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THE MEASUREMENT OF DIFFUSE REFLECTANCE OF PIG SKIN, TITANIUM DIOXIDE PAINT AND INDIA INK; THE TRANSMITTANCE OF TITANIUM DIOXIDE AND INDIA INK.

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ABSTRACT

Diffuse reflectance measurements were made on the bare skin of Chester White pigs and also on TiO_2 paint and India ink painted on the skin. The wavelength region from 0.4 μ to 2.6 μ was investigated. Transmittance studies were also made on these coatings of TiO_2 and India ink in the same wavelength range.

For this study it was necessary to construct a spherical type integrating reflectometer which was an improvement over previous equipment.

INTRODUCTION

In the study of the effect of TiO_2 paint and India ink (1) on the 50% effective radiant exposure on 2+ and 4+ burns on Chester White pigs, it became necessary to know not only the total reflectance of pig skin to the 24 inch carbon arc burning source, but also the total transmittance and reflectance of the TiO_2 paint and India ink. It is the purpose of this investigation to determine these reflectances and transmittances. The method for finding the reflectance consisted of comparing the deflections resulting from energy diffusely reflected from a sample of known reflectance and from an unknown sample; in order to find the transmittance, the deflections resulting from passing energy through a substance painted with the cream of interest and the substance alone were compared. In order to accomplish this, it was necessary to construct an integrating sphere reflectometer because the Coblentz type reflectometer (2) used previously did not lend itself to finding the reflectance of pig skin on the side of a pig and because there were certain inherent errors in the latter type of reflectometer.

The above data will be used (1) to evaluate the severity of burns as a function of transmittance and reflectance.

METHODS AND MATERIALS

All of the equipment used, except the integrating sphere and electrostatic depositor, has been described in detail previously (2). A block diagram of the equipment appears in Fig. 1. Light from the source S was focussed on the entrance slit of the Perkin-Elmer model 83 monochromator by means of two spherical mirrors M_1 and M_2. The monochromatic radiation passing through

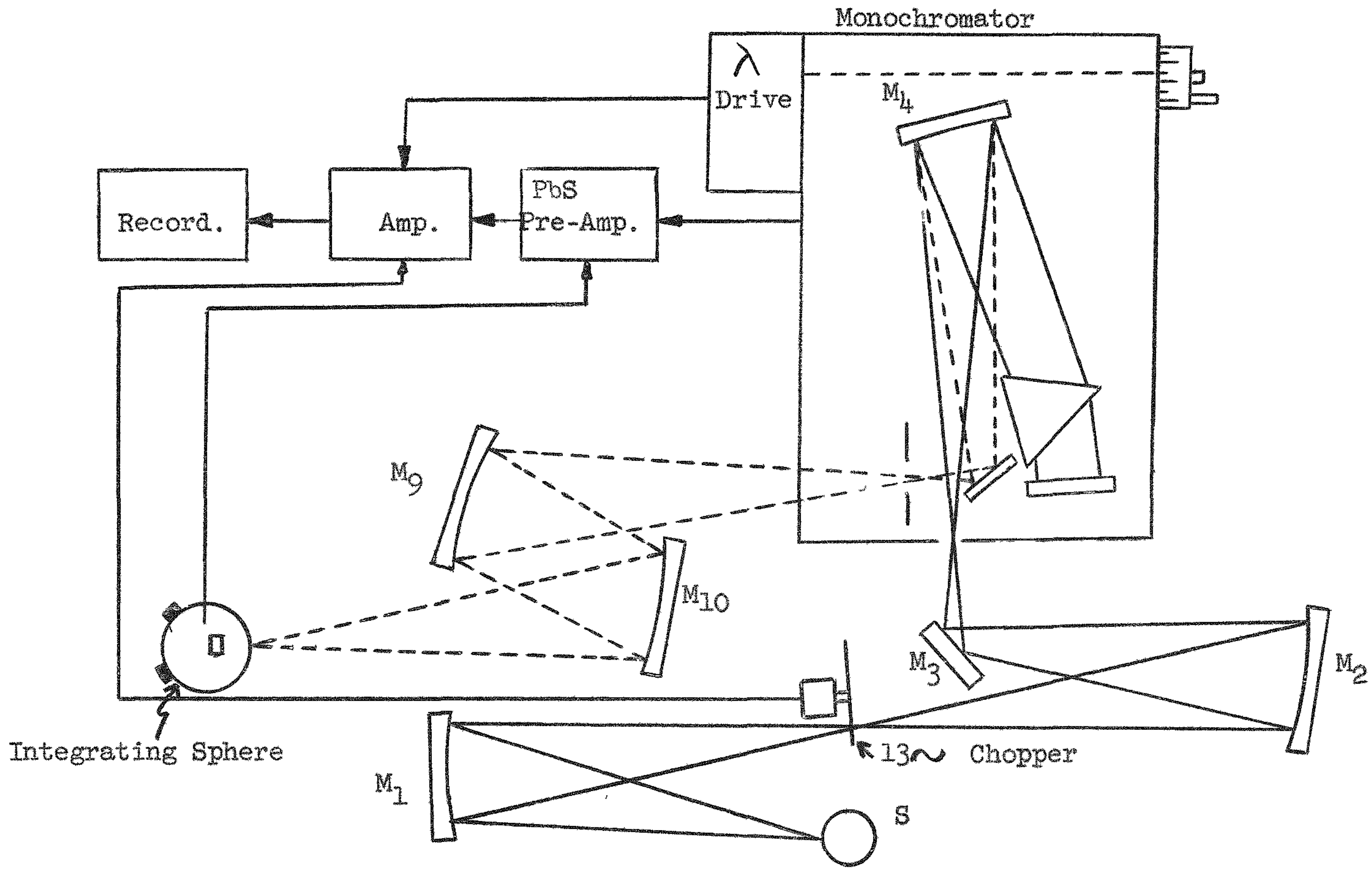

Figure 1

REFLECTOMETER BLOCK DIAGRAM

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the exit slit of the monochromator was focussed on the sample, the reflectance of which was to be found, by means of two off-axis parabolic mirrors M_3 and M_4. In the case of the transmittance measurements, the sample was placed in front of the entrance port of the integrating sphere and monochromatic radiation was passed through.

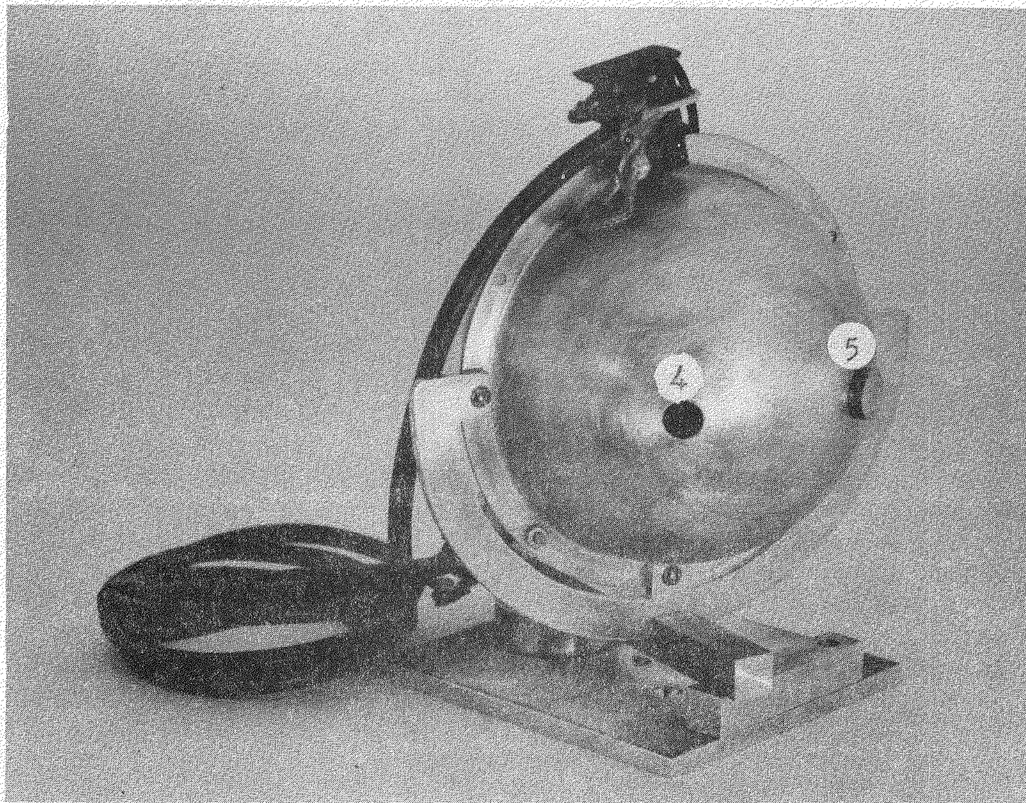
In previous studies utilizing a hemispherical mirror type reflectometer (2), it was found that the high reflectivity of the PbS receiver resulted in an inherent error in the reflectivity measurements. Work is now in progress to develop a relatively black cavity type PbS cell. Meanwhile, it was decided to fabricate an integrating sphere type reflectometer as suggested by Jacquez et al (3). The construction of the sphere was based on the theoretical conclusions of Jacquez and Kuppenheim (4).

The spherical integrator was made up of two hemispheres spun from 1/32 inch 24 ST aluminum sheet. The hemispheres had 5/16 inch wide flanges so that they could be joined to form a sphere 4-1/2 inch in diameter. A 3/4 inch entrance port was located at the apex of one of the hemispheres; further, a sample and standard port, .420 inch in diameter and subtending an angle of 30° at the entrance port, were located on the other hemisphere as shown in Figs. 2 and 3. A receiver window, for a 10 mm Ektron detector, was located in the entrance port hemisphere as shown in the above figures. The sphere mount was made so that the sphere could be rotated about a vertical axis through the center of the entrance port. The mount could index the sphere so that radiant energy entering the sphere would be incident on either the sample or standard port.

Because the thickness of the coat of paint, and thus its reflectance, varied from application to application, a method was devised to standardize

FIGURE 2

1. Entrance Port
2. PbS Cell (Ektron Detector)
3. Sphere Mount
4. Sample Port
5. Sample Port with MgO Standard Plug Inserted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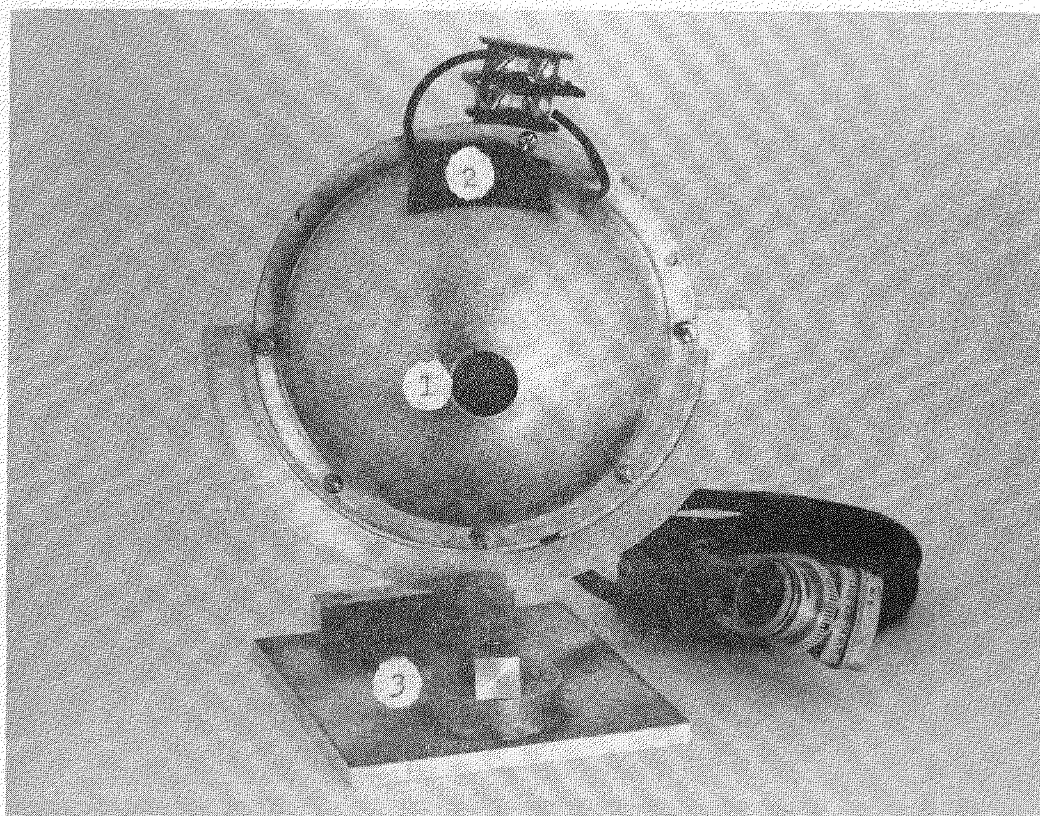
2
1
3

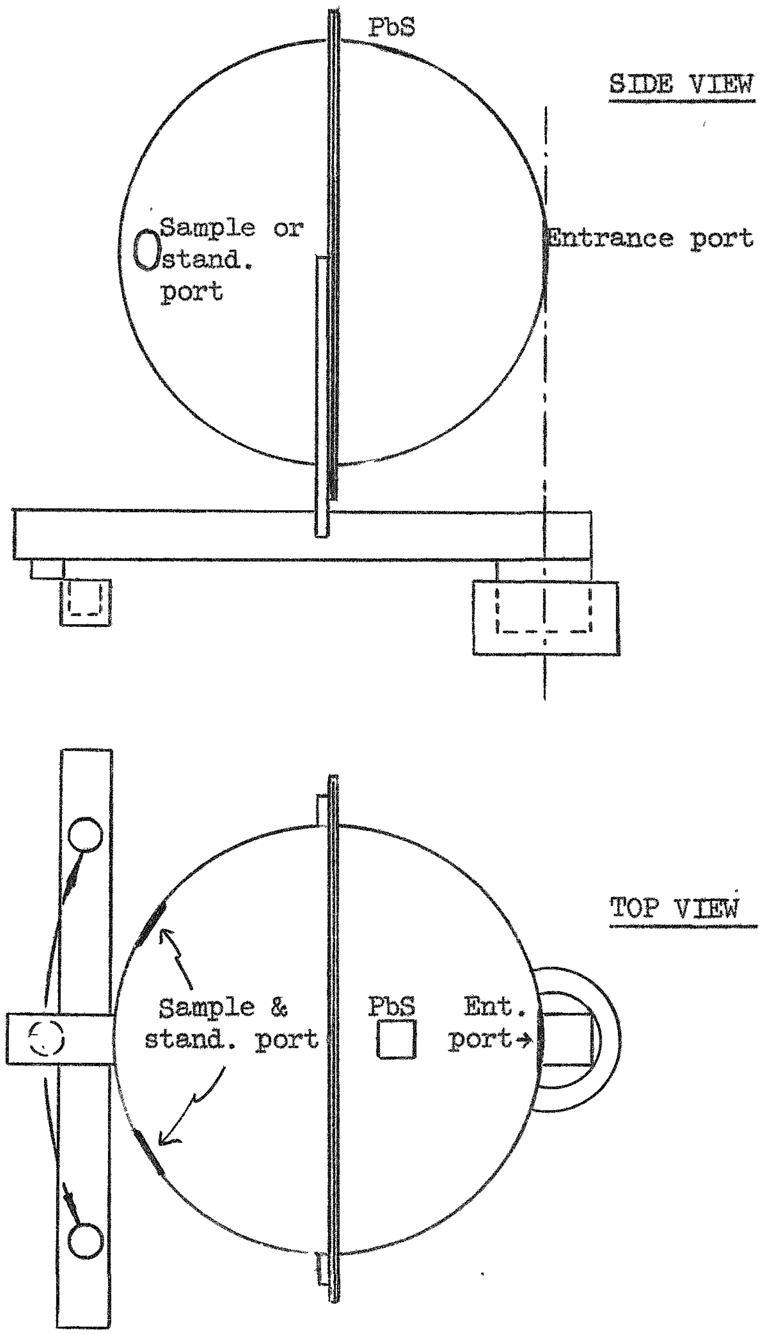

Figure 3

INTEGRATING SPHERE

the thickness within arbitrary limits. A tungsten light source was placed about 6 inches from the painted spot on the side of the pig at about a 20° angle of incidence. A Photronic cell was placed at the same distance on the normal to the surface. The source and the cell were in a housing which restricted the illumination on the side of the pig to a 3/4 inch circle. The voltage across the cell developed by the light reflected from the painted spot, was measured with a self balancing potentiometer. A standard piece of white paper was placed over the aperture and a rheostat across the lamp adjusted until the potentiometer registered a given deflection. The aperture was then placed over the painted spot and the coating accepted only if the deflection of the potentiometer fell within chosen limits.

With the unknown sample in place at one of the ports and a standard MgO coated sample (5) in place at the other, monochromatic radiation was focussed on either of the ports. A run was then made through the spectrum from .4 μ to 2.6 μ, the procedure being repeated after indexing the sphere, for the radiation incident on the other port. At a given wavelength, the ratio of the deflection resulting from irradiation at the unknown sample to that for the standard sample was the reflectance of the sample at that particular wavelength.

In the transmittance measurements, the two sample ports were filled with MgO samples and a piece of thin excised pig skin was placed over the entrance port of the sphere. A run was made between .4 μ and 2.6 μ. The excised skin was then painted in turn with the TiO_2 paint and the India ink and identical runs made, the ratios at a given wavelength between the deflections resulting with a paint to that of just the skin alone gave the transmittance of the paint at a given wavelength.

The transmittance of the paints were also determined by painting them on a base of quartz and a base of Aeroplast* instead of on excised skin. The Aeroplast was sprayed over a 2 inch by 2 inch area of a live pig according to the directions on the dispenser. After drying, the piece was pulled off. It was found that the under portion had the same topography as that of the pig skin.

The two paints investigated were titanium dioxide ** and India ink. The India ink was a commercial brand with a few drops of detergent added so that it would wet the surface of the skin.

The total reflectance to the spectral distribution of the 24 inch carbon arc was found between .4 μ and 2.6 μ by

$$\frac{\sum_{.4\,\mu}^{2.6\,\mu} r_\lambda \; J_\lambda \; \Delta\lambda}{\sum_{.4\,\mu}^{2.6\,\mu} J_\lambda \; \Delta\lambda}$$

where r_λ = Spectral reflectance of sample at given wavelength

J_λ = Relative spectral energy distribution of 24 inch arc.

The same expression holds for the total transmittance with r_λ replaced by t_λ .

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* Aeroplast - A liquid surgical dressing made by Aeroplast Corporation.

** TiO_2	9 Gms.
H_2O	7.5 cc.
"Joy"	(a commercial liquid detergent) 6 drops
Glycerol	4.5 cc.

Because it is very difficult to deposit a uniform coating of MgO on a large surface such as the inside of the integrating sphere, a system used by Tellex and Waldron (6) was used. A schematic diagram is shown in Fig. 4. In general, the procedure consists in applying a dc potential of about 6000 v between the hemisphere to be coated and a nichrome wire gauze on which burning magnesium is placed. By using this method of electrostatic deposition, very uniform coatings of MgO of about 1 mm thickness were obtained.

RESULTS

A summary of the reflectance and transmittance data are given in Table 1. All of the total reflectances and transmittances shown are for the spectral distribution of the 24 inch carbon arc used in this laboratory (7). The first four reflectances were taken on one pig on the same spot and the next four were made at different points on another pig's side.

Fig. 5 represents an average curve of spectral reflectance versus wavelength for bare, unpainted pig skin. Figs. 6 and 7 show the spectral reflectances of TiO_2 and India ink on pig skin for the extreme acceptable limits.

In a previous report (3) reflectance measurements were done on excised pig skin with the Coblentz type reflectometer. The average of the results of this set of readings are given in Fig. 8 along with the reflectance curve of Fig. 4.

Fig. 9 gives spectral transmittance curves for TiO_2 on excised pig skin and also the spectral transmittance of India ink on quartz. The

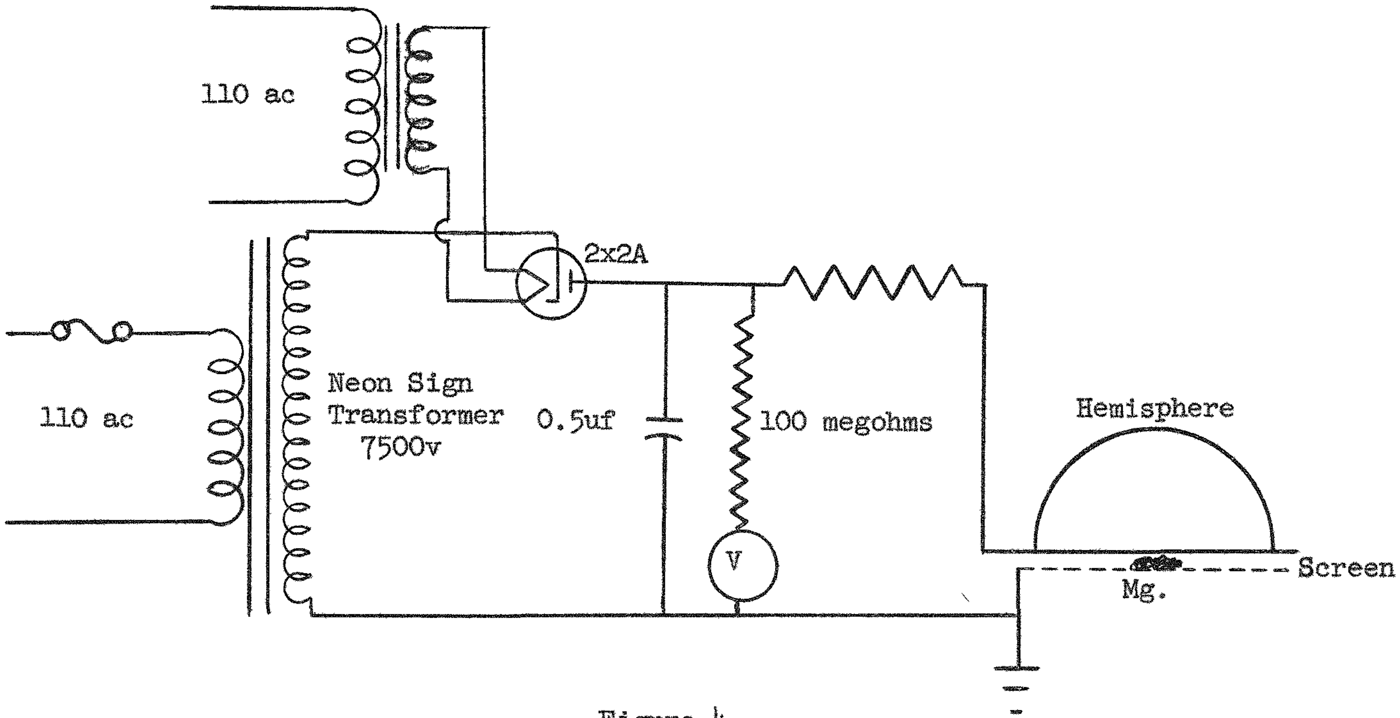

Figure 4

ELECTROSTATIC DEPOSITOR SCHEMATIC

TABLE 1

PIG SKIN REFLECTANCE, TiO_2 PAINT AND INDIA INK REFLECTANCE AND TRANSMITTANCE

Description of Substance	Total Reflectance (R_t) and Transmittsnce(T_t)
Pig, bare skin	
One skin area four different readings	R_t = .41
	R_t = .41
	R_t = .42
	R_t = .40
Four skin areas	R_t = .38
	R_t = .39
	R_t = .41
	R_t = .36
Pig with TiO_2	
Lower limit	R_t = .49
Upper limit	R_t = .62
After 0.3 sec. 2+ burn	R_t = .54
" 3.0 " " "	R_t = .52
" 30.0 " " "	R_t = .51
No burn, control	R_t = .54
Pig with India ink	
Lower limit	R_t = .06
Upper limit	R_t = .14
TiO_2 Transmittance	
On excised pig skin	T_t = .26
On quartz	T_t = .27
On Aeroplast	T_t = .29
India ink transmittance	
On quartz and Aeroplast	T_t = .11

Chester White Bare Skin
Reflectance
With Spherical Integrator

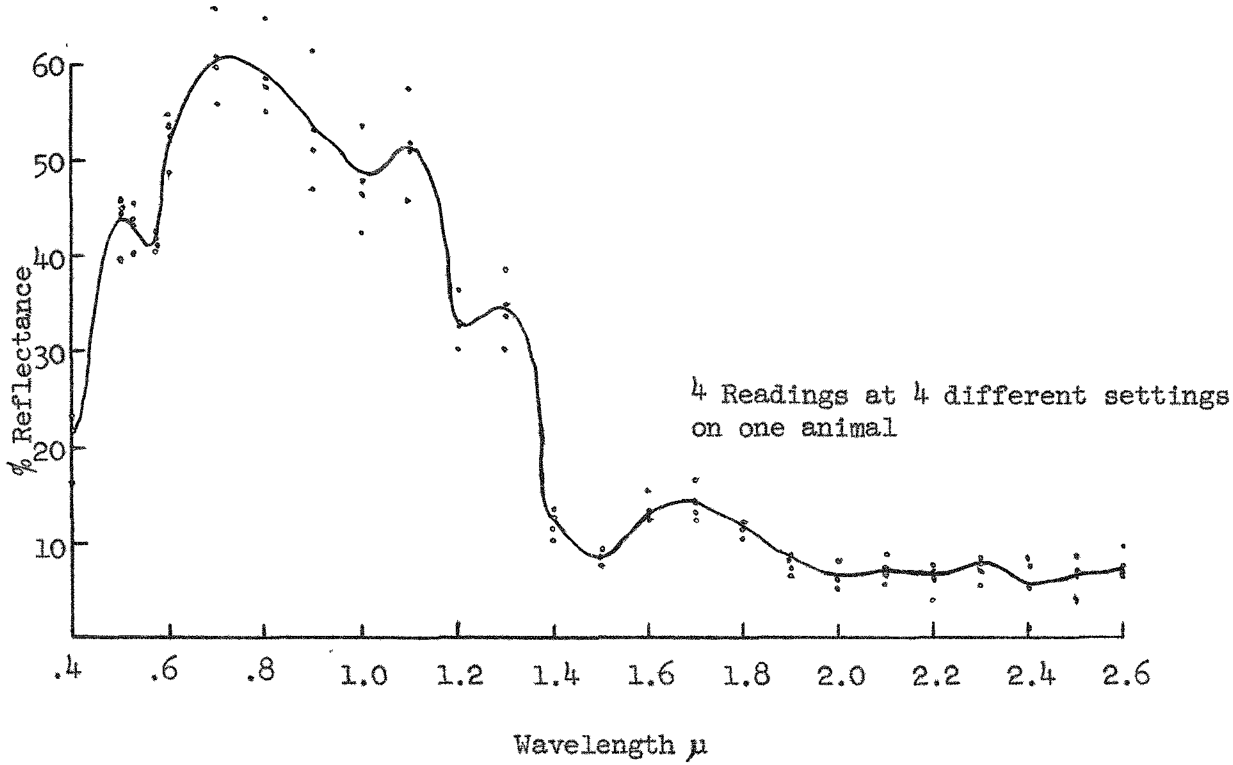

Figure 5

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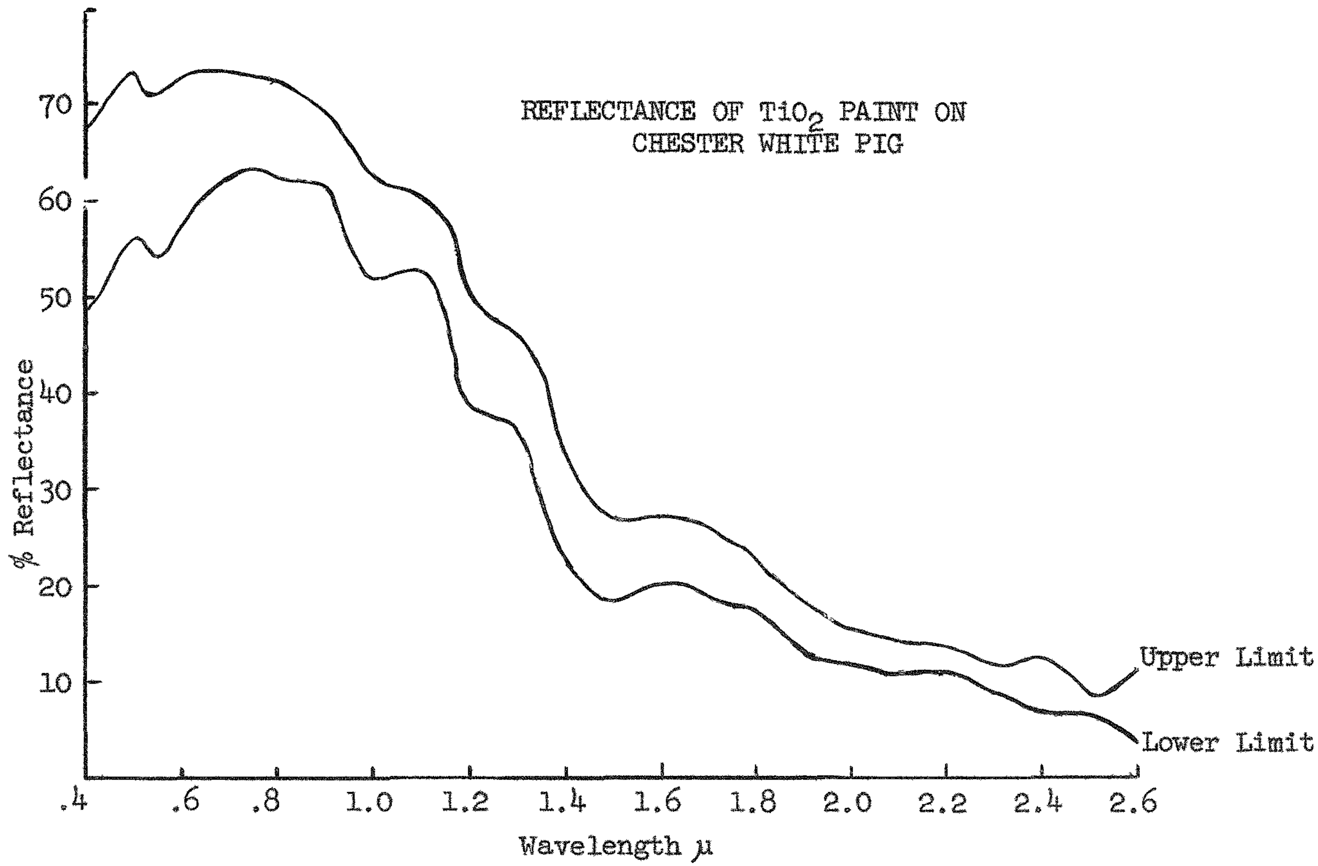
REFLECTANCE OF TiO_2 PAINT ON
CHESTER WHITE PIG
% Reflectance
70
60
50
40
30
20
10
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Wavelength μ
Upper Limit
Lower Limit

Figure 6

14

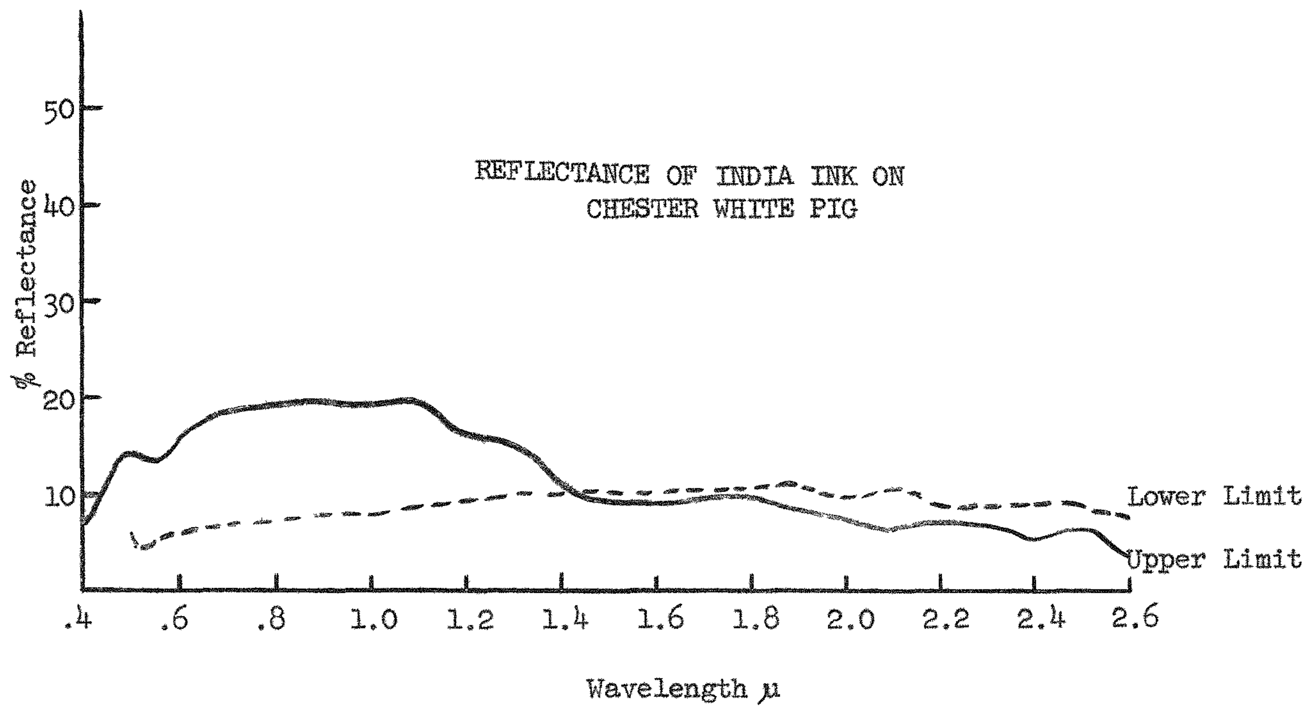
REFLECTANCE OF INDIA INK ON
CHESTER WHITE PIG
% Reflectance
50
40
30
20
10
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Lower Limit
Upper Limit
Wavelength μ

Figure 7

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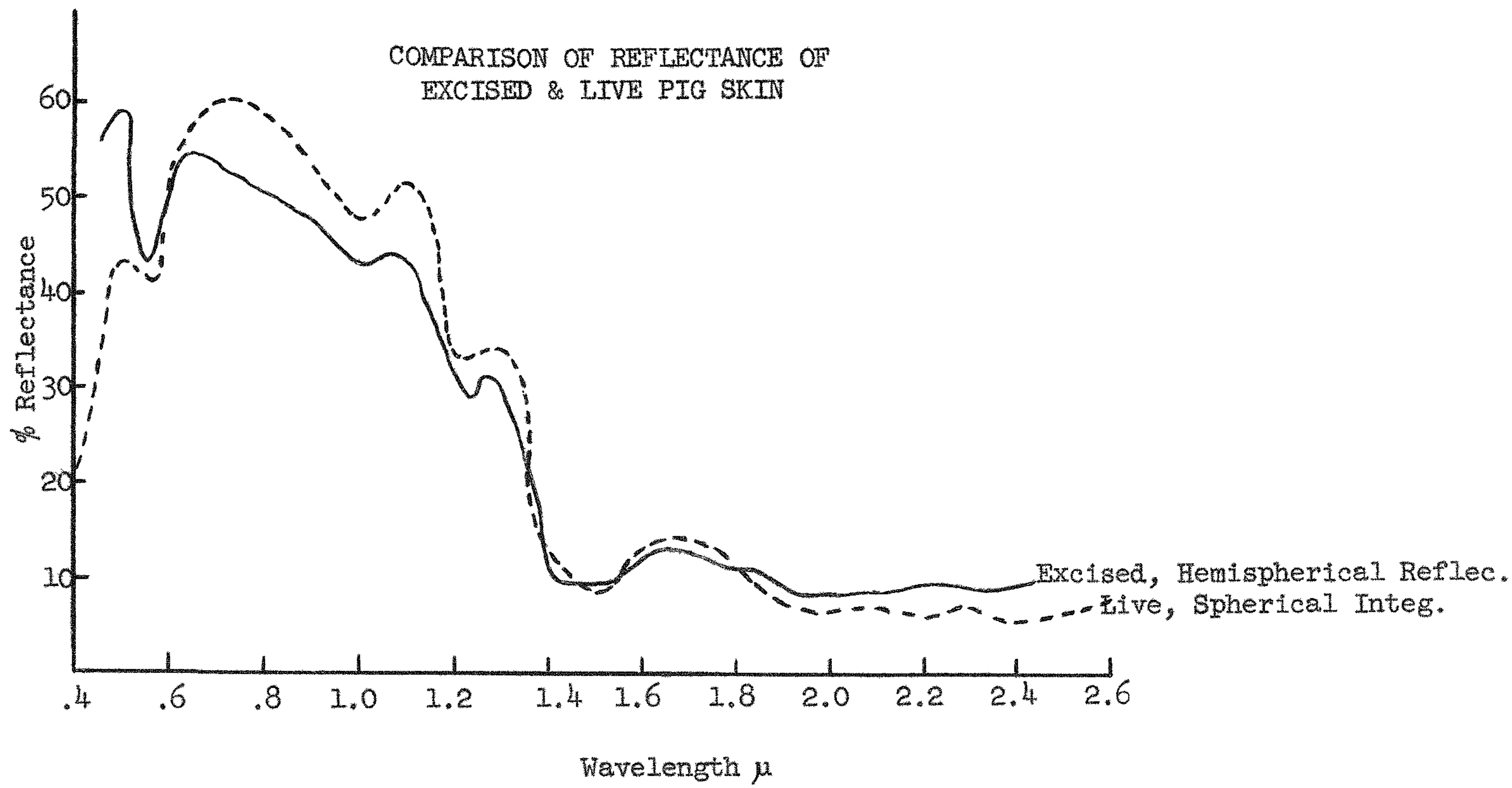
COMPARISON OF REFLECTANCE OF
EXCISED & LIVE PIG SKIN
% Reflectance
60
50
40
30
20
10
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Excised, Hemispherical Reflec.
Live, Spherical Integ.
Wavelength μ

Figure 8

TRANSMITTANCE OF TiO_2 & INDIA INK

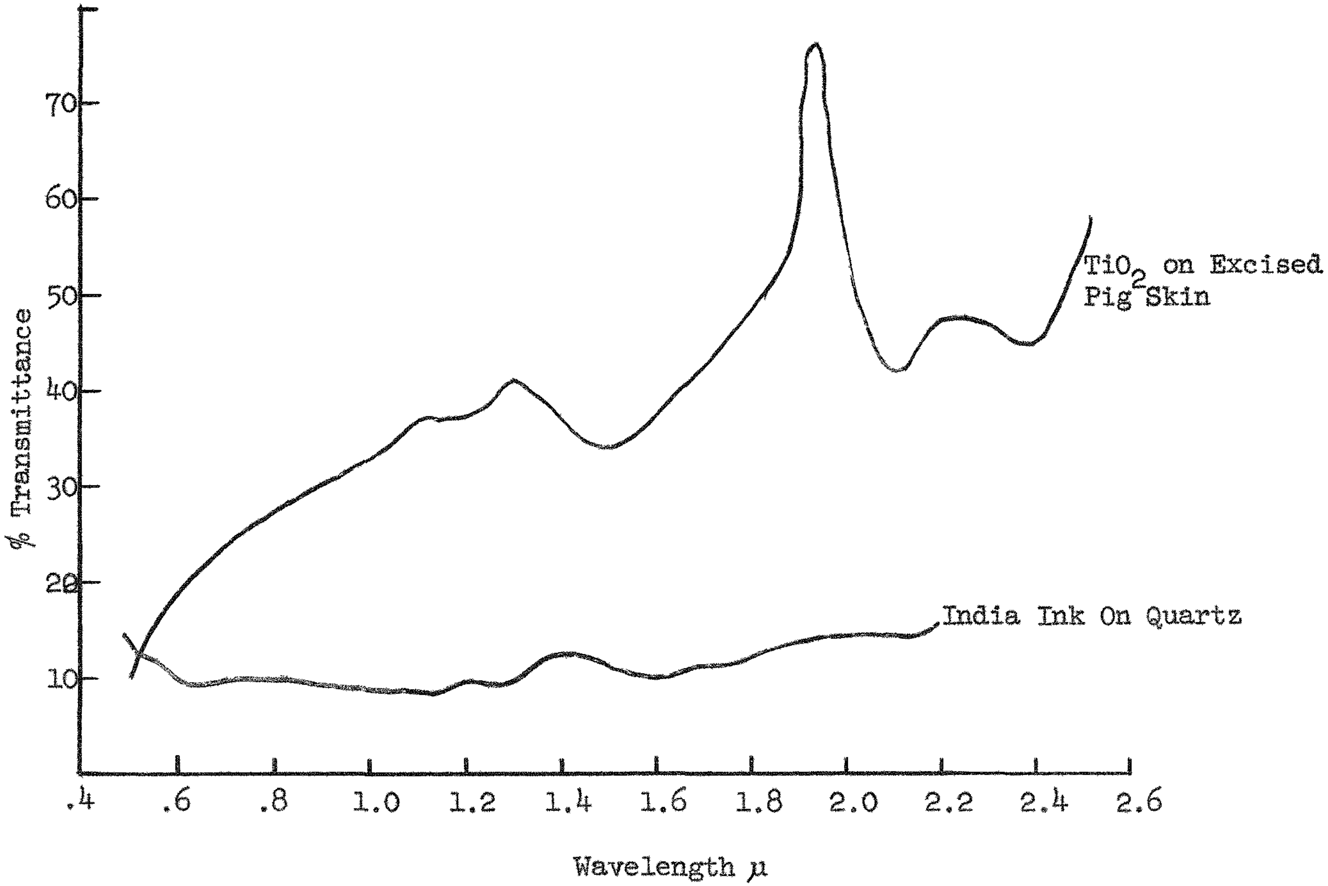

Figure 9

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lower curve extends only to 2.2 μ because of the low detectivity (sensitivity/noise) between 2.2 μ and 2.6 μ for India ink. Fig. 10 gives the spectral transmittance, reflectance and absorptance of TiO_2 cream on quartz.

DISCUSSION OF RESULTS

The average of the eight total reflectance readings on the side of a live pig was 0.39. It is interesting to note here the similarity between the results obtained for excised pig skin measured with a hemispherical reflectometer (3) and those of the present experiment. The average total reflectance found in the former study was 0.41. The spectral distributions in Fig. 8 are quite similar, the differences in the blue and red portions of the spectrum probably being due to a lack of blood in the excised tissue.

The changes in the total reflectances of TiO_2 on a pig after suffering a 2+ burn given in 0.3 sec., 3.0 sec. and 30.0 sec. are not significant. This portion of the experiment was undertaken to see if there were differences in the reflectance of painted skin after burns at the above exposure times were applied. If there were, this might help explain some of the results obtained in studying the protective effect of paints (1). The evidence at the present time also indicates that there are no significant transient reflectance changes during the time of the exposure.

In looking at the transmittance curve for TiO_2 in Fig. 9 one would expect that this substance is quite transpartent at about 1.93 μ, a water absorption band. Because there is considerable water in tissue, the absorption curve of the tissue taken alone would contain this band. If this water

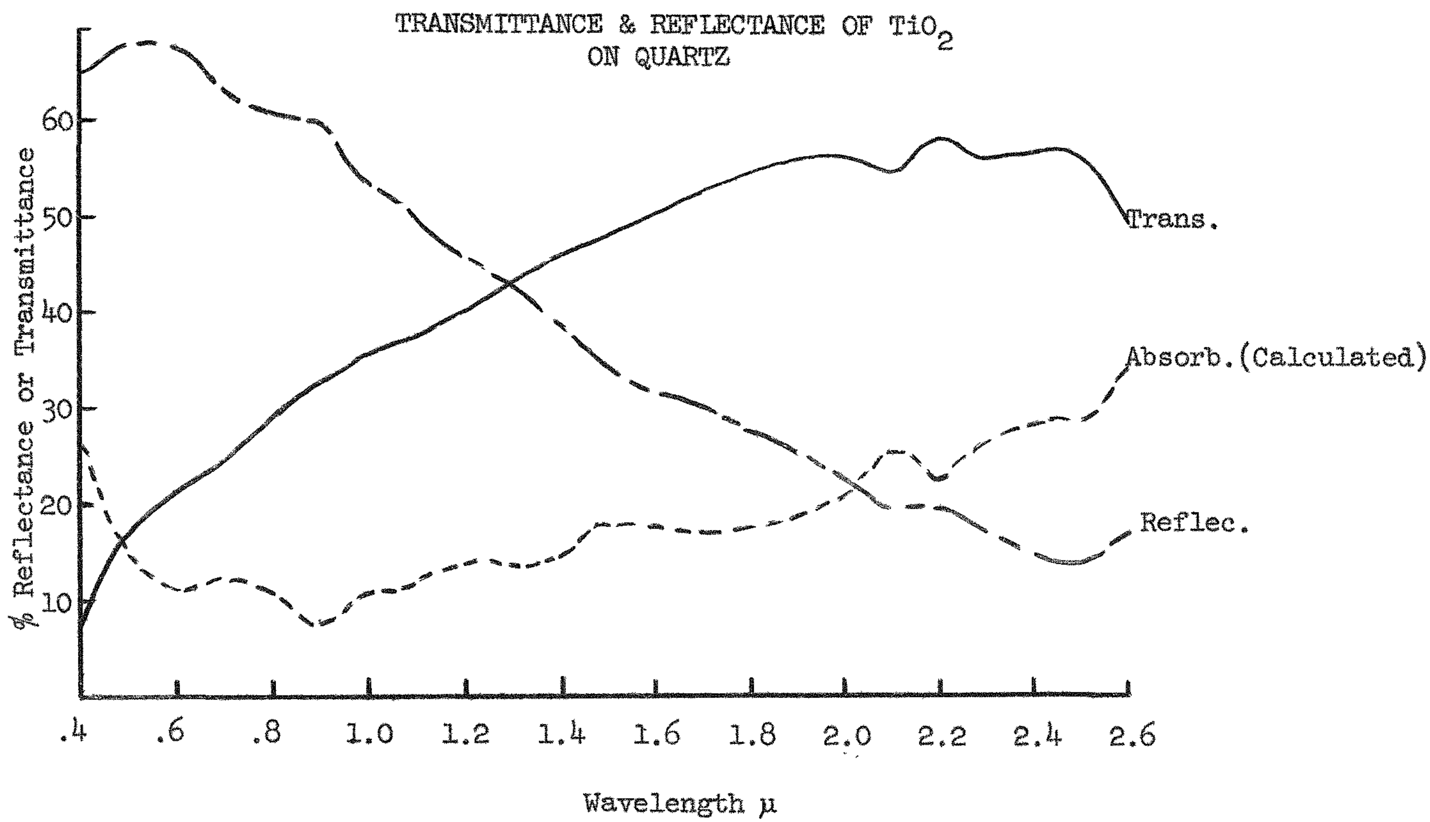
TRANSMITTANCE & REFLECTANCE OF TiO_2
ON QUARTZ
60
50
40
30
20
10
% Reflectance or Transmittance
Trans.
Absorb.(Calculated)
Reflec.
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Wavelength μ

Figure 10

remained in the tissue after the paint was applied and dried, the absorption band would be cancelled in finding the absorptance of the paint. However, with the results of Fig. 9, it is reasonable to assume that the paint absorbed some water from the tissue and, in drying, there was some net water loss. To correct this, the transmittance of the TiO_2 and the India ink was found by using the Aeroplast "pig skin" mentioned previously.

The reflectance and transmittance of the TiO_2 paint, using the Aeroplast "pig skin", added up to more than 100% at several wavelengths. Even if there were no absorption in the paint one would certainly have to account for the fact that the sum of the reflected and transmitted energies was greater than the incident energy. The characteristic of the Aeroplast is such that the incident energy which gets through the paint layer is scattered back toward the paint. Since the reflectance of the TiO_2 paint is quite high throughout the wavelength region of interest, a good deal of this back scattered energy is reflected by the under portion of the TiO_2 layer and contributes to that energy entering the integrating sphere. Since the transmittance is found by taking the ratio of the energy passing through the Aeroplast with and without a coating of paint, the readings will be higher than they should be. The same holds for the reflectance readings with the Aeroplast and TiO_2 paint except that in this case the back scattered energy re-enters the TiO_2 film and constributes to the reflectance.

In order to obviate the above, the paint was applied to a thin piece of well polished quartz which has very little back scatter. This resulted in a lowering of both the transmittance and reflectance to the point where the sum of the two was well below 100%, as shown by the absorptance curve of Fig. 10. The fact that the topography of the quartz and the pig skin are quite different does not seem to have any effect upon the reflectance in the two cases, and the difference resulting in the transmittance, if any, certainly is within the upper and lower limits for an acceptable coat set by the conditions of the experiment (1). The transmittance of the India ink on quartz is the same as it is on Aeroplast, largely due to the low reflectance of India ink.

SUMMARY AND CONCLUSIONS

1. A method for measuring the diffuse reflectance of pig skin and the diffuse reflectance and transmittance of titanium dioxide (TiO_2) paint and India ink was described.
2. A comparison type spherical integrating reflectometer was designed and constructed because of some inherent disadvantages found in a Coblentz type reflectometer used in this laboratory.
3. Very little difference was found between reflectance readings on excised pig skin and on skin of the living animal. The reflectance to the wavelength distribution of the 24 inch carbon arc source was 0.41 for the former and 0.39 for the latter.
4. The reflectance of TiO_2 on the skin of a live pig did not change significantly after infliction of 2+ 0.3 sec., 3.0 sec. and 30.0 sec. burns.
5. The reflectance to the wavelength distribution of the 24 inch carbon arc source of TiO_2 paint on pig skin ranged from 0.49 to 0.62 for the thinnest and thickest coats respectively; for the India ink, 0.06 to 0.14 respectively.
6. The transmittance of thin films of TiO_2 paint and India ink was 0.27 and 0.11 respectively.

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