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THE TESTING OF A RELIC

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INTRODUCTION

Enshrined for 400 years in Torino, Italy is a linen cloth bearing the front and back images of a tortured man believed by many to be Jesus of Nazareth. Visible, besides the body images, are stains representing blood and serum from wounds, scorch marks running the full length, and patches covering burn holes.

One question which is of interest to a group of American scientist is — how was an image formed on a linen cloth centuries ago? A private research group has been formed to study this and other questions. A group of nondestructive tests was performed in Turin, Italy during the period of October 9 —13, 1978. The primary objective was to collect data which would characterize the image.

TESTS

Six major tests were performed. These were x-ray fluorescence, chemical analysis, photography, infrared, radiography and visible and ultraviolet spectroscopy.

A special test fixture was constructed to support a fragile fabric and its protective backing cloth. The backing cloth had been added in 1532 after a fire had nearly destroyed the linen. The cloth has the dimensions 4.3 meters by 1.1 meters. The cloth was spread out on the horizontal frame and secured along the edges with magnets. The frame was rotated to a vertical position for the tests. Panels, 20 cm wide and extending the width of the frame, were removed singly for some tests, such as, radiography and x-ray fluorescence.

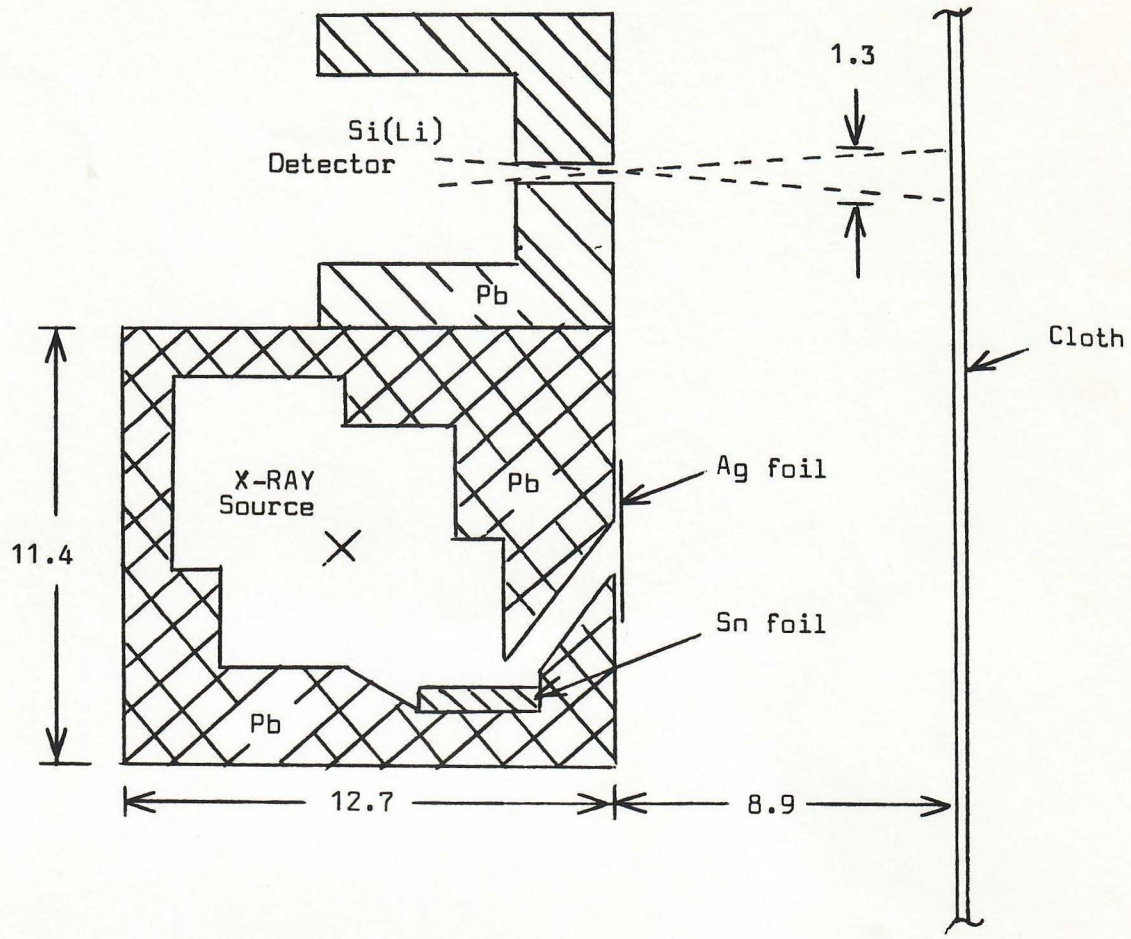
X-ray Fluorescence

The x-ray source used for radiography was used to excite a foil of tin. A lead collimator was installed over the end of the x-ray tube (Figure 1). The tube was located so that a 50 kVp x-ray beam would impinge upon the tin. The 25.5 keV K-alpha was filtered by a silver foil at the exit end of the collimator. A Si(Li) detector was mounted coaxially above the x-ray source. A lead shield with a 4 mm collimation hole was fitted over detector. This arrangement defined a one square centimeter sample area on the cloth.

The combination of x-ray source and detector was mounted on a heavy duty camera tripod. It could, thus, be raised and lowered across the width of the cloth. Also, the arrangement could be rotated for background and calibration measurements.

Pulses from the detector were fed to a linear amplifier and stored in a 512 channel pulse height analyzer. After a 2000 second counting interval, the accumulated spectrum was stored on a digital tape cassette for subsequent analysis.

Titanium and copper foils were used for calibration. From the measured positions of the K-fluorescence lines of these standards and their tabulated energy values a calibration curve was determined. Calibration data were collected before and after each test data run.



Note: Dimensions in cms.

FIGURE 1 -- X-ray source and detector shielding and collimation.

Chemical Analysis

Trace samples of surface materials were obtained by means of adhesive tape. The tape and the adhesive were compounded of pure hydrocarbon. A specially designed roller was used to apply the adhesive to selected areas of the linen cloth. After being carefully removed the tapes were attached, with the adhesive side up, to microscope slides and identified. Spectral photometric measurements were made on each sample area before and after application of the adhesive. All slides were stored in a plastic box which was tightly sealed.

The tapes are being examined by microscope and analyzed by the micro Raman method. Additional analysis will be performed by electron spin resonance, electron spectroscopy, ion microprobe and scanning electron microscope.

Photography

Mosaics at 5.6:1 and 22:1 reduction were made of the entire surface of the cloth. For each section a successive series of exposures were made with red, green and blue filters for color separation. In another series ultraviolet transmission filters were used for contrast enhancement. To detect fluorescence in a different series, ultraviolet transmission filters were used over the light sources while ultraviolet blocking filters were used over the camera lens. For another series the visible spectrum was partitioned into 100 Angstrom intervals by a series of filters.

Specific areas of interest were photographed at approximately 3:1 enlargement. Other areas were photographed through a microscope with 3x to 50x zoom capability and a 35 mm camera attachment. Also, stereo pairs on 35 mm film were made.

Infrared

Infrared sensitive film was used to photograph the images and stains on the cloth. By placing filters over both the light sources and camera lens photographs were made in the near-infrared region.

Reflectance measurements, as a function of wavelength, were made in the ranges of 3 to 5 microns and 8 to 14 microns. All measurements were digitized and recorded on tape for analysis later.

The integrated emissivity in the ranges of 3 to 5 and 8 to 14 microns were recorded by a thermographic camera. The cloth was illuminated by unfiltered tungsten light. The thermographic images were recorded on Polaroid film for later analysis.

Radiography

Low energy radiography was performed at 15 kVp. The x-ray source with a 1.5 mm square focal spot was positioned on a heavy duty tripod 1 meter from the linen cloth. A 20 cm wide panel was removed from the frame on the side opposite the source. A 36 cm x 43 cm film pack, containing a type DR and type M film, was taped over the opening. Following the exposure and removal of the film pack the source was moved vertically one-quarter the width of the cloth (approximately 27.5 cm). Another two film pack was taped over the opening in line with the source and exposed. After the third relocation of the x-ray source and exposure the panel was re-installed and an adjacent panel removed. The tripod with the x-ray source was aligned with the new opening and three more exposures made. In this manner the entire subject was radiographed.

An aluminium frame, approximately 1.25 m by 1.5 m, was suspended on the source side of the cloth. The frame was strung with horizontal and vertical wires spaced 20 cms apart. Each intersection of wires was identified with a unique letter-number pair. Thus, each radiograph was identified by shadows of wires and their intersection identifiers.

A darkroom was set up in a nearby room. All films were manually processed shortly after exposure. In another room film viewers were located and the processed films were given a preliminary examination. Any needed correction in exposure was relayed to the test room.

Visible and Ultraviolet Spectroscopy

A special reflectometer (Figure 2) was constructed. It was used interchangeably for reflectivity and fluorescence measurements.

For the reflectivity measurements the broad band radiation from a xenon arc lamp was directed through a source monochromator. The beam from the monochromator was imaged on a 6 mm by 3 mm area. Reflectivity scans were made from 250 to 750 nanometers. From 420 to 750 nanometers a long pass filter was inserted before the detector manochromator. The band width of the monochromator was 5 nanometers. Magnesium oxide was used as a reference for the reflectivity scans.

For the fluorescence measurements the light source used was a mercury arc lamp. The source monochromator was fixed at 365 nanometers. An ultraviolet transmission filter was inserted after the source monochromator and another which blocked ultraviolet and transmitted visible light was inserted before the detector monochromator. The detector monochromator was scanned from 390 to 700 nanometers. The band width was 8 nanometers for the fluorescence measurements.

Reflectivity and fluorescence scans were also made on sample cloths from the Egyptian Museum in Turin. In addition scans were made on filter papers which had been scorched and smeared with various paint pigments.

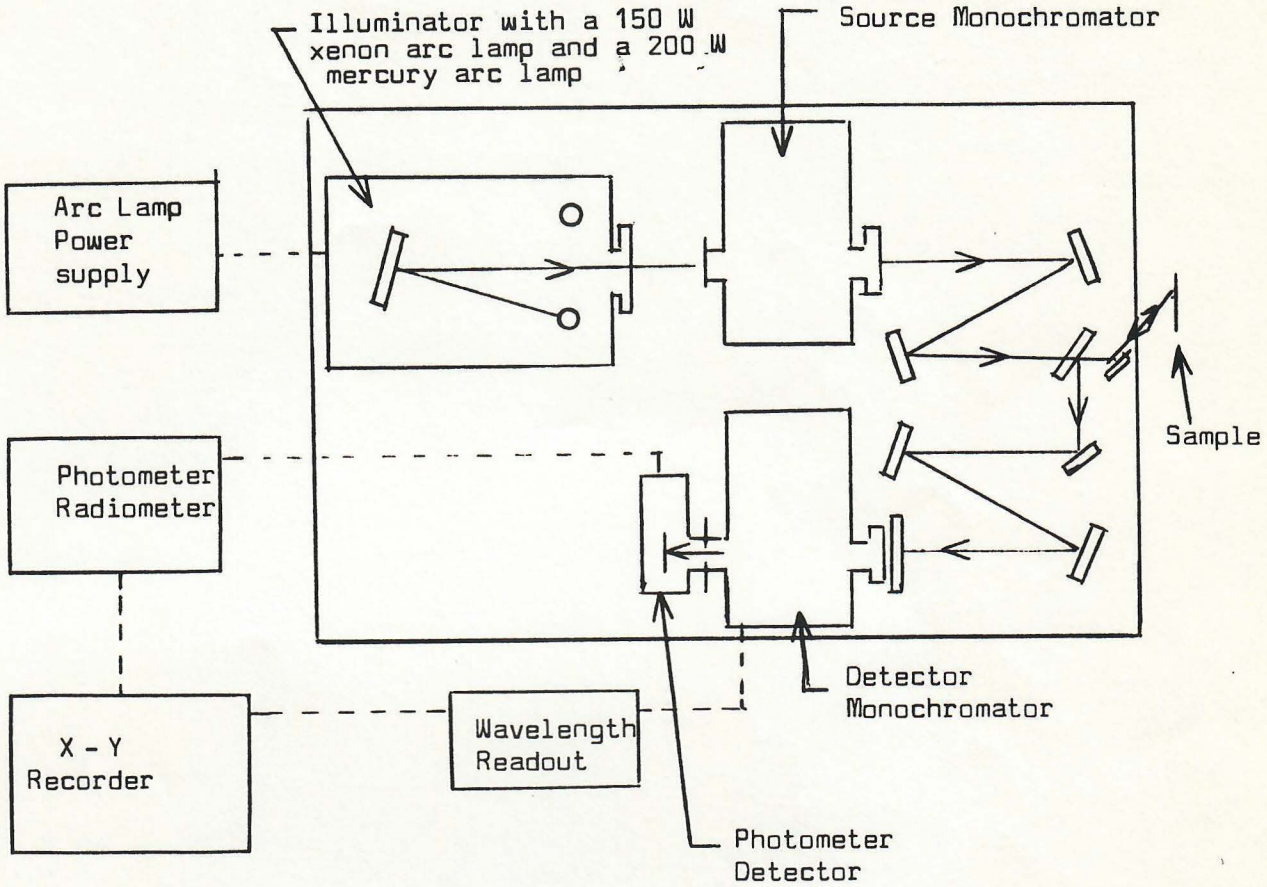


FIGURE 2 - - Block diagram of reflectometer/fluorimeter.

SUMMARY OF RESULTS

More than 100 hours of test time was shared by Italian, Swiss and American scientific teams. Whenever possible two or more tests were conducted at the same time during the around-the-clock schedule. The American team alone took almost 600 photographs, exposed and developed more than 60 pairs of x-ray film. A total of 25 x-ray fluorescence spectra were recorded. Eighty-five infrared reflectance scans and 18 thermograms were recorded. Thirty-six samples for chemical analyses were obtained. Besides spectroscopic scans of 34 areas of the cloth, 13 scans were made of sample cloths from the Egyptian Museum in Turin.

Details of the test methods and initial analyses of data will be published as soon as practicable. Future work will involve computerized scanning of negatives and thermograms, as well as, correlation and comparison of data. Laboratory tests and experiments will supplement the original data.