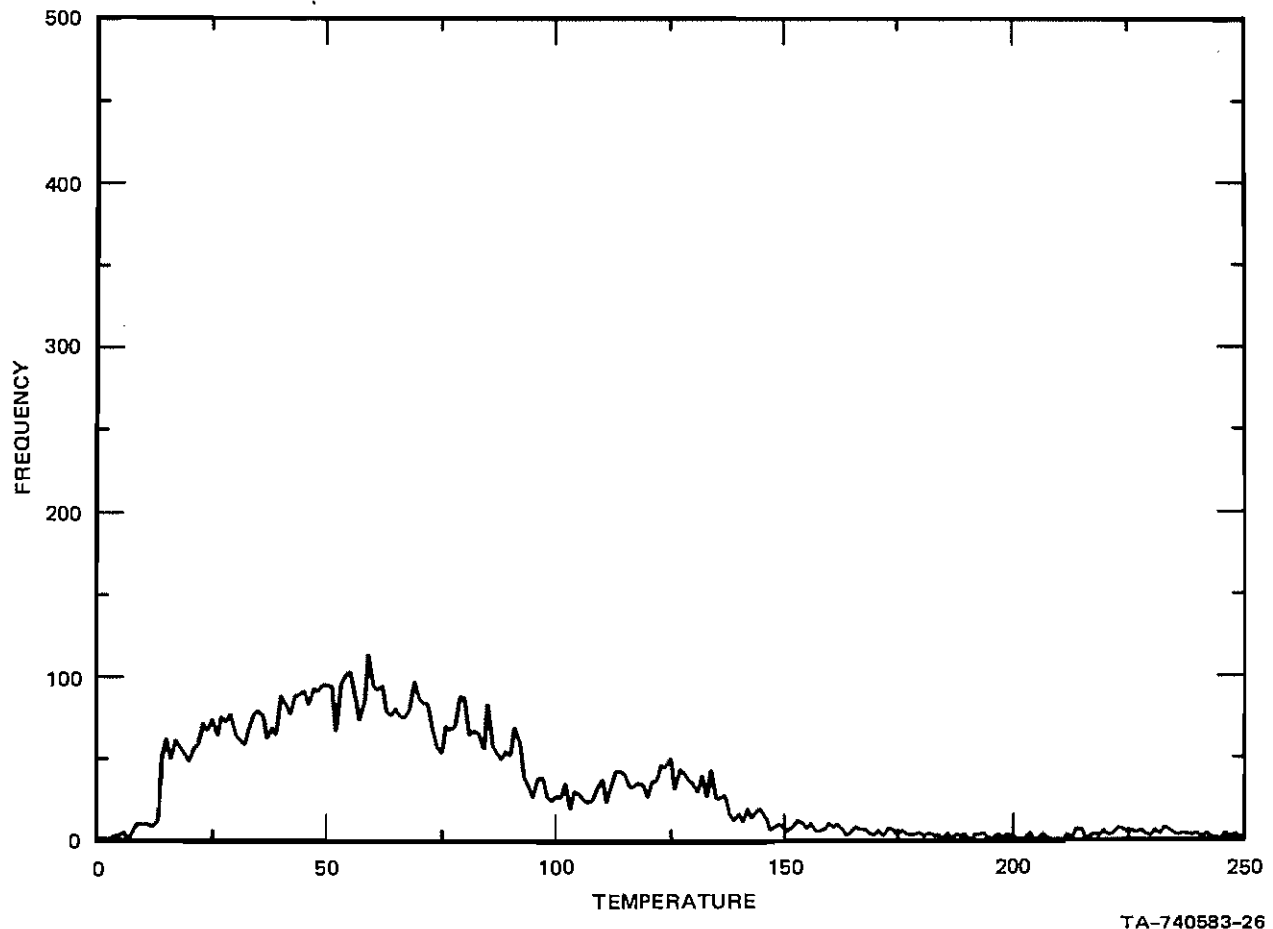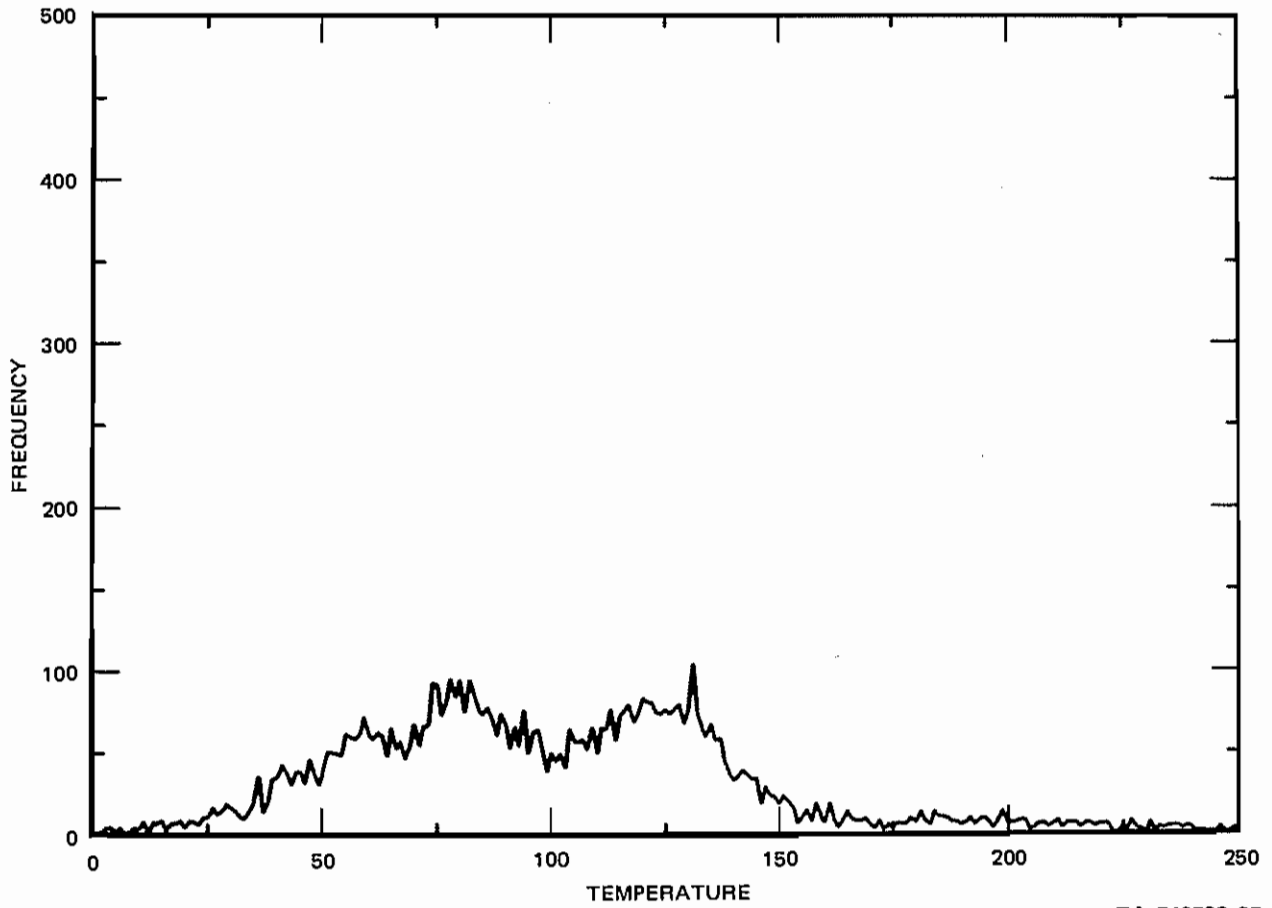
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FIGURE 11   HORIZONTAL TEMPERATURE PROJECTION

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FIGURE 12   FULL BREAST TEMPERATURE HISTOGRAM

FIGURE 13   LEFT BREAST TEMPERATURE HISTOGRAM

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FIGURE 14   RIGHT BREAST TEMPERATURE HISTOGRAM