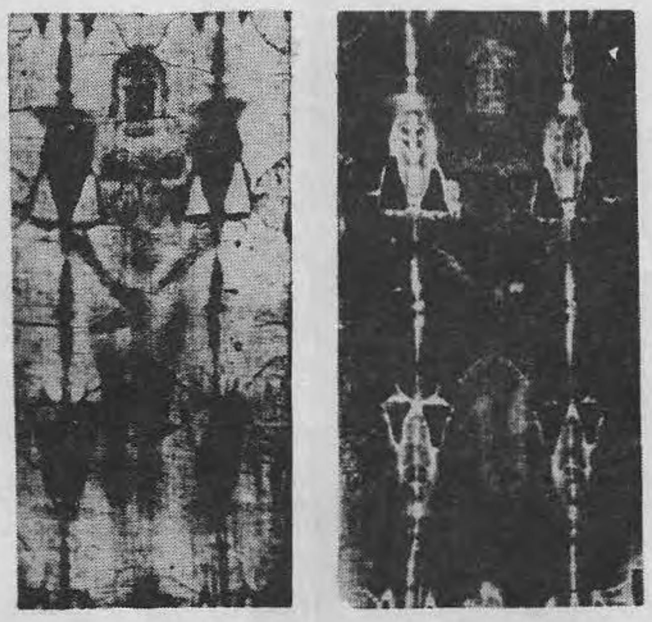
BARRIE M. SCHWORTZ

OPERATIONS TEST PLAN

FOR

INVESTIGATING



THE SHROUD OF TURIN

BY ELECTROMAGNETIC RADIATION

AT VARIOUS WAVELENGTHS

NAME Barrie M. Schwortz

OPERATIONS TEST PLAN

FOR

FOR INVESTIGATING THE SHROUD OF TURIN

BY

ELECTROMAGNETIC RADIATION AT VARIOUS WAVELENGTHS

Prepared by

The Shroud of Turin Research Project, Inc.

In conjuction with

The Holy Shroud Guild

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Introduction

In 1969 and again in 1973, selected scientists and scholars, at the invitation of authorities in Turin, made a preliminary examination of the Shroud of Turin. Their report, released in 1975, was the first organized attempt in scientific research on the Shroud relic. This investigation represented a major advance in the understanding of the Shroud, for not only did it bring to light new discoveries, but it also paved the way for further research. All over the world, including the United States, new interest and enthusiasm for more research had been stimulated by the bold step made in Turin almost one decade ago.

Only several months after the release of Turin's scientific commission report, a conference on the Shroud was held in Albuquerque, New Mexico (March 23 and 24, 1977) to determine what we in the United States might offer towards furthering the understanding of the Shroud. We concluded that only non-destructive tests should be performed and therefore, on September 19, 1977, a delegation of scientists met with the International Center of Sindonology in Turin to present our ideas in the form of a written proposal and two published volumes of the proceedings of the Albuquerque Conference.

On April 26, 1978, we received word through Father Rinaldi that we should begin preparing our tests for October, 1978, at the time of the World Congress and Exposition of the Shroud. On June 3 and 4, 1978, the team of scientists met with Father

Rinaldi in Colorado Springs and formulated a plan by which all test procedures, procurement of test equipment, and financial preparations would be made in time for October. On September 3 and 4, 1978, a dry run of all test procedures was successfully completed in Amston, Connecticut. And on September 29, 1978, the scientific team departed for Turin. It goes without saying that the entire team is grateful to the Turin authorities for this opportunity to obtain and share scientific data on the Shroud.

This operations plan represents the fruit of all these labors. It has been designed so that our study of the Shroud can occur with the maximum amount of efficiency in the minimum amount of time.

GENERAL REMARKS IN THE USE OF THIS OPERATIONS PLAN

1. All team members should be familiar with the entire test plan prior to Monday, October 2, so that he (she) can best integrate their efforts into the overall effort.
2. The Operations Plan is organized into the following sections:
   a. General remarks by Team Coordinators.
   b. Description of the Grid Coordinate System to be used by all team members.
   c. Photograph of Shroud (front and back) with test locations indicated.
   d. List of Experimental Groups and Members.
   e. General Test Plan Organization.
   f. Specific Test Plan Descriptions.
   g. Individual Planning Calendar
3. Blank pages have been deliberately placed into the Operations Plan for the convenience of taking notes or making last minute alterations.
4. Please write your name on the upper right hand corner of the cover sheet of this book for easy identification if misplaced.
5. Please bring any inaccuracies in the Operations Plan to the immediate attention of the Team Coordinators, Eric Jumper or John Jackson.

General Remarks by Team Coordinators

Because of certain sensitivities of Turin and so as to not jeopardize the success of anyone's tests, all team members are asked to observe the following guidelines while in Turin.

1. Immediately upon arrival in Turin, press contacts are expected to be heavy. All team members are strongly requested to refrain from discussing anything regarding the tests and to kindly direct the press to Ken Stevenson. While in principle our tests are approved, final approval has been withheld pending discussions of Turin with our scientists, examination of our equipment and test procedures. We anticipate no problems, but please do not complicate our situation by granting interviews with the press or even give "innocent" information to reporters of any kind. Reporters can add two and two and come up with four as well as anyone.
2. Please do not show or discuss this operations plan to any unauthorized person.
3. Any problems of any kind should be directed immediately to the appropriate test group coordinator or to the team coordinators, John Jackson and Eric Jumper. Limited amounts of time require that all problems be solved as quickly as possible.
4. Discussions with Turin will be handled via the Holy Shroud Guild since this is the only body which the

Turin authorities know or recognize. A warm relationship with Turin has been developed by the Holy Shroud Guild over the past 25 years. Of course, no agreements will be made with Turin without the full knowledge and consent of the appropriate team members. Therefore, no team member need or should take it upon him (her)self to discuss specific problems with authorities in Turin.

5. All team members should avoid giving the impression that "the Americans have landed". Turin is very sensitive to this unfortunate American stereotype and this will be complicated by the fact that we are a large American group. Turin is the host and we are the guests.

6. While all of us are interested in seeing the sights of Turin and Europe, let us remember that our only reason for being in Turin is the Shroud. Thus, we should all arrange our schedules accordingly. (We anticipate that the first week, Monday through Friday, i.e. October 2 and 6 ,will be used in negotiations, setting up and dry running experiments; Saturday and Sunday i.e. October 7 and 8, the World Congress; and Monday i.e. October 9 through 12,testing.)

Perhaps these seem restricting, but we, the team coordinators, strongly believe that these are the necessary minimum for ensuring a successful test program in Turin. Accordingly, we wish all the team members success and we stand eager to help you in whatever way we can.

Coordinate System

It is important that all experiments, while referenced to the same 20 x 20cm coordinate grid attached to the test frame, use the same system of coordinates which is described herein.

The system will be Cartesian with the origin at the lower left hand corner as one normally looks at the Shroud mounted in the test frame. The y-axis is vertical, the x-axis horizontal. General coordinate labels will be marked on the Shroud frame while Specific (highly resolved) labels marked on the movable coordinate grid. To minimize error, letters will be used as General coordinate labels for the y-axis and numerals for the General coordinate labels of the x-axis. Numerals will be used, however, for both the x and y axes of the Specific coordinates on the moveable grid. Thus, as illustrated in the accompanying figure, the General coordinates designate the particular 20 x 20cm square, while the Specific coordinates designate the location of the point in question within that square. The notation to be used is shown for several points of the accompanying figure.

The locations of these points are written as follows:

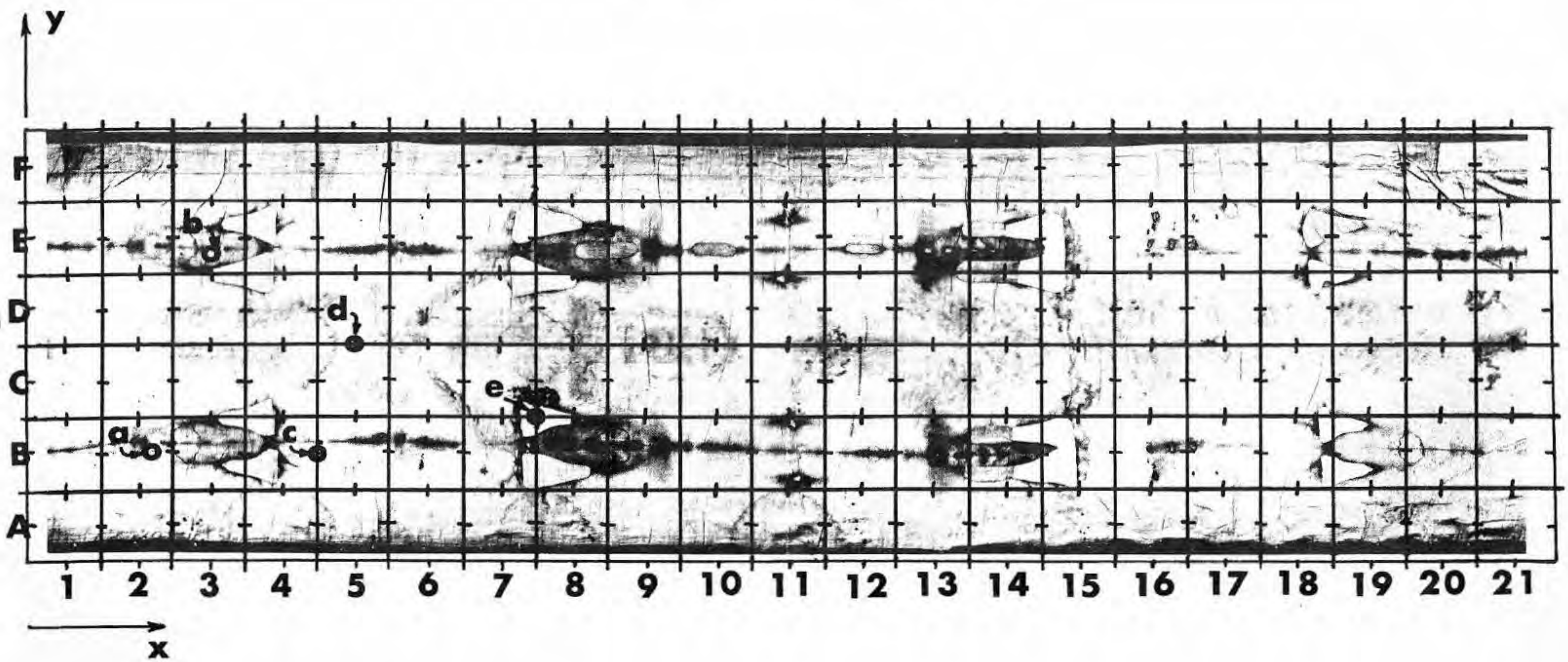
```
              specific x   specific y
              coord in cm  coord in cm
For point a     (2/15.0,  B/10.0)
                General   General
                x-coord.  y-coord.

    point b     (3/10.0, E/5.0)

    point c     (4/20.0, B/10.0)  or  (5/0.0, B/10.0)

    point d     (5/10.0, C/20.0)  or  (5/10.0,D/ 0.0)

    point e     (7/20.0, B/20.0)  or  (8/0.0, B/20.0)
            or  (7/20.0, C/0.0)   or  (8/0.0, C/0.0)
```

Coordinate System (cont.)

Page 2

Note that in some cases, there is an ambiguity as to notation, but these ambiguities are easily recognized by the appearance of 0.0 or 20.0 anywhere in the notation. All numbers shall be recorded to the nearest tenth of a centimeter (millimeter). All photo documentation should photograph this coordinate system and use this notation.

APPROXIMATE GRID PATTERN



Preselected Examination Points

The points selected are shown on the attached Figures labeled FRONT IMAGE and BACK IMAGE. All points are labeled starting from 1 on the front image and also starting from 1 on the back image; therefore, when refering to locations they should be refered to as FRONT 3A (or F3A) when refering to the fingers for example or BACK 1E (or B1E) for the ankle area.

The locations were carefully chosen in groups so that the change in reflectivity between the types of Shroud image can be compared. Each group has a spot in a clear area for control, a spot in a "blood" stain area, a spot in the body image area, and a spot in a scorched area. Note, for example, such groupings in the hand-wrist area on the front image and the foot and side area in the back image. Additional locations include spots on serum area, water marks and on the repair and backing cloths.

The description of the location points is as follows:

FRONT IMAGE

(identification number)

(1) Edge-Strip patch near bottom

(2) Thigh-level water mark

(3) Hand group
- a. Middle finger image
- b. Contrôl
- c. Light scorch to match density
- d. Dark scorch
- e. Blood on wrist

(4) Control below patch outside scorch area

(5) Red spot near patch

(6) Lance thrust group
    a. Intersection, blood/scorch
    b. Dark blood, lance entrance
    c. Serum area
    d. Control

(7) Scorch above patches
    a. Dark
    b. Light
    c. Control

(8) Face group
    a. Control outside face image near hair on way to left patch
    b. "3" mark, light part
    c. "3" mark, dark part
    d. right eye
    e. right cheek

(9) Wet/Dry controls above head
    a. Inside water mark
    b. Outside water mark
    c. At margin

<u>BACK IMAGE</u>

(identification number)

(1) Foot group
    a. Blood Flow
    b. Control near flow
    c. Scorch on same level to match density
    d. Heel of foot
    e. Calf/Ankle image area (non-contact)

(2) Side strip
    a. Side strip near seam (near old burn marks)
    b. Main cloth near seam

(3) Blood flow from side (near patch)
    a. Control
    b. Serum
    c. Blood
    d. Light-colored patch

(4) Scorch/Image intersection
    a. Heavy scorch

b. Light scorch in line
c. Intersection in line
d. Shoulder image (free of blood)

(5) Holland cloth backing

ADDITIONAL POINTS OF INTEREST NOT SHOWN ON EITHER THE FRONT OR BACK

(1) Dust from casket

(2) Spectrum after pull tape

(3) Right side of neck image-dry

(4) Calf blood/image-dry

The following areas are requested from the visible spectra equipment in support of the photographic experiment. Many of these are already labeled for testing.

1. Blood (3 or 4 measurements)
   Foot (rear, off body)
   Wrist (at wound)
   Head wound ("3" mark)
   Scourge mark on back

2. Body (6 measurements)
   Cheek (unbruised)
   Hand (right hand fingers)
   Off calf of back image
   Right low intensity image of clavical area
   Chest (off center right; above blood, high intensity area)
   Left Thigh (below right hand; low intensity area)

3. Lightly scorched area same intensity as corresponding body measurement (3 measurements)
   Near head measurement
   Near back off calf measurement
   Near hand measurement

4. Background (3 to 4 measurements)
   Head left
   Head right
   Near hand
   Anywhere on back image

5. Water (1 measurement)
   Area above with only water stain

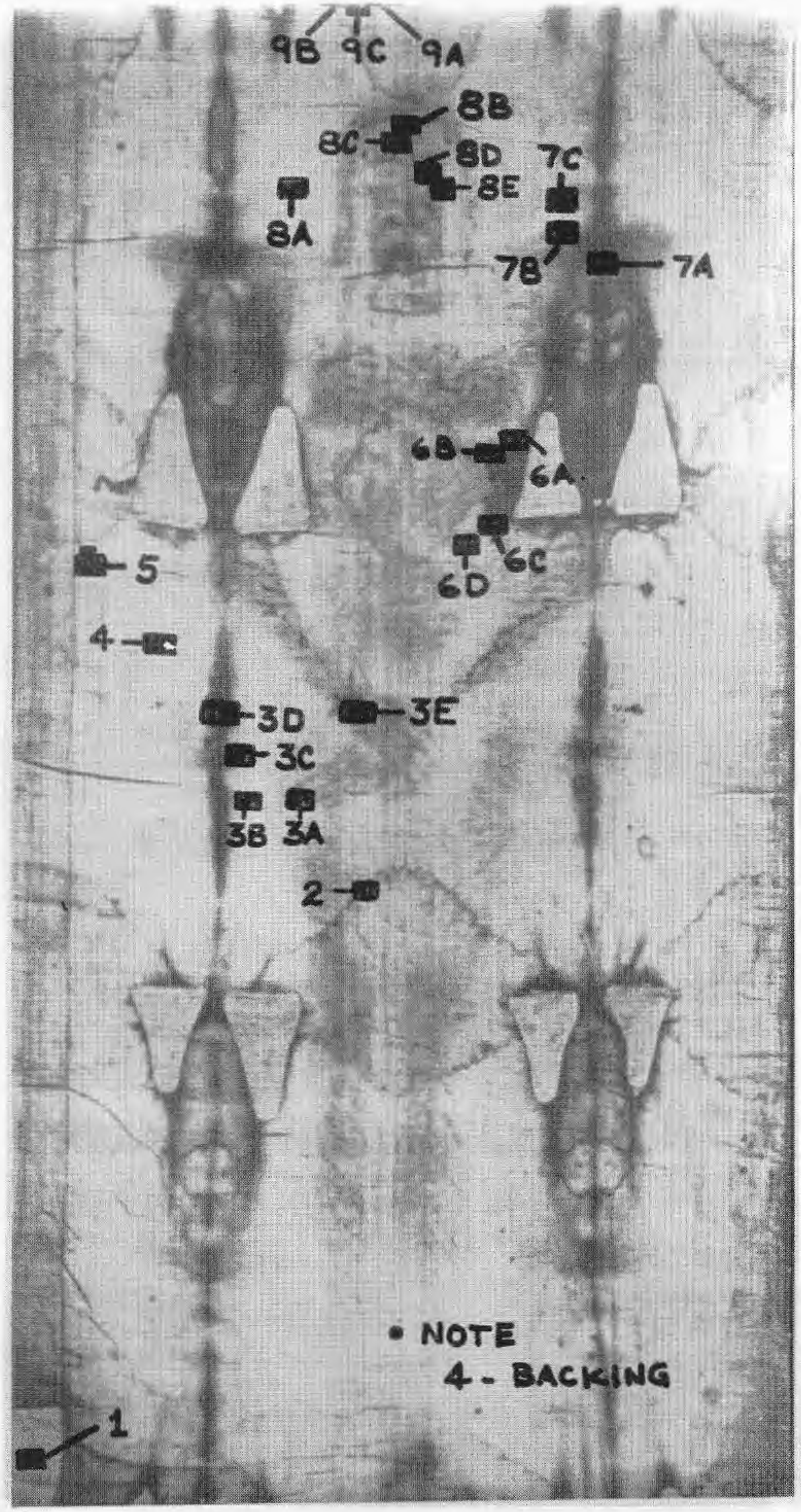
6. Deep scorch (3 measurements)
   Areas corresponding to light scorch measurements-maximum scorch without loss of cloth

Order of Priorities:

A. One of each class
   1. Blood/Foot (off-body)
   2. Body (Unbruised left cheek)
   3. Light scorch (closest to body measurement spatially and in intensity)
   4. Background (closest to light scorch measurement)
   5. Water Stain
   6. Heavy scorch (closest to light scorch measurement)

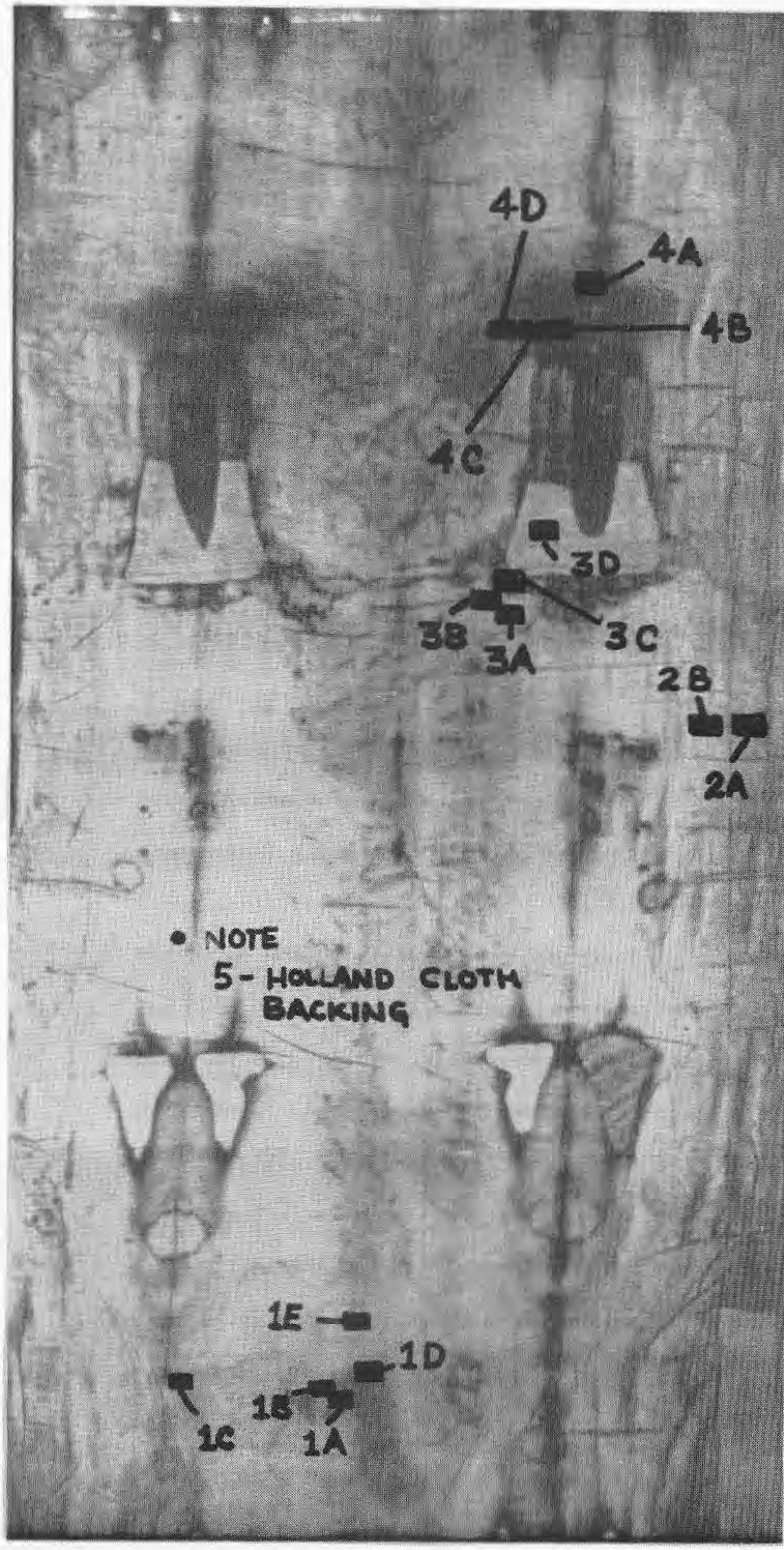
B. Three of each of the above

C. Rest


9B
9C
9A
8B
8C
8D
8E
7C
8A
7B
7A
6B
6A
5
6C
6D
4
3D
3E
3C
3B
3A
2
• NOTE
4 - BACKING
1

FRONT IMAGE

BACK IMAGE



4D
4A
4B
4C
3D
3C
3B
3A
2B
2A
• NOTE
5- HOLLAND CLOTH BACKING
1E
1D
1B
1C
1A

COMPOSITION OF UNITED STATES RESEARCH TEAM

Teams:

1. Coordination

1 John Jackson - Co-coordinator

2 Eric Jumper - Co-coordinator

2. Support

3 Tom D'Muhala - Logistics Support Coordinator

4 Rudy Dichtl - Electronic Equipment Maintenance Specialist

5 Dee German - Electronic Equipment Maintenance Specialist

6 Tom Dolle - Logistic Support Technician

7 Kay Jackson - Logistic Support Technician

8 Marge Jumper - Logistic Support Technician

9 Mary Stevenson - Logistic Support Technician

10 Patsy German - Logistic Support Technician

11 Joan Dichtl - Logistic Support Technician

3. Photographic / Computer Analysis and Enhancement

12 Don Devan - Photographic Test Coordinator

13 Don Lynn - Photographic Computer Analysis and Enhancement Specialist

14 Jean Lorre - Photographic Computer Analysis and Enhancement Specialist

15 Don Janney - Photographic Computer Analysis and Enhancement Specialist

16 Vern Miller - Head Photographer

17 Mark Evans - Assistant Photographer

33 ERNIE BROOKS

18 Sam Pellicori - Optical Engineer

19 Barrie Schwartz - Documenting Photographer

4. Tape Sample Analysis

20 Ray Rogers - Tape Sample Analysis Coordinator and Chemical Consultant

21 Bob Dinegar - Chemical Consultant

5. X-Ray Radiography

22 Bill Mottern - Radiographic Test Coordinator

23 Roger Morris - Radiographic Specialist

24 Joe Accetta - Radiographic Specialist

6. X-Ray Fluorescence

Roger Morris - X-Ray Fluorescence Test Coordinator

25 Ron London - X-Ray Fluorescence Equipment Specialist

Bill Mottern - X-Ray Fluorescence Specialist

7. Spectroscopy

26 Roger Gilbert - Spectroscopic Test Coordinator

27 Marty Gilbert - Assistant Spectroscopist

8. Infrared

Joe Accetta - Infrared Test Coordinator

28 Tom Haverty - Infrared Specialist

29 Steve Baumgart - Infrared Technician

9. Public Affairs

30 Kenneth Stevenson - Public Affairs Coordinator

10. Computational Support

31 Bob Ewing - Computer Specialist

32 David Bowman - Computer Specialist

The General Test Plan

The following table indicates the order in which the tests will proceed. (Notifications of any changes will be given as soon as possible.) The time for doing these tests has been allocated in the basic units of hours. In all cases, the amount of time allocated is slightly greater than or equal to the actual time indicated in the Special Test Plan descriptions. Setup and breakdown times (as indica- in the Special Test Plan) sometimes overlaps with the time allocated to other experiments. In that case, coordination should be made between adjacent groups where overlap must occur.

As time is expended by each test group, the hours may be checked off. Should it be necessary to rearrange the ordering of some tests, the hour numbers associated with the interchanged tests will remain the same and therefore the hour numbers will be checked off as they are accomplished. For example, suppose X-Ray Radiography (Block 2) and Photography (Block 2) were for some reason interchanged. This would only mean that hours 28-33 would be performed before hours 21-27. If an experiment were lengthened, we would consider the last hour as being repeated several times; if one is shortened, the remaining hours would be automatically be checked off. For example, if X-Ray Radiography (Block 1) were given two extra hours, rather than try to shift all subsequent experiments down two hours, we would simply repeat hour 8 twice and annotate the test plan accordingly. If X-Ray Fluorescence (Block 3) was finished 3 hours early, hours 70, 71, and 72 would automatically be checked off and an indication that this was done recorded on the test plan. Prior to testing, a system will be arranged so that those not involved in a particular test will know what time it is according to our "General Test Plan Clock." The team coordinators, Eric and John will always have the "correct time."

However, all experimentors should plan on being given <u>only</u> the time allocated and at the time indicated unless advised otherwise by Eric or John. No one should, therefore, automatically assume that additional time will be given, for it is imperative that all groups be given a fair chance to collect data during the time constraints by which we must operate. However, it should be pointed out that 15 hours may be utilized at the end of the testing (under the direction of the team coordinators.)

Turin authorities have determined that only those necessary for a given test will be allowed in the test room at any given time. The number of personnel required from our team is therefore indicated on the General Test Plan. This isn't meant to get us into a "numbers game", but to serve as a reminder that access to the testing room is a sensitive issue with Turin.

Finally, we should expect to work round the clock so as not to leave the Shroud in "suspended annimation". Notice that we will have compressed over two 40 hour work weeks into the span of only 96 hours by the time we are finished.

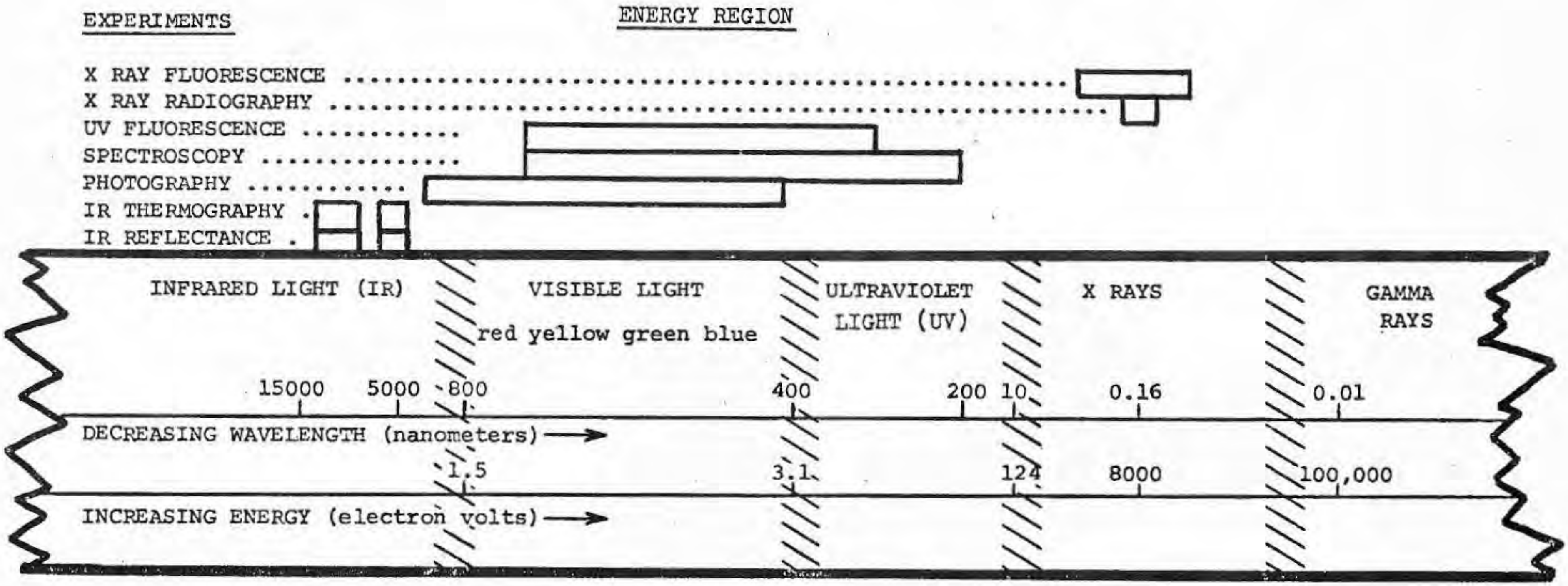
GENERAL TEST PLAN

Hour		Test Group	Number Personnel Required	Time Allocated Hours	Remarks
Begin	1				
	2				4 1/2 hours
	3	Photography	8	6	photo-mosiac
	4	(Block 1)			
	5				1 1/2 hours
	6				spectral coverage
	7	X-Ray Radiography	7	2	Preliminary test
	8	(Block 1)			exposures taken
	9				
	10	X-Ray Fluorescence	6	4	foot blood
	11	(Block 1)			
	12				
	13	Infrared (Block 1)	6	1	I-R Photos test exposure
	14				
	15	Spectroscopy (Block 1)			Infrared reflectance
	16				follows Spectroscopy
	17	Infrared (Block 2)	10	7	(reflectance and UV
	18				fluorescence) location
	19	Tape (Block 1)			by location
	20				Tape samples collected
	21				
	22				Complete
	23	X-Ray Radiography	7	7	X-Ray Radiographic
	24	(Block 2)			coverage
	25				
	26				
	27				
	28				
	29				3 1/2 hour close-up
	30	Photography	8	6	
	31	(Block 2)			2 1/2 hour spectral
	32				coverage
	33				
	34				
	35				
	36				
	37	X-Ray Fluorescence	6	10	Fingers and Face
	38	(Block 2)			blood
	39				
	40				
	41				
	42				
	43				
	44	Infrared	6	2	Thermographic test
	45	(Block 3)			exposures
	46				
	47	Infrared	6	3	Infrared photographs
	48	(Block 4)			

GENERAL TEST PLAN

Hour	Test Group	Number Personnel Required	Time Allocated Hours	Remarks
Continued 49				
50	Spectroscopy (Block 2)			Infrared reflectance
51				follows spectroscopy
52	Infrared (Block 5)	10	7	(reflectance and UV
53				fluorescence)
54	Tape (Block 2)			location by location
55				Tape samples collected
56				
57				Microphotographs
58	Photography	8	6	Stereophotographs
59	(Block 3)			Rear Surface Photographs
60				(2 hours apiece)
61				
62				
63				
64				
65				Face scan and watermarks
66	X-Ray Fluorescence	6	11	
67	(Block 3)			Other areas as time
68				permits
69				
70				
71				
72				
73				
74				
75				
76				
77	Infrared (Block 6)	6	9	Thermography
78				
79				
80				
81				
82				
83				
84				
85				
86				
87				
88	To be determined			
89	based on results		15	
90	obtained			
91				
92				
93				
94				
95				
96				

average number of United States scientists around Shroud = 7.25 ± 1.50



THE ELECTROMAGNETIC SPECTRUM

This diagram shows where the various Shroud experiments are located in the electromagnetic energy spectrum, and demonstrates how we are extending our visibility into normally "invisible" regions of the spectrum.

TEST PLAN FOR: ELECTRONIC MAINTENANCE

GROUP COORDINATOR: J. DEE GERMAN

TEAM MEMBERS: PATSY S. GERMAN

RUDOLPH J. DICHTL

JOAN L. DICHTL

BACKGROUND AND BASIC THEORY:

To ensure that all groups are supplied with proper power and to maintain all equipment in good working order.

BASIC PLAN:

1. Upon arrival, Rudy, Joan, and an Italian electrician will get the Elgar power supplies hooked up and working. Available power will consist of:

a. 220-volt, single phase, 14-amp, 60 cycle (i.e.Standard American 220) and 115-volt, single phase, 14-amp, 60 cycle (Standard American 115) power anywhere in the test room.

b. 230-volt, single phase, 7-amp, 50 cycle "dirty" (Standard Italian wall outlet) power in room.

c. Two separate 115-volt American circuits in set-up room for equipment check-out and repair.

2. Rudy, Joan, Dee and Patsy (Starting Oct. 5) will be available for general electrical/electronic set-up, repair and parts procurement.

SPECIAL NEEDS:

Besides the aforementioned electrical power, we need:

1. A room as close to the Shroud test room as possible, on the same floor level, with 2 standard European electrical wall outlets for equipment set-up and repair. This room should have a cot.

2. We need to be able to reach someone who knows where to obtain electrical/electronic parts; preferably someone who speaks English.

TEST PLAN FOR: PHOTOGRAPHY

GROUP COORDINATOR: DON DEVAN

TEAM MEMBERS: DONALD J. LYNN

JEAN J. LORRE

VERNON MILLER

BARRIE M. SCHWARTZ

ERNEST H. BROOKS, II

MARK EVANS

SAM PELLICORI

BACKGROUND AND BASIC THEORY:

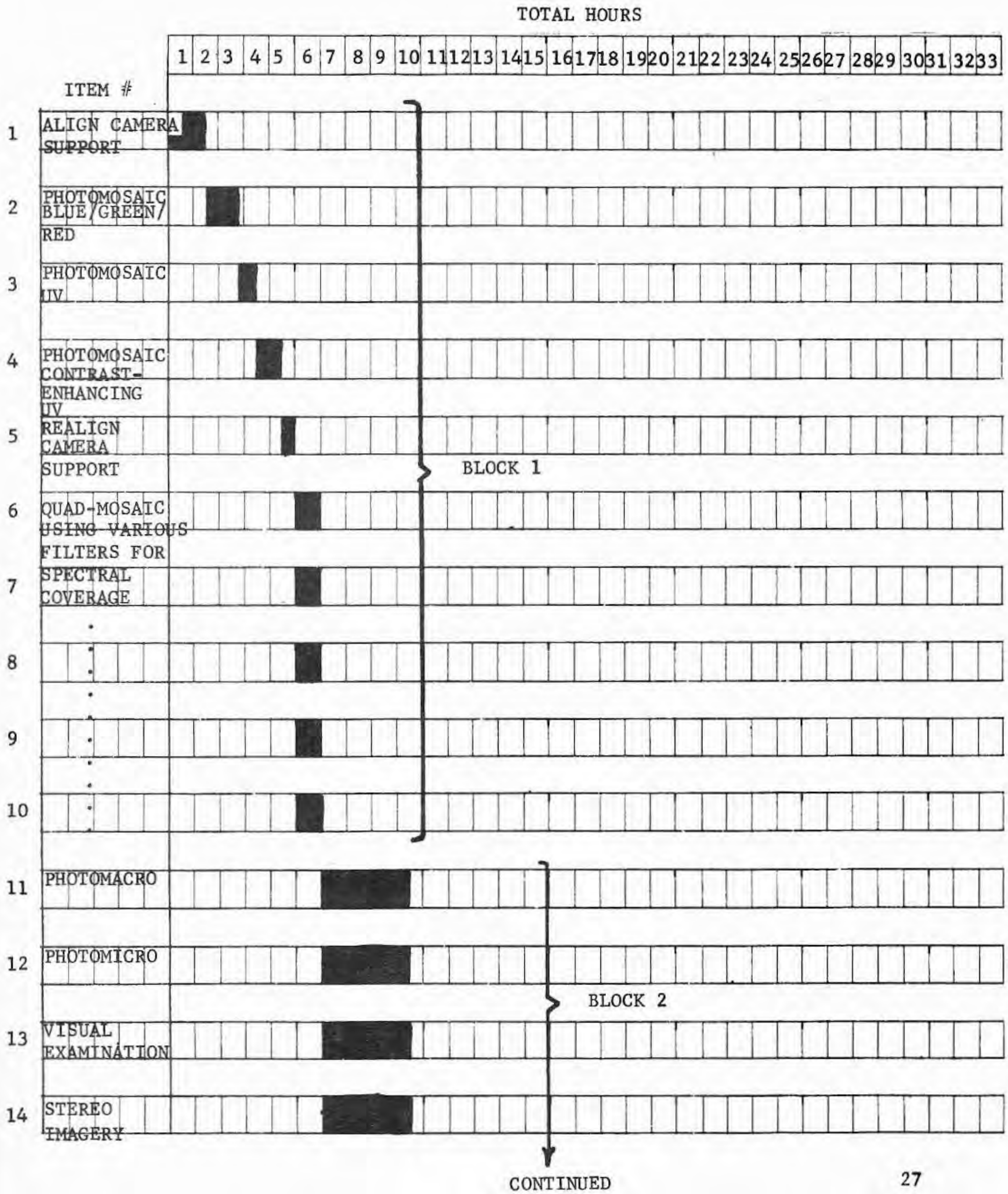
Three major photographic experiments will be performed: (1) Photomosaic coverage (5.6:1 reduction) will cover the entire Shroud with enough spatial detail to permit computer weave removal and detailed feature analysis. Filtration will be: (a) blue/green/red color separation; (b) UV-reflected for contrast enhancement; (c) UV-transmission over light sources/ UV-blocking over lens for UV-fluorescence. Film: Kodak SO-115; camera/lens: Hasselblad/150mm; lights: Norman 200 strobes (2 units providing crossed-field illumination).

(2) Photomacro/micrography. Photomacrography will provide approximately 3:1 enlargement of specific areas of interest so that details of fibers can be seen. SO-115 film will permit total enlargements on the order of 100X. Filtration will be gels (blue or green) over Sun-Pak strobes to provide contrast enhancement. Camera/lens: Beseler TOPCON/TOPCOR (microscope objective). Micrography will be obtained with Wild microscope with 35mm camera attachment.

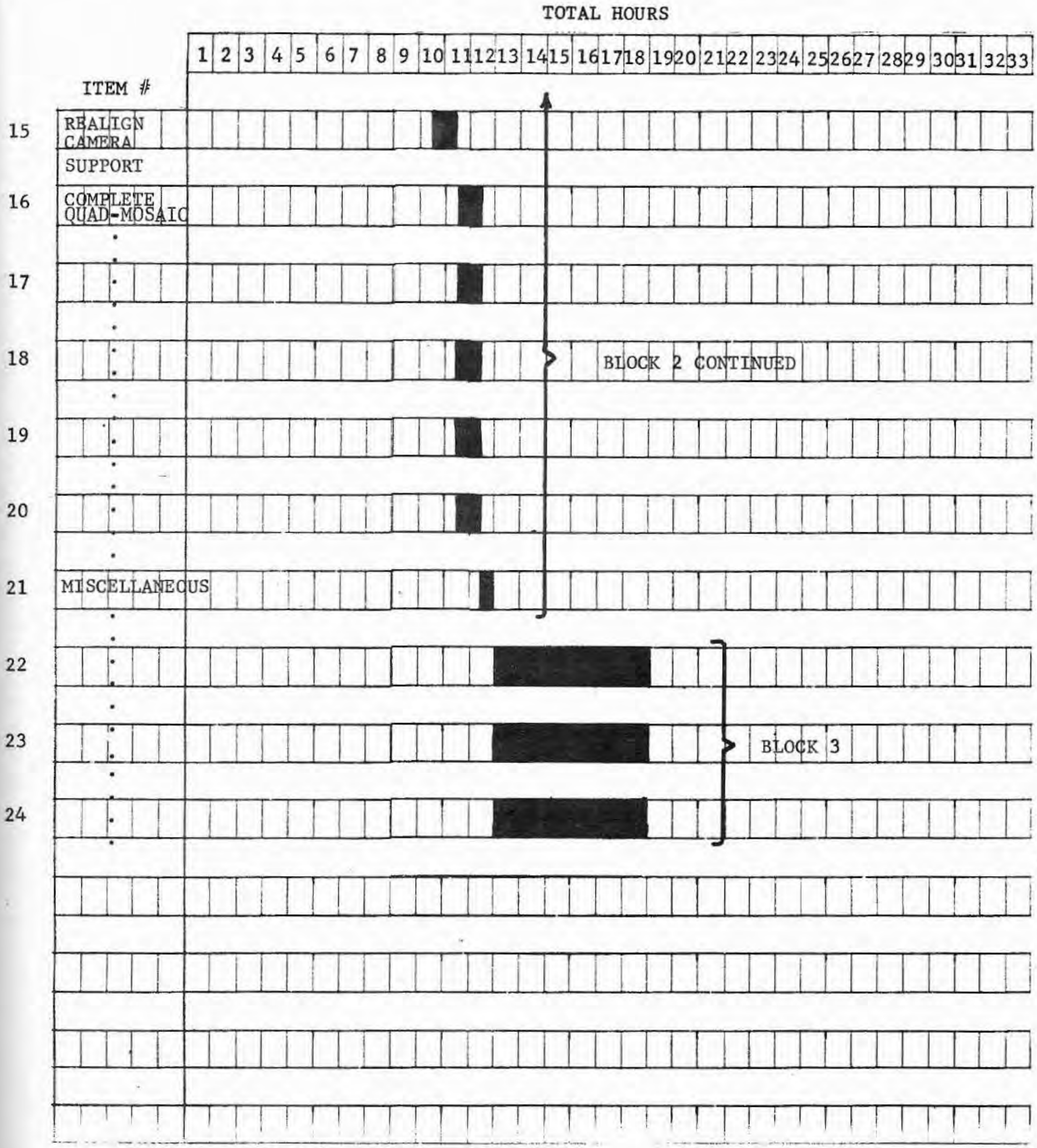
(3) Spectrally-resolved quad-mosaic photography (~ 22:1 reduction - each image will cover a 4'x 4' region on the Shroud). Filtration will be: (1) B/G/R color separation; (2) narrow band (~ 100 A°) spaced over visible spectrum; (3) unfiltered.

(4) Miscellaneous coverages: (a) portable digital spectrometer readings of features of interest using a circularly variable interference filter spectrometer with a silicon photodiode sensor and digital volt meter readout. (b) Binocular (opthalmic) microsc^pe (10-100 X) for visual examination. (c) Stereo imaging system for analysis of directional dependence of Shroud coloration. (d) Fiber optics examination and photography of rear surface of Shroud.

OPERATION PLAN TIME TABLE FOR PHOTOGRAPHY



PHOTOGRAPHY CONTINUED



VERBAL DESCRIPTION BY ITEM #

Item 1:

Align camera support rail with Shroud frame so that image plane is everywhere as parallel as possible with surface of Shroud. This entails measuring the distance from the Shroud frame to the camera rail at the four corners of the Shroud and ensuring that both the Shroud frame and the camera support are level both horizontally and vertically.

Item 2:

Obtain photomosaic images using blue/green/red color separation filters. Each image will cover a square region 31-32cm on a side on the Shroud surface. Images will be spaced 30 cm apart so that there will be a 1-2 cm overlap for registration purposes. Lens focal length = 150mm; film will be Kodak SO-115; image reduction factor will be $\sim$ 5.6:1. Images will be taken with each filter (B/G/R) before camera is moved to the next position. Lighting will be with 2 Norman 200 strobes affixed to the camera support.

Item 3:

Obtain photomosaic using UV fluorescence setup. Geometry, lens and film will be the same as Item 2. Light source will be filtered by UV-transmitting liquid filter cells and filter glass (improved version of "Woods" glass) which pass light only in the

Verbal description by item #

Page 2

Item 3 (cont.):

waveband from 330-360 mm. Lens will be covered with a UV blocking filter to eliminate exposure due to reflected UV.

Item 4:

Obtain photomosaic using contrast-enhancing UV filter. Set will be the same as Item 2. Filter passes reflected UV (centered around 386.5 mm) which provides enhanced image contrast.

Item 5:

Realign camera support rail for quad-mosaic (spectral coverage) geometry. The rail will be moved back; lens will be changed to 80 mm. Full image will cover a region about 4' on a side of the Shroud.

Items 6 - 10:

Obtain quad-mosaic spectral images using: (1) various narrow band spectral filters; (2) B/G/R color separation filters; (3) no filter. Each mosaic will require about 12 minutes; thus the first 5 (of an estimated 10 mosaics) will bring the time (from the start of Item 1) up to six hours, after which the X-ray radiography will begin (under the 3-4 day plan).

Verbal description by item #

Page 3

Item 11:

Obtain photomacrographic images of regions where spectra have been taken with Oriel spectrometer. Macrographs will be made with Beseler TOPCON camera and TOPCOR lens (microscope objective). Enlargement will be 3:1 --- a region on the Shroud $\sim$ 8 x 12mm in extent is imaged onto a 35mm frame (25.4 x 38mm). Enlargements on the order of 30 - 40 X can be made from the 35mm images on SO-115 film with no significant loss due to film grain. Thus, overall enlargements on the order of 100 X are available.

Item 12:

Obtain photomicrographs of regions where spectra have been taken. Micrographs will be obtained using a Wild microscope / 35mm camera attachment. 3-50X zoom capability is provided with this system.

Item 13:

Visual examination. A binocular (opthalmic) microscope will be available to allow visual examination of the Shroud. Several objective lens will be available to permit magnifications in the range from $\sim$ 10-100 X. (Color film will be used to document regions of interest through 35mm camera adapter).

Item 14:

Stereo - imagery. A stereo imaging system will be available consisting of a 35mm camera on a pivot arrangement which will permit photography of the same image region from 2 angles (in consecutive photographs). About 1:1 magnification is obtained. Stereo viewing is accomplished by projecting image pairs (from 2 projectors) through crossed-polarizing filters and viewing the overlapped projections through crossed-polarized glasses.

Item 15:

Realign camera support system for continuation of quad-mosaic coverage. Note that the macro/micro coverages (Items 11 - 14) listed above are scheduled just after the spectrometer/tape experiments. This will enable those experimenters to place small magnetic "push pins" over the regions they have measured so that the photomicrography can cover exactly the same regions. Just before the close-up coverage, the entire Shroud will be photographed for documentary purposes so that the location of the "push pins" is recorded. (The "pins" will, of course, be removed pri^r to the continuation of the quad-mosaic [spectral] experiment).

Items 16 - 20:

Completion of quad-mosaic spectral coverage. Any spectral

Verbal description by item #

Page 5

Items 16 - 20 (cont.):

filters not used during the coverage described under Items 5 - 10 will be used during this period.

Item 21:

Miscellaneous. A small block of time is available for miscellaneous experiments or to complete or recheck portions of previous experiments if necessary. Fiber optics boroscope examination of the rear of the Shroud could be performed during this period. 1/30 sec @ f 1.4

TEST PLAN FOR: X-RADIOGRAPHY

GROUP COORDINATOR: R. WILLIAM MOTTERN

TEAM MEMBERS: J. RONALD LONDON

ROGER A. MORRIS

Radiation Monitoring Technician (to be named)

BACKGROUND AND BASIC THEORY:

The attenuation of x-ray photons follow the fundamental equation:

$$I = I_o e^{-aX}$$

Where I = Intensity of the transmitted x-ray beam.

I_o = Intensity of the incident beam.

e = base of natural logarithim 2.718....

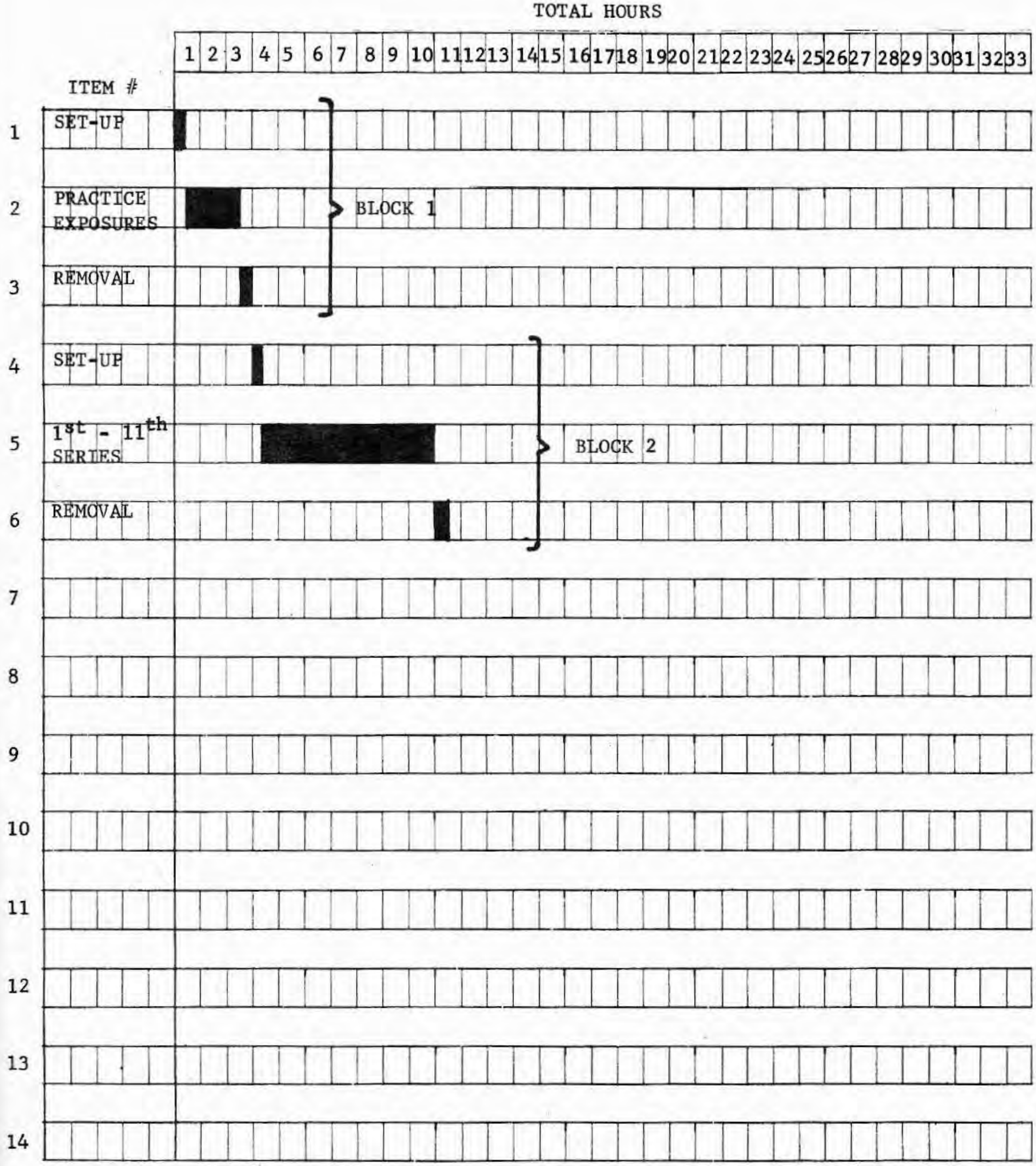
a = linear absorption coefficient.

x = thickness (material), cm.

After the incident x-ray beam passes thru the material where it has been reduced in intensity (attenuated) by absorption, it interacts (exposes) film in proportion to the intensity. Where the intensity is low (high absorption) the film is lightly exposed. Where the beam is more intense the film will be dark. This differential absorption is then interpreted (or measured) to reveal details of the material.

The linear absorption coefficient, a, is a function of both the density and atomic number of the absorbing material.

OPERATION PLAN TIME TABLE FOR X-RADIOGRAPHY



VERBAL DESCRIPTION BY ITEM #:

Item 1: Equipment Set-up.

Only set-up required is to connect power supply and water source.

Items 2 and 3:

Procedure:

The x-ray source will be set up to two meters from the Shroud. A panel will be removed from the area to be x-rayed. One or two film packets (35cm x 42cm) will be suspended behind the Shroud and in line with the source. The packets, each containing one Type R and one Type M, will be attached to panels on either side of the opening. Identification will be written on the front (Shroud) side on the paper envelope. This identification will be recorded on the film by the x-rays at the time of exposure. The size of the x-ray beam will be confined to the film area by suitable shielding.

Exposures will be taken along a vertical line and each encompassing approximately 40cm x 40cm area. Three such exposures will be taken along each line. The system will then be indexed 40cms (either left or right) and a series of three will then be repeated. Thus, 11 series of three exposures will be made (total 33). At the beginning and after each series, an exposure will be made of a pair of control films. Attached to the packet of the controls will be a reference object made of cellulose paper (filter paper) in the form of steps of different thickness.

Items 2 and 3 (cont.)

The exposed films will be developed, dried and their densities measured prior to development of the Shroud films. This will be to check the consistency of film development.

All films after development and drying and each having a unique identification will be stored in paper envelopes appropriately marked. Interpretation by qualified radiographers will be performed in the U.S. Duplicate copies (1:1) will be made as needed for use by the evaluators, the original retained as archival films.

Safety Procedures:

To provide maximum safety to personnel, procedures will be established to confine the x-ray beam to the minimum size necessary to expose film, to control the activities of a personnel in the area, and to monitor the radiation levels in the area.

Prior to the test, mapping of the radiation levels will be performed and based on the results, barricades will be installed. Prior to activating the x-ray equipment, one or more warning beacons, will be turned on. Upon termination of an exposure, the beacons will be turned off.

Personnel, other than team members, wishing to enter the vicinity will be instructed in the safety procedures, sign a log book and in some cases, provided a dosimeter. Readings from the

Items 2 and 3 (cont.)

dosimeter will be recorded upon entry and again on departure, thus providing a record of exposures.

The Radiation Monitoring Technician will be responsible for:

1. Assisting in the radiation area monitoring.
2. Periodic survey of area.
3. Maintenance of log.
4. Issuance and retrieval of dosimeters.
5. Safety instruction of visitors (casuals).

TEST PLAN FOR: X-RAY FLUORESCENCE

GROUP COORDINATOR: ROGER A. MORRIS

TEAM MEMBERS: J. RONALD LONDON

R. WILLIAM MOTTERN

JOSEPH S. ACCETTA

BACKGROUND AND BASIC THEORY:

X-ray fluorescence analysis is capable of producing quantitative estimates of the elemental content of an unknown sample by exciting characteristic x-rays and measuring their intensities. In the case of the Shroud, however, the experimental conditions preclude any attempt to make true quantitative judgements. Accordingly, the experimental plan will emphasize the measurement of the experimental precision and the production of qualitative results.

The priority list of areas to be inspected is (in order of priority):

1. Blood stain on the foot, dorsal image (see tape plan).
2. Control area near #1 (5 samples).
3. Vertical scan through image of fingers on right hand (9 samples).
4. Control area near #3 (10 samples).
5. Blood stain on face (3 mark).
6. Control area near #5.

Prior to starting this series of data, the equipment will be calibrated and the repeatability will be measured. A standard object consisting of Cu, Mo and Ti will be counted 10 times by removing and replacing the object between counts. From this data, the precision by which the object (Shroud) can be positioned will be judged.

The purpose for including control areas in the priority list should be obvious. Each control point will be counted a minimum of three times at slightly different points ($<$ 1.0cm shift) to measure the variability of the object's elemental content over a nominally uniform area.

The blood on the foot will be counted the same way as a control point. This point (#1) will be compared with the face blood data (#5) to see if one of them (#5) has been retouched by some unknown "artist".

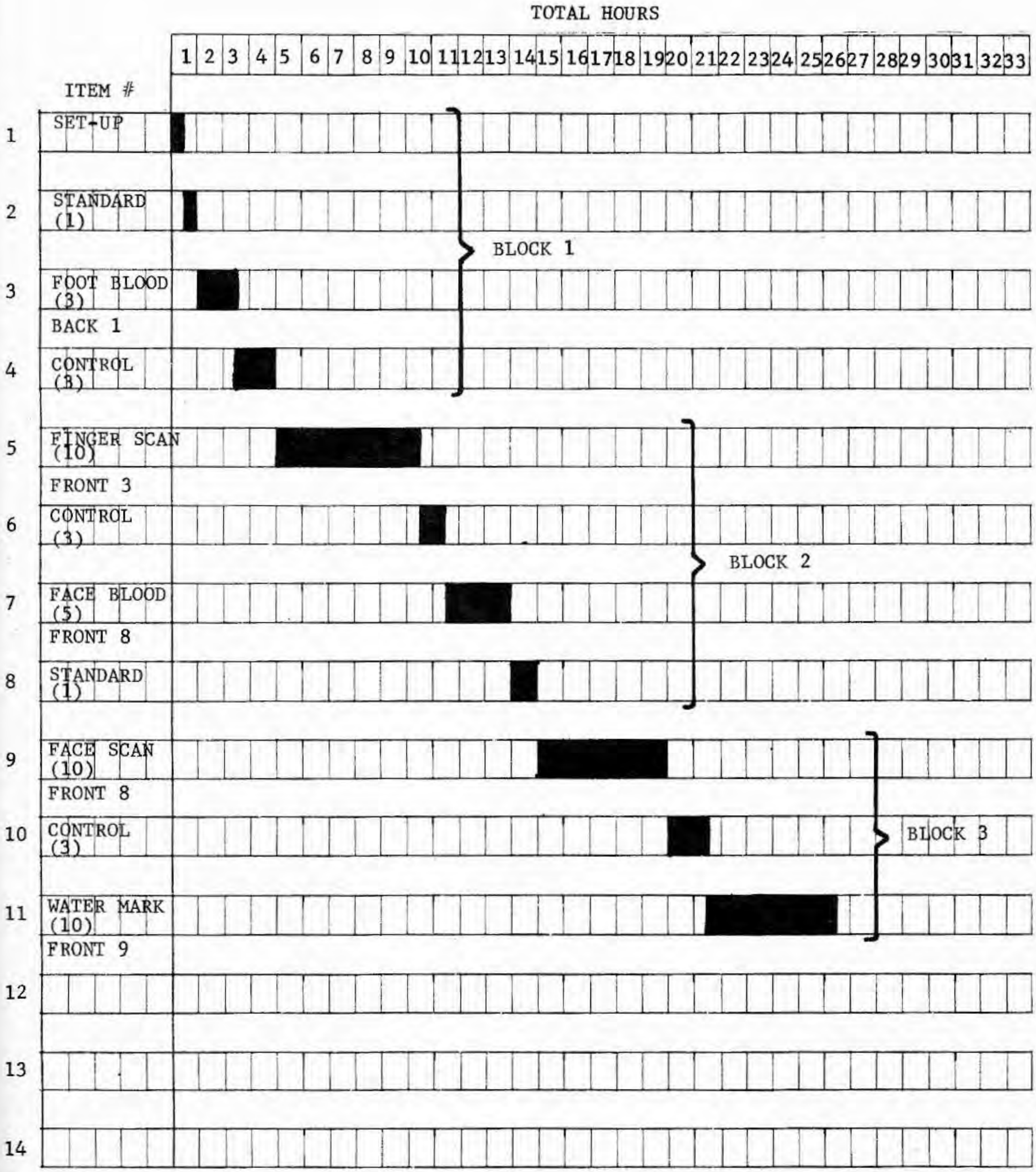
Scan #3 is designed to collect data over a wide range of image intensities. The results will be correlated with the image intensity and significant correlation noted. The scan will be parallel with the long dimension of the cloth which will be (or should be) roughly parallel to the isotherms produced in the 1532 fire.

All of the areas scanned (image as well as control points) will also be covered by the UV scanner and the tape, the other sampling tests. Radiography, IR and visible photography are all 100% samples and hence automatically cover the x-ray fluorescence.

If time permits, other points and lines will be scanned. The exact areas will depend on the results obtained in scans

#1 through #6 as well as the results obtained by the other experimentors.

OPERATION PLAN TIME TABLE FOR X-RAY FLUORESCENCE



VERBAL DESCRIPTION BY ITEM #:

Item 1: Set-up

Set-up involves mounting the collimators, detector and source on the tripod and making all electrical connections with the source and detector.

All other items:

Since the only significant difference between any of the items is only the area being investigated, they will all be described together:

a. Alignment

The exciting x-ray beam ($\sim$ 25KeV Sn K_α line) will cover an area on the Shroud about 7.5cm in diameter when the Shroud is 8cm from the collimator face. The detector collimator permits radiation from a 5cm circle (8mm collimator) or 2.5cm circle (4mm collimator) to enter the detector.

The assembly will be moved by hand until the detector is centered in front of the desired area. A flexible plastic rule will be used to accurately position the assembly. Photo documentation of each position will be made.

b. Data Collection

The x-ray source will be operated at 50 PKV, 20 ma, for the duration of the test. The ADC will be set for 1024 channels and the memory will also be set to 1024. The lower level discriminator will be set to just eliminate the low energy noise. The ADC

Verbal Description by Item #:

Page 2

All other items: (cont.)

will operate in the PHA mode counting for a pre-set line time. The time will be determined in Turin and will be sufficient to insure precise results.

c. Data Storage

After the spectra is collected, it will be visually checked on the PHA CRT for obvious errors, photographed, transmitted to a cassette, transmitted back to the PHA, visually compared to the first photograph, and finally transmitted again to a different cassette. In this fashion, the correctness of the data as stored on the first cassette can be checked and a duplicate tape made. The spectra photo will be used only for the notebook.

A notebook will be maintained that lists:

1. The Shroud coordinates of every spectra stored.
2. Starting tape coordinate of the spectra.
3. Photo of set-up.
4. Photo of spectra.
5. Narrative description of location on Shroud.
6. Comments.
7. Signatures.

Special Considerations

The irradiation source is a 50 PKV X-ray tube and emits potentially dangerous x-rays. Accordingly, the number of people

Verbal Description by Item #:

Page 3

Special Considerations (cont.)

in the room will be kept to an absolute minimum. The experimental crew will consist of:

1. Team Coordinator - maintains the notebook and insures that the set-up is properly placed and safe.
2. X-ray Operator - operates the equipment and assists in the set-up.
3. Health Physics - Sole duty is to monitor the radiation field.
4. Photographer - Documents the experiment photographically.

See the radiographic procedure for more details.

TEST PLAN FOR: INFRARED

GROUP COORDINATOR: JOSEPH S. ACCETTA

TEAM MEMBERS: TOM W. HAVERTY

J. STEPHEN BAUMGART

BACKGROUND AND BASIC THEORY:

Infrared investigations deal with a property of all matter usually referred to a thermal radiation - that is, all objects radiate energy over a wide range of wavelengths. The integrated total energy over all wavelengths is usually expressed by the modified Stefan-Boltzmann law for real bodies

$$E = \varepsilon \sigma T^4$$

where E is the emissive power in watts/cm^2

σ is the Stefan-Boltzmann constant

T is the absolute temperature in °K

ε is the emissivity

The quantity ε expresses the emission efficiency of a radiating body compared to a perfect emitter (a black body).

The radiation properties are intimately connected with the absorption quality of a surface. If an incident radiant intensity I shines on a surface, the energy is either reflected, transmitted or absorbed. This can be expressed mathematically by the sum of the reflected fraction of the energy plus the transmitted fraction plus the absorbed fraction being exactly equal to the energy striking the surface or

$$\rho I + \tau I + \alpha I = I$$

where ρ is the reflectivity

τ is the transmissivity

α is the absorptivity

Thus,

$$\rho + \tau + \alpha = 1$$

and this relationship also holds for a given wavelength, λ ,

$$\rho_\lambda + \tau_\lambda + \alpha_\lambda = 1$$

Further, if the surface is opaque or nontransmitting, then τ is zero and we have

$$\rho_\lambda + \alpha_\lambda = 1$$

Further, for a given wavelength $\alpha_\lambda = \varepsilon_\lambda$ so that

$$\rho_\lambda + \varepsilon_\lambda = 1$$

In order, then, to determine either the reflectivity or emissivity of an opaque surface we need only measure the one or the other.

While emission characteristics are not extremely distinct for given solid material, by looking at several aspects of the surface characteristics in the infrared, some information might be obtained.

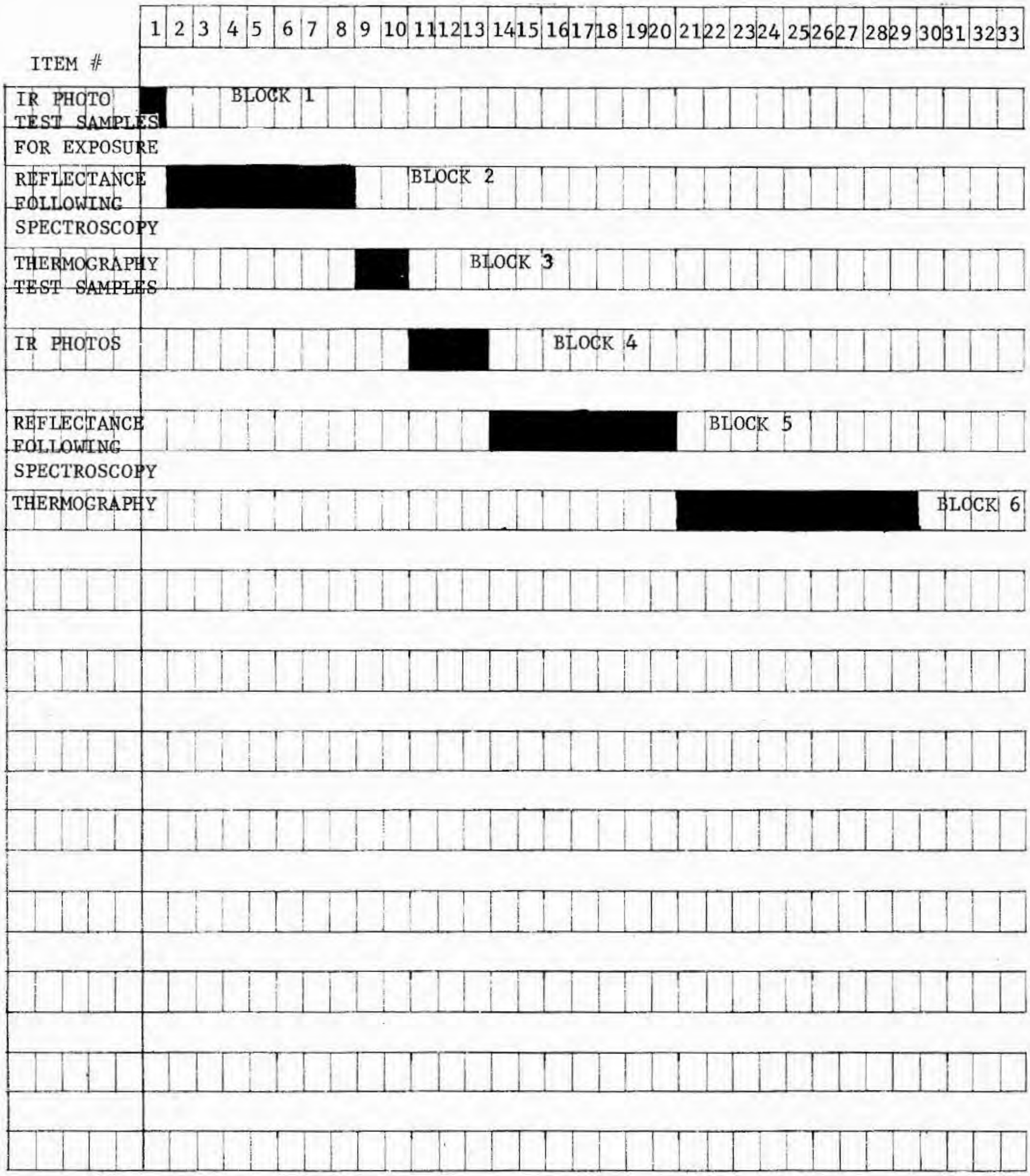
This test is made up of several parts, each designed to detect information about the infrared radiation characteristics of the Shroud surface and possible changes due to the presence of the Shroud image. The first test is designed to simply extend the photographic work into the near infrared region. By selecting the lighting and selectively filtering the radiation returning to the camera, we intend to image the Shroud in the wavelengths from approximately 0.73 microns (just above visible) to about 2.5 microns (the cut off wavelength of the camera lens). We intend then to look at the integrated reflectance of the Shroud image in this waveband. This technique has been used extensively to pick up images which are not present in the visible, enhance images which have experienced fading in the visible and detect images which have been attempted to be removed. In addition, some infrared fluorescence may be found. There is some hope that this information will be useful in determining the chemical composition of the image.

The second type of test is designed to map the reflectance of the image, ρ_λ , as a function of wavelength in the regions from 3 to 5 microns and from 8 to 14 microns. In so doing, according to the relations mentioned previously, we will obtain the emissivity information of the image and background cloth.

Finally, the integrated emissivity pattern will be examined in the 3 to 5 and 8 to 14 micron region to see if any images are present on the cloth in the far infrared, well beyond the capability of the eye.

OPERATION PLAN TIME TABLE FOR INFRARED

TOTAL HOURS



VERBAL DESCRIPTION BY ITEM #

Items 1 and 4:

Special procedure for infrared photography experiments in the areas of Reflection, Transmission, Stimulated Emission (fluorescence), and Film Processing.

REFLECTION (This test to be run in conjuction with photographic tests)

a. Make final exposure and focus tests on actual target in the 4x4 mode, the 30 cm x 30 cm mode, and the macro mode.

b. Energy source to be same strobes as used in photo tests except filtered.

c. Filters to be Wratten 89B (700nm), Wratten 87C (800nm), and Wratten 88A (730nm) (87C and 88A to be dropped at discression of test director) Wratten 12 to be used with color IR.

d. Camera to be suitable 35mm with 35mm and 100mm macro lenses.

e. Film to be used Kodak Hi Speed Infrared HIE 135 - 20 and Kodak Infrared Ektachrome IE 135 - 20.

f. Focus correction:
focus thru Wratten 61 filter - value G
focus thru Wratten 29 filter - value R
IR focus = IR = R+ 2(R-G) for apochromat lenses
IR focus = IR = R+ 2.8(R-G) for achromatic lenses

g. Exposure base line:
HIE film and 89B filter use guide number of 100
HIE film and 88A filter use guide number of 85
HIE film and 87C filter use guide number of 70
IE film and 12 filter use guide number of 200

h. Grid coverage to be same as in photo tests, see photo test plan for details.
4x4 grid
30x30 cm grid and macro

TRANSMISSION (this test to be run at the end of the first photo test)

a. Using 4x4 grid system photograph using strobes (filtered) on the backside of the target with back pannels removed.

b. Exposure index to be 1/10 th of reflection exposure for a baseline.

Transmission c. (cont.)

c. HIE film and 89B, 87C, and 88A filters
IE film and 12 filter

STIMULATED EMISSION

Blue green light: to be run with photo tests.

a. 4x4 grid mode in standard photo set up.

b. HIE film and 89B filter.

c.Two 500 watt spot lights with Corning glass 8780 and 3966 filters.

d.Focus correction as in IR 4x4 grid.

e. Exposure: six minutes at f/5.6.

f. During this test and all emission tests extreme care must be taken to exclude stray IR light from camera.

Ultra violet: to be run with uv fluorescence tests.

a. 4x4 grid mode in standard photo set up.

b. HIE film and 89B filter.

c. uv lamps used in uv fluorscence tests.

d. Focus correction as in IR 4x4 grid.

e. Exposure: six minutes at f/5.6.

f. During this test and all emission tests extreme care must be taken to exclude all stray IR light from camera.

X-ray emission: to be run with x-ray fluoescence test.

a. 4x4 grid mode in standard photo set up.

b. HIE film and 89B filter.

c. X-ray source used in x-ray emission test.

d. Focus correction as in IR 4x4 grid.

e. Exposure: six minutes at f/5.6.

X-ray emission f. (cont.)

f. During this test and all emission tests extreme care must be taken to exclude all stray IR light from camera.

g. Camera should be shielded with lead foil to prevent x-ray fogging.

h. This test to be done at the discression of the x-ray safety officer and with his complete control, with the understanding that the IR personel are not familar with x-ray dangers.

FILM PROCESSING

a. Preliminary test films will be processed immediately after exposure for evaluation necessary for focus and exposure data.

b. HIE film to be processed in for 11 minutes in D76 developer at 20°c. or 3 ft/min. in Versamat processer and Versaflo developer.

c. Darkroom to be checked by allowing an open roll of film (HIE). to remain exposed for 30 minutes and then processed and examined for signs of fogging. Processer will also be checked by running an unexposed roll of HIE film thru at the slowest possible speed.

THIS TEST TO BE DONE PRIOR TO ANY FILM HANDLING

d. IE film to be processed in process EA5 or if not available E4.

e. All IR film will be shipped in lead foil bags, and kept at 4°C. or colder.

TEST PLAN FOR: TAPE EXPERIMENT

GROUP COORDINATOR: RAYMOND N. ROGERS

TEAM MEMBERS: ROBERT H. DINEGAR

MARY A. STEVENSON

BACKGROUND AND BASIC THEORY:

Objective: To obtain minute samples of surface coloration to be used for chemical analysis.

Method: Apply chemically inert adhesive tape to surface of cloth in carefully controlled manner (with a pressure sensitive roller). Withdraw with adhering surface sample. Adhesive is pure hydrocarbon - inert, non-corrosive.

Analysis: Since adhesive is hydrocarbon, it will not produce confusing background during chemical analyses; therefore,

(a) surfaces can be analyzed by electron spin resonance (observing free radicals);

(b) by electron spectroscopy (observing chemical bond types);

(c) by scanning electron microscopy (observing color-body structure and elemental composition); and

(d) by ion microprobe (observing chemical composition).

OPERATION PLAN TIME TABLE FOR TAPE SAMPLE ANALYSIS

TOTAL HOURS

	ITEM #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	SAMPLING					BLOCK 1																												
2	SAMPLING							BLOCK 2																										
3																																		
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TEST PLAN FOR: ULTRAVIOLET - VISIBLE SPECTROSCOPY

GROUP COORDINATOR: ROGER GILBERT, JR.

TEAM MEMBER: MARTY GILBERT

BACKGROUND AND BASIC THEORY:

The objectives of these tests are to obtain ultraviolet-visible reflectance spectra and ultraviolet fluorescence spectra to aid the analysis of substances found on various parts of the Shroud, especially the body image, blood and serum stains and water marks. The reflectance spectra will also support the spectral photographic work.

DESCRIPTION OF TESTS ON THE SHROUD:

At each of thirty spots on the Shroud, we will obtain a plot of reflectance vs. wavelength in the ultraviolet and visible spectral regions from 250 to 750 nanometers. We will also measure fluorescence vs. wavelength using both 365 nm and 248 nm ultraviolet excitation. For the reflectance measurements, white light from a xenon lamp illuminates the entrance slit of a monochromator which divides the beam into its spectrum and produces monochromatic light (light of a single color or wavelength) at the exit slit. The monochromatic exit beam is focused onto a small 3 by 5mm spot on the Shroud. The light, reflected from the Shroud, travels through a second monochromator and then to a photomultiplier detector.

The monochromators are then scanned in unison through the spectrum from 250 nm in the ultraviolet through the visible region from 400 to 700 nm to the 750 nm in the near infrared. The wavelength is electronically displayed on the horizontal (or X) axis of an X-Y recorder. The reflected light level measured by the photomultiplier is fed to the vertical (or Y) axis. As the monochromators are scanned, a plot of relative reflectance vs. wavelength is obtained.

While doing fluorescence measurements, a mercury lamp is used. The monochromator on the light source side is fixed at either 365 nm or 248 nm in the ultraviolet. This "excitation" ultraviolet energy is absorbed by the cloth causing the cloth to "fluoresce" or to emit longer wavelength visible light. The monochromator on the detector side will be scanned to obtain a spectral plot of this fluorescence.

CHOICE OF SPOTS AND INTENDED INTERPRETATION OF DATA:

Spots have been chosen in groups so that the change in reflectivity between the types of Shroud surface can be compared. Each group has a spot in a clear area for control, a spot in a "blood stain" area, a spot in the body image area, and a spot in a scorched area.

These groups are located at the hand-wrist area and face area on the front image and the foot and side area in the rear image. In addition, we will be measuring spots on serum area, the water marks and on the repair and backing cloths.

By comparing the reflectivities of the image stain, blood stain and scorched areas with that of the clear area, we can produce approximate plots of absorption of the stains themselves. These can be compared with similar spectral data on known compounds and on known pigments and coloring agents. The reflectivity of image and blood stains can also be compared with that of the scorched areas.

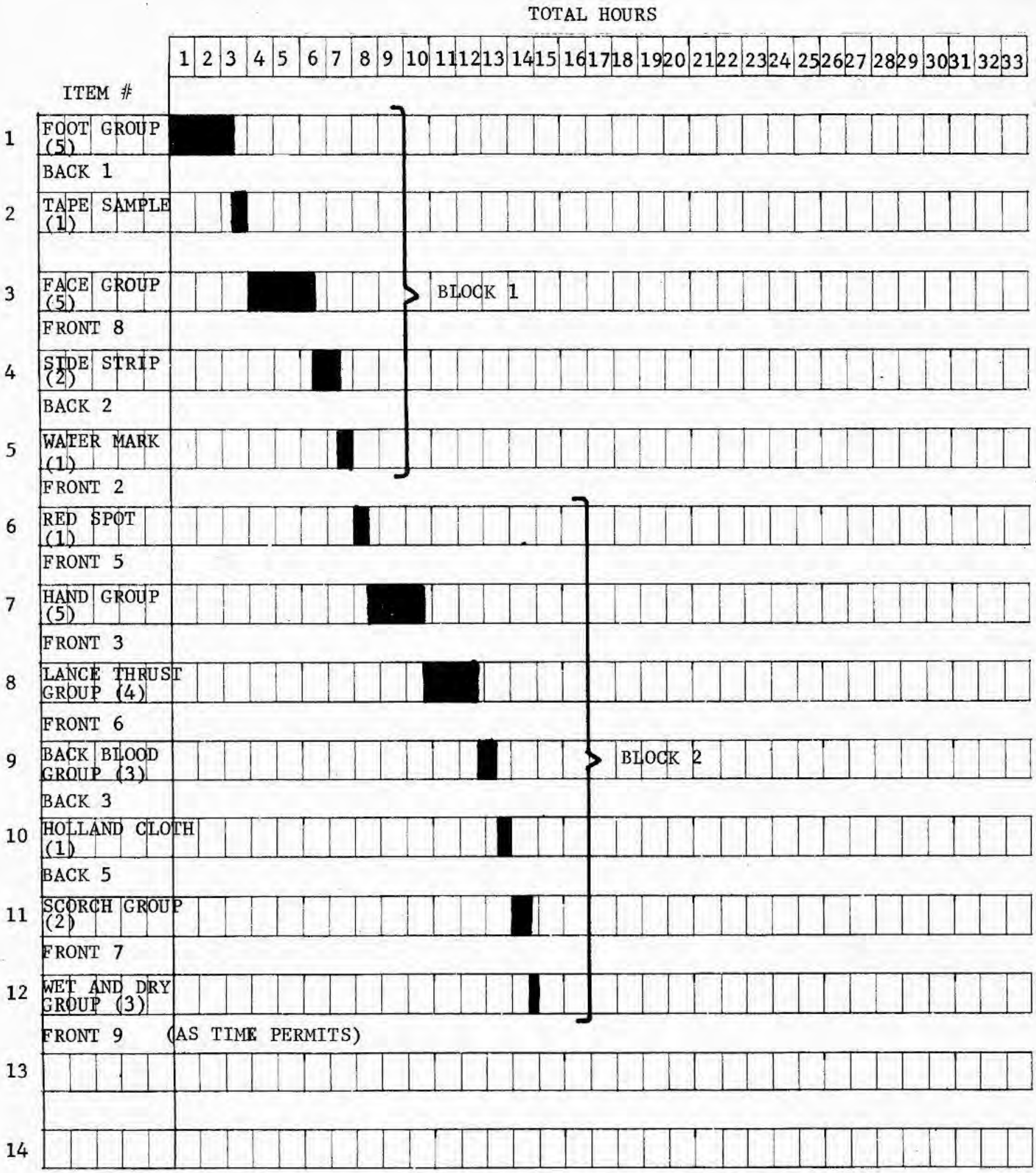
The spectral plots of the clear areas as well as the backing and repair cloths will be compared to a magnesium oxide reference for possible future comparison with other known cloths. The fluorescence spectra will be corrected for spectral variances within the measuring instrument and replotted. These corrected spectral plots can then be compared with those of known compounds pigments and coloring agents. Again, we can compare the image and blood stain fluorescence with that of the scorched area.

SAFETY CONSIDERATIONS:

In this measurement, the maximum power incident on the Shroud on the 3 x 5mm spot is less than 1 milliwatt (one thousandth of a watt). This corresponds to approximately 7% of the total irradiance from the sun. This should produce a temperature rise on the cloth of less than 1°C.

The possibility of ultraviolet degradation has been investigated by subjecting a test linen cloth with a dyed area and a scorched area and a clear area to an accelerated test. Exposures at 248 and 365 nm of fifty times the maximum that will be used during these tests produced no discernable damage to the test cloth.

OPERATION PLAN TIME TABLE FOR ULTRAVIOLET - VISIBLE SPECTROSCOPY



VERBAL DESCRIPTION BY ITEM #

ALL ITEMS:

Spectral scans of reflectivity from 250 - 750 nm and of fluorescence using both 365 and 248 nm excitation will be made on 30 points on the Shroud (15 points on the one day plan).

Present plans call for performing the reflectivity scans on groups of 5 - 7 spots then converting the instrument to the fluorescence mode and doing fluorescence scans on the same group. This will necessitate two setups for each spot. We are now investigating a fast conversion which will allow us to do reflectivity and fluorescence on the same spot without moving the instrument. Each reflectivity scan including setup should take approximately 10 minutes. Each fluorescence scan series (i.e. both at 248 and 365 nm) will take approximately 12 minutes. All 30 spots will take 660 minutes or 11 hours. 15 spots will take 5.5 hours. A copy of the list of spots by Shroud location and the operation plan time table showing spots in initial order of priority is attached.

ELECTRICAL REQUIREMENTS:

If possible, we would like 110 volts - 60 Hz at 12 amperes from one power converter and an additional 6 amperes from another. We may have two lamp power supplies going at the same time. Being SCR regulated, they do feed some spikes back into the line which may interfere with other equipment on at the same time.

Perhaps if we had one power converter for our use only during our test period, the other group operating with us could use the other converter.

In a pinch, we could operate directly from the 220V 50 Hz line, but with more risk. (Only one of our two recorders operates at 50 Hz).

PHOTOGRAPHIC REQUIREMENTS:

We would like documentation photographs of each setup showing the illuminated spot on the Shroud.

We will have either 30 or 60 setups depending on whether we can quick convert between reflectance and fluorescence or not. This will be cut to 15 or 30 setups on a one day plan.