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STUDIES OF FLASH BURNS: THE INFLUENCE OF SKIN TEMPERATURE
IN THE PRODUCTION OF CUTANEOUS BURNS IN SWINE

by:

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Authorizing Official
Date *9/2/68*

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1946

OFFICE OF THE ATTORNEY GENERAL

MEMORANDUM FOR THE ATTORNEY GENERAL
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THE UNITED STATES OF AMERICA
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STUDIES OF FLASH BURNS:
THE INFLUENCE OF SKIN TEMPERATURE IN THE PRODUCTION
OF CUTANEOUS BURNS IN SWINE.

By

K. M. Berkley

H. E. Pearse

T. P. Davis

ABSTRACT.

The influence of ambient temperature on skin temperature was first studied. It was found that the skin temperatures in multiple areas on the sides of anesthetized pigs stabilized at about 31.5, 33.5 and 36.5° C. in ambient temperatures of 16, 23 and 31-36° C. respectively. At these ambient temperatures the temperature of skin overlying the thoracic cage is usually cooler than that over the abdomen, that over the spleen or liver is the warmest, and that nearer the head is cooler than that approaching the hind flank. The largest range of skin temperatures from the coolest to the warmest subarea recorded at any one time was 3° C. or 1.9° C. at ambient temperatures of 16° C. or 31-36° C. respectively. With changes in ambient temperatures from 31-36° C. to 16° or from 16° to 31-36° C. skin temperatures could be changed from above 36° C. to below 32° C. and from below 32° C. to above 36° C. Using Chlorpromazine, a fall in skin temperatures to below 28° C. could be obtained in a room temperature of 16° C.

Following this study, the influence of skin temperature on the production of cutaneous burns was studied. When the degree of damage

was judged by surface appearance and exposures of 0.5 sec. were used, there was found to be a significant difference in the 50% effective exposures of 25% for 2+ burns and 11% for 3+ burns if the average burn skin temperature prior to burning differed between 30.6° C. and 36.7° C. At exposure times of 0.5, 1.0 and 4.0 sec. a difference of 30 to 40% was found in the 50% effective exposure required for 2+ burns when the average skin temperatures prior to burning differed between 26.7° C. and 36.4° C. The lower the skin temperature the greater the thermal energy required to produce burns of equivalent severity. A similar difference was found when the severity of damage was judged by microscopic evaluation of the burns.

It is concluded that control of the skin temperature is important in dose-response studies of radiant energy burns in the laboratory. This being true then, the knowledge of the ambient temperature and its effect on skin temperatures is necessary for the proper evaluation of thermal burns studies in the field. Furthermore, cold climatic conditions could lessen the severity of radiant energy burns of exposed parts of the body such as hands and face and serve as protective measures in comparison to burns incurred in warm climates.

Part I

STUDIES OF FLASH BURNS: THE INFLUENCE OF AMBIENT
TEMPERATURE ON SKIN TEMPERATURE IN SWINEINTRODUCTION

Since the advent of atomic weapons, the need for the study of the local lesions produced by short exposures of high intensity radiant thermal energy is evident. Various investigators in this laboratory have studied the effect of different physical factors on burn production and the protective effect of fabrics (1, 2, 6, 8).

During the course of this work biological variation has been high in most of the experiments done. The carbon arc used provides a source with energy variation of only $\pm 5\%$. At a given intensity with burns produced on both sides of a number of animals on different days, burns may vary from mild erythema to dermal coagulation. Since it was noted that burns were less severe when produced in a cold room than in a warm room, it seemed that the local skin temperature might very well be a factor in the host resistance or susceptibility to burning.

The study of the effect of skin temperature on the production of burns would not only be of value in elucidating fundamental mechanisms, but also might be of considerable practical value in the consideration of the protection of such exposed areas of the body as the hands and face.

Our purpose was to study the effect of skin temperature on burn production. But first, it was necessary to do experiments designed to investigate the response of skin temperatures of pigs over a period of time to different ambient temperatures.

EQUIPMENT

The skin temperature measuring device utilized a Western Electric type 23-A thermistor mounted in a cup-shaped holder as shown in figure 1. A small bead on the loop of the thermistor is placed so that it comes in contact with the skin when the holder is flush with the skin. A small wire was placed beneath the loop of the thermistor to give it support. The thermistor, which is a temperature-sensitive resistor, was connected in the unknown arm of a Wheatstone Bridge; changes in thermistor resistance unbalanced the bridge producing an output voltage which was measured and recorded by a ten millivolt full scale Leeds and Northrup "Speedomax" recording potentiometer. An adjustable reference arm in the bridge permitted selection of convenient base temperatures, and the sensitivity of the circuit could be adjusted to secure full scale temperature ranges of five, ten and twenty degrees Centigrade.

The temperature-resistance characteristic of the thermistor used had previously been determined by Taylor Instrument Co., Rochester, N. Y. Calibration of the temperature measuring circuit was accomplished simply by substituting an adjustable precision resistor in place of the thermistor and observing the output voltage as a function of resistance. These data were then converted to output voltage versus temperature, using the known temperature-resistance curve of the thermistor.

In application, the holder was placed against the skin surface for five seconds, at which time the curve had usually leveled. The temperature was read from the highest point on the recorded curve.

A 5-ton temperature control unit manufactured by the York Corporation, York, Pennsylvania, provided about a 20° C. range in ambient temperature with a variation at any setting of about $\pm 3/4^\circ$ C.

METHODS

Chester White pigs, weighing about 10 Kg, were anesthetized with Dial in Urea-urethane (Ciba) by the intraperitoneal route in doses of 70 mg/kg body weight (4). The hair was closely clipped and the skin gently sponged. The animals were put into a constant temperature room from 1/2 to 1 hour following the induction of anesthesia.

A side of the pig was divided into three rows and ten columns to produce a grid of 30 small subareas. The grid covered the area from behind the front legs to the hind legs, and dorsally from the lumbar muscle group, ventrally to the posterior axillary line. The placement of the grid is seen in figure 2. The animals were put into a constant temperature room from 1/2 to 1 hour following induction of anesthesia. Skin temperatures were taken at intervals of 1/4 to 1 hour in each of the subareas in the grid pattern. Rectal temperatures were also noted periodically.

There were three types of experiments designed as follows:

- I. In the entire experimental period the room temperature was kept constant at one of three levels, 16, 23 or 35° C. The skin temperatures were recorded in 30 subareas during a 2-1/2 to 6 hour period of observation.
- II. With this design, animals were placed in room temperature of 16 or 35° C. After 2 to 2-1/2 hours the room temperature was changed to the opposite extreme. The skin temperatures were measured during the initial 2 to 2-1/2 hours and for five hours following the change in ambient temperature.

III. In this experiment the effect of the drug, Chlorpromazine*, was studied to determine if the skin temperatures could be lowered to a level less than 28° C. in a fairly short period of time. Chlorpromazine has been used to produce hypothermia in experimental animals, apparently acting by abolishing the shivering reflex. Animals were given 1.5 mg per Kg intramuscularly in addition to Dial. They were placed in a constant room temperature at 16° C. The skin temperatures were measured over a period of 3-1/2 to 5 hours.

Table 1 shows the type of experiments, the number of animals and the conditions under which they were studied.

Table 1

Type of Experiment	Ambient Temperature °C.	No. of Animals Studied
I	16°	6
	23°	2
	31-36°	6
II	35° for 2-1/2 hours-then lowered to 16°	2
	16° for 2 hours-then raised to 33°	4
III	16°	4

*Chlorpromazine was generously supplied as "Thorazine" by Smith, Kline and French.

GENERAL OBSERVATIONS

At an ambient temperature of about 16° C. the skin temperatures followed a fairly standard profile, which is demonstrated on the recording (figure 3). The first ten readings represent the top row, the second ten readings the middle row, and the last ten readings the most ventral row. In all three rows the readings were taken from front to rear of the animal.

In any row, the lowest temperature was usually found in the sub-area placed most cephalad in that row. Progressing caudad, the skin temperatures rose. Usually, within the last three subareas of any one row, the highest skin temperature for that row was recorded. In any column progressing from the dorsal row to the ventral row there was a fairly constant rise in the temperature.

Figure 4 shows the actual values obtained on a pig, 2 hours after induction of anesthesia and 1-1/2 hours after being in an ambient temperature of about 16° C. A few points are of interest here. The area over the thoracic cage is generally the cooler. The areas approaching the abdomen and particularly that over viscera are the warmer. There is frequently a quite warm area in the middle of the bottom row, which, anatomically, overlies the liver or the spleen.

A very similar pattern is present in animals brought to equilibrium in ambient temperatures of 35° C., but the differences which exist over the surface from subarea to subarea are much smaller than at 16° C. Figure 5 shows the recording of the skin temperatures as observed under these conditions.

RESULTS

Figures 6 - 11 show the response in one animal under the different conditions studied. Time of anesthesia was used as the reference point in the discussion. The time after introduction of animals in the constant temperature room will be 1/2 to 1 hour less.

I. Experiments in Constant Temperatures

A. Ambient Temperature 16° C.

The findings in one animal are shown in figure 6. In this pig within 2 hours of induction of anesthesia the skin temperatures stabilized at a level below 31.0° C. The maximum range in the skin temperatures from the coolest to the warmest subarea recorded at any time in this animal was 3° C. The rectal temperature remained about 36° C. The ambient temperature varied from 15.5 to 17° C.

In the six animals studied, the skin temperatures stabilized 2 hours following anesthesia and then varied only about 1° C. during the 5 to 6 hour period of observation. This variation followed that of the ambient temperature. The skin temperatures in five animals fell below 31.5° C. in 2 hours but rose slightly beginning 3 hours after induction of anesthesia. The range of skin temperatures from the coolest to warmest subarea recorded at any one time varied from a minimum of 1.7° C. to a maximum 3° C. The rectal temperatures fell to an average of 35.0° C. After 3 hours of anesthesia the rectal temperatures differed several degrees; a rapid rise was noted in one animal which probably represented lightening of anesthesia.

Two of the above animals were left in the control temperature room at 16° C. over night. The following morning they were anesthetized. The

initial skin temperatures were from 31.5 to 34° C., but fell with anesthesia in a similar manner to the other animals studied at 16° C.

In general, stabilization of skin temperatures occurred after 2 hours of induction of anesthesia at a level less than 31.5° C., and in the majority of animals remained at this level for 5 to 6 hours observation.

B. Ambient Temperature of 23° C.

Two anesthetized animals were placed in the constant temperature room at 23° C. 1 hour after induction of anesthesia. One hour later, the skin of one of the pigs was below 33.5° C., the other below 31.5° C. Both animals kept fairly constant skin temperatures for 6 hours following anesthesia. The maximum range of skin temperature at any one time was 1.5° C. Figure 7 represents the response of one of these animals.

C. Ambient Temperature of 31 - 36° C.

The findings in one animal are shown in figure 8. In this pig within 2 hours of induction of anesthesia the skin temperature stabilized at a level above 37.5° C. The maximum range in the skin temperatures from the coolest to the warmest subarea recorded at any time was 1.9° C. The rectal temperature varied from 37 to 39° C. The ambient temperature varied considerably the first 2 hours then stabilized about 35° C.

II. Experiments in Changing Room Temperatures

A. Changing Conditions from 35° to 16° C.

Two animals were placed in the constant temperature room at 35° C. 1/2 hour following anesthesia. After 2 hours the skin temperatures of both

were above 37° C. The room temperature was lowered and became stabilized at about 16° C. in 5 hours. Within 2-1/2 hours of the change, the skin temperatures of both animals were below 34° C. In one animal the rectal and skin temperature began to rise, but a small dose of Nembutal given intravenously reversed this. In the other animal the skin temperature fell to less than 32.0° C. 5-1/2 hours after the change in ambient temperature was instituted.

Figure 9 shows the response in one animal. By altering the ambient temperature in this manner the range of skin temperatures changed from 38.5 - 39.3° C. to 32.2 - 34.0° C. It is to be noticed that the range became larger with the lower temperature.

B. Changing Conditions from 16° to 33° C.

Four pigs were placed in room temperatures at 16° C. from 1/2 to 3/4 hour after anesthesia. Two hours after anesthesia the room temperature was raised, reaching 33° C. in 1-1/2 hours. Three pigs had stable skin temperatures below 32° C. at the end of 2 hours in the 16° C. room, one pig continued to cool. After the change in ambient conditions the skin temperatures of all four pigs were greater than 36.5° C. in 5-3/4 hours.

Figure 10 represents the pattern observed in one animal.

III. The Effect of Chlorpromazine

To reduce the skin temperatures of the animals consistently to a level of less than 28° C. at an ambient temperature of 16° C., the drug Chlorpromazine in dosage intramuscularly of 1.0 mg per Kg body weight proved most effective. The results were as follows:

Four animals anesthetized with Dial and given Chlorpromazine were introduced into a room of 16° C. from 1/2 to 3/4 hour after anesthesia. Three hours following anesthesia the skin temperatures of all animals had fallen rapidly to below 28° C. After 3 hours there was a variable response. One animal showed stabilization of skin temperatures between 26 to 28° C., as shown in figure 11. Two animals showed a continued slow fall of 2° C. in 1 hour at which time the rectal temperature was 27.8° C. so the experiment was discontinued and the animal warmed. With the approach of rectal temperatures to 28° C. respirations slow considerably and may stop. With artificial respiration and warming, there was no mortality in this group of animals, although artificial respiration was necessary in two animals.

Comparison of figures 6 and 11 shows the effect of the addition of Chlorpromazine in decreasing to a greater extent the skin and rectal temperatures in anesthetized pigs in room temperatures of 16° C.

SUMMARY AND CONCLUSIONS

General

1. The skin temperatures recorded in 30 subareas on the side of anesthetized animals in a constant ambient temperature show a fairly standard pattern. The area over the thoracic cage is the cooler; that over the abdomen and particularly over the liver or spleen is the warmer. In any row the lowest temperature was usually found in the subarea placed nearest the head. Progressing caudad, the skin temperature rose.
2. The largest range of skin temperatures from the coolest to the warmest subarea recorded at any one time was 3° C. at the ambient temperature of 16° C. and 1.9° C. at 31-36° C.

Experiments in Constant Temperatures (Experiment I)

3. The skin temperatures of anesthetized animals were stabilized at about 31.5°C . within 1-1/2 hours after being placed in a constant room temperature of 16°C .

4. In a room of 23°C . stabilization occurred in 1/2 hour at a level below 33.5°C .

5. At a room temperature of $31-36^{\circ}\text{C}$. the skin temperatures were fairly stable at a level greater than 36.5°C . within 1-1/2 hours.

Experiments in Changing Room Temperatures (Experiment II)

6. By lowering the ambient temperature from 35 to 16°C . after the stabilization at the initial temperature, skin temperatures could be changed from a level above 37°C . to one less than 32°C . About 5-1/2 hours elapsed before the lower level was reached.

7. When the ambient temperature was raised from 16° to 33°C . after stabilization at the initial room temperature, the skin temperatures rose from a level less than 32°C . to one greater than 36.5°C . in 5-3/4 hours.

8. Skin temperature alone is quite sensitive to changes in ambient temperature and follows any change closely.

The Effect of Chlorpromazine (Experiment III)

9. Chlorpromazine, given intramuscularly, in dosage of 1.0 mg/Kg body weight to anesthetized animals in a room temperature of 16°C . caused a fall in skin temperature to below 28°C . within 3 hours. The level generally continued to fall unless the animals were warmed.

10. Chlorpromazine together with Dial in Urea-urethane caused a greater and faster decrease in skin and rectal temperatures in pigs in room temperatures of 16°C . than did Dial in Urea-urethane alone.

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Figure 1

Skin Temperature Measuring Thermistor

1. Lucite Holder
2. Supporting Wire Beneath Thermistor
3. Leads of Thermistor

Figure 1

Figure 2

This figure shows the placement on the side of a pig of the grid of subareas in relation to topographic features, the thoracic cage and the liver or spleen.

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Figure 3

This figure is a recording of skin temperatures on a pig in an ambient temperature of 16° C. The numbers designate the position on the animal on which the temperature was obtained.

Figure 4

This figure shows the skin temperatures recorded on a pig two hours after anesthesia in an ambient temperature of about 16° C.

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Figure 5

This figure is a recording of skin temperatures on a pig in an ambient temperature of 35° C. The numbers designate the position on the animal on which the temperature was obtained.

Figure 6

THE EFFECT OF AMBIENT TEMPERATURE OF 16° C.
ON SKIN AND RECTAL TEMPERATURES OF PIGS

Figure 7

THE EFFECT OF AMBIENT TEMPERATURE OF 23° C.
ON SKIN AND RECTAL TEMPERATURES OF PIGS

Figure 8

THE EFFECT OF AMBIENT TEMPERATURE OF 31 TO 36° C.
ON SKIN AND RECTAL TEMPERATURES OF PIGS

25

Figure 9

THE EFFECT OF CHANGING AMBIENT TEMPERATURE FROM 35 TO 16° C.

ON SKIN AND RECTAL TEMPERATURES OF PIGS

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Figure 10

THE EFFECT OF CHANGING CONDITIONS FROM 16 TO 33° C.
ON SKIN AND RECTAL TEMPERATURES OF PIGS

Figure 11

THE EFFECT OF CHLORPROMAZINE ON SKIN AND RECTAL TEMPERATURES
ON PIGS IN AMBIENT TEMPERATURE OF 16° C.

Part II

STUDIES OF FLASH BURNS: THE INFLUENCE OF SKIN TEMPERATURE
ON THE PRODUCTION OF CUTANEOUS BURNS IN SWINE AT A CONSTANT
EXPOSURE TIME

INTRODUCTION

It has been shown in the preceding section that when pigs were placed in constant ambient temperatures $1/2$ to $3/4$ hour after anesthesia, their skin temperatures become fairly stable within $1-1/2$ to 2 hours. Furthermore, with a change in ambient temperature the skin temperature would follow and stabilize at a different level. By changing the ambient temperature from 16 to 35°C . ($60-90^{\circ}\text{F}$.) or from $35-16^{\circ}\text{C}$. skin temperatures at least 4°C . apart could be effected.

Our purpose in this part was to investigate the effect of skin temperatures above 36°C . or lower than 32°C . on the production of 1+, 2+ and 3+ burns at a constant exposure time of 0.5 sec.

METHODSEquipment

A 24" carbon arc searchlight, modified as described by Davis et al (3), was the source of the radiant energy.

The skin temperature measuring device described in the foregoing section was used in the experiment.

Biological

Chester White pigs, weighing about 10 kg were anesthetized with Dial in Urea-urethane (Ciba) by the intraperitoneal route in doses of 70 mg/Kg

of body weight. The skin was closely clipped and gently sponged prior to burning. The sides of the animals were divided into three columns and eight rows to provide 24 subareas.

Experimental Design

Four animals (group A) were introduced into a constant temperature room at 16° C. 1/2 to 3/4 hour following induction of anesthesia. Skin temperatures were measured in each of the subareas at about 15 minute intervals. When the skin temperatures of all the subareas to be burned on one side were below 32° C. the burns were produced.

Following burning at the initial ambient temperature, the room was heated to 32° C. When all the skin temperatures in the subareas to be burned were above 36° C. those subareas were burned.

In four other animals (group B) the ambient temperatures were reversed; the initial one was 32° C. and the following one, 16° C. The subareas with skin temperatures greater than 36° C. were burned first, those less than 32° C. were burned second. By this reversal the possibility of time after anesthesia rather than the skin temperature producing the observed response was minimized.

Eight radiant exposures from 3.3 to 7.5 cal/cm², and eight from 4.0 to 8.0 cal/cm² were made when the skin temperatures were above 36° C. or below 32° C. respectively. The exposure time was constant at 0.5 sec.

The combination of eight radiant exposures with each of two levels of skin temperatures produced 16 treatments, which were replicated 24 times. The subarea to be burned was determined randomly. Each treatment fell on each pig three times, but no three replications fell on the

same side. There was an equal probability of any treatment falling in any one subarea.

In 24 hours the burns produced were evaluated and biopsied, specimens were fixed in Bouin's solution and stained by hematoxylin and eosin.

Evaluation

The lesions were graded by surface appearance according to the following classification (7, 8):

Grade	Surface Appearance
1+	Red (Erythema)
2+	Patchy White
3+	Uniform White

Each of the three grades were subclassified mild, moderate or severe. By histological examination, the depth of damage was classified as follows: epidermal, transepidermal and dermal.

In the least severe burns epidermal cells show vacuolization and an affinity for eosin. As the severity increases, the cells become distorted and begin to separate from the dermis. This is at first focal but progresses to complete separation before there is visible damage to the dermis. This is termed complete transepidermal damage. Damage in the dermis is manifested by swelling of collagen fibers and loss of fibrillary structure, so that the appearance is glassy. A demarcation between damaged and undamaged collagen can thus be detected and placed into superficial, middle or deep positions in the dermis.

Statistical Analysis

The simplified method of evaluation of dose-effect experiments of Litchfield and Wilcoxon (5) was used to estimate 50% effective doses and potency ratios with their 0.95 confidence intervals.

RESULTS

I. The Conditions Existing at the Time of Burning

The time after anesthesia of burning, the average and the range of skin temperatures in the subareas burned, and the rectal temperature at that time are shown in table 2 for the eight animals used.

In group A from 2 to 2-1/2 hours after anesthesia elapsed before the skin temperatures fell below 32° C. The skin temperatures at this time varied from 27.9 to 32° C. Previous experience had shown that stabilization of skin temperatures was present about 2 hours after induction of anesthesia and that thereafter only small degrees of change occurred. Therefore, although stabilization of skin temperatures was not demonstrated conclusively in the animals burned, it is felt that it was present at the time of burning and that the range of temperatures given in table 2 is an accurate representation of the conditions existing at the time of burn production.

In this group from 6 to 9-1/2 hours after anesthesia elapsed before the skin temperatures rose from below 32° to above 36° C. The skin temperatures at time of burning ranged from 36 to 37° C.

In group B animals were burned 1-1/2 to 1-3/4 hours after anesthesia, at which time the skin temperatures ranged from 36.0 to 37.6° C.

From 7 to 9-1/4 hours after anesthesia elapsed before the skin temperatures fell below 32° C. At the time of burning the range was between 28.4 and 32° C.

The rectal temperatures, when the skin temperatures were greater than 36° C. or less than 32° C. were very close in both groups, although the actual time of burning was quite different. Thus, the gradient between surface temperature and depth temperature was similar in the two groups.

II. The Effect of Skin Temperature on the Production of Burns

Table 3 shows the response obtained for the listed radiant exposure given at 0.5 sec. when the skin temperatures were either greater than 36° C. or less than 32° C., and the average was 36.7° C. or 30.7° C. Table 2a shows the estimate of the 50% effective exposure and 0.95 confidence interval under the conditions of these two skin temperature criteria. This is shown graphically in figure 12.

It is quite plainly indicated that the 50% effective exposure is significantly higher for 2+ and 3+ burns produced when the average skin temperature is 30.6° C. than when the average skin temperature is 36.7° C. For 2+ burns there is a 25% change in energy requirements; for 3+ burns, 11%.

The potency ratio of the 50% effective exposures for the cool skin to that of the hot skin for 2+ burns is 1.25 with a 0.95 confidence interval of 1.16 to 1.35; the same ratio for 3+ burns is 1.11 with 0.95 confidence interval of 1.05 to 1.17. With no significant difference in the potency ratios, the 25% change in energy requirements for 2+ burns is likewise not significantly different than the 11% change for 3+ burns.

Table 4 shows the response obtained as evaluated microscopically for radiant exposures at 0.5 sec. with skin temperatures above 36° C. or

less than 32° C. Table 4a shows the estimate of the 50% effective exposure and 0.95 confidence interval obtained from this data.

With change in the average skin temperature from 36.6 to 30.6° C. there is a 7.5% difference in the 50% effective exposure required to produce a complete transepidermal burn. This difference, although not significant at the 0.95 level of confidence, is nevertheless consistent with and in the same direction as that found for 2+ and 3+ burns.

Assuming that tissue must be brought to some critical temperature before it is altered, it is understandable that more energy is necessary to produce the same amount of damage with a decrease in the initial skin temperature prior to burning.

SUMMARY AND CONCLUSIONS

1. Anesthetized pigs were introduced into constant temperature rooms of 16 or 32° C. After burning at the initial temperature the ambient temperature was changed to the opposite temperature. With these changes, (1) the skin temperatures in multiple areas on the sides of the animals in room temperature of 32° were greater than 36° C., the average being 36.7° C. and (2) those in room temperatures at 16° C. were less than 32° C., the average being 30.6° C.
2. There was a significant difference of 25 and 11% at the 0.95 level of confidence in the 50% effective exposures for 2+ and 3+ burns respectively when the average skin temperature was either 36.7 or 30.6° C. More energy is required when the skin temperatures are lower.
3. The 25% change in energy requirements for 2+ burns is not significantly different at the 95% level of confidence than the 11% increase for 3+ burns. Therefore it may be stated that for each degree Centigrade

fall in skin temperature there is a 2 to 4% increase in the energy requirements required to produce burns of equivalent severity in the range studied.

4. If severity of damage is judged microscopically the 50% effective exposure to produce complete transepidermal burns was 7.5% higher when the average skin temperature prior to burning was 6° C. cooler. This represents an increase of 1.25% in energy requirement for each degree Centigrade decrease in skin temperature.

Table 2

Group	Pig	Time of Burning Hours Min.		Skin Temperature °C.		Rectal Temperature °C.	Time of Burning Hours Min.		Skin Temperature °C.		Rectal Temperature °C.
				Range	Average				Range	Average	
A	627R	2	00	31.2-32.2	31.6	35.0	6	00	36.7-37.2	37.1	37.6
	627L	2	10	30.0-32.0	31.4	35.0	6	15	36.5-37.2	37.1	37.6
	628R	2	15	29.6-31.3	30.9	34.0	8	40	36.1-36.7	36.3	36.7
	628L	2	30	30.7-31.4	31.0	34.0	8	50	36.0-36.6	36.4	36.7
	629R	2	00	29.6-31.3	30.4	34.3	8	50	36.7-37.6	37.2	38.0
	629L	2	15	27.9-31.1	29.6	34.3	8	55	36.4-37.3	37.0	38.0
	630R	2	25	28.0-31.3	29.9	34.7	9	15	36.0-36.9	36.5	37.8
	630L	2	30	28.1-30.5	30.0	34.7	9	20	36.0-36.5	36.3	37.8
B	633R	2	00	36.0-37.2	36.6	37.7	7	00	28.4-30.0	29.2	34.2
	633L	2	05	36.0-36.5	36.5	37.7	7	10	28.9-30.2	29.5	34.2
	634R	2	15	36.0-37.1	36.5	37.3	7	30	30.4-31.6	30.8	33.5
	634L	2	25	36.3-36.9	36.6	37.3	7	40	30.4-31.6	30.8	33.5
	635R	1	30	36.6-37.4	37.0	37.8	5	50	30.3-31.8	31.2	35.3
	635L	1	45	36.8-37.3	37.1	37.8	6	00	30.8-32.0	31.6	35.3
	636R	3	25	36.3-36.8	36.6	37.8	8	45	30.3-31.6	31.0	34.6
	636L	3	45	36.8-37.6	37.1	37.8	9	10	29.9-31.8	30.9	34.6

This table shows the time after anesthesia of burning, the average and the range of skin temperature existing, and the rectal temperature observed in two groups of pigs studied under different ambient temperature conditions at different intervals of time after anesthesia.

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Table 3

RESULTS OF EVALUATION OF SURFACE APPEARANCE

Skin Temp. (°C)	Radiant Exposure (cal/cm ²)	No Burn	1+			2+			3+			Total No. of Exposures
			Mild	Mod.	Sev.	Mild	Mod.	Sev.	Mild	Mod.	Sev.	
36.7	3.3	1 (4%)		9 (36%)	9 (36%)	6 (24%)						25
	3.6	1 (4%)	2 (8%)	5 (21%)	11 (42%)	5 (21%)						24
	4.0	1 (4%)		2 (8%)	8 (33%)	12 (50%)		1 (4%)				24
	4.5		2 (8%)		4 (17%)	10 (43%)	5 (21%)	3 (12%)				24
	5.1					4 (18%)	4 (18%)	11 (45%)	3 (14%)			22
	5.8	1 (4%)				1 (4%)	2 (8%)	5 (21%)	8 (33%)	7 (30%)		24
	6.6						1 (4%)	4 (17%)	3 (13%)	15 (65%)		23
	7.5							1 (4%)	1 (4%)	18 (75%)	4 (17%)	24
30.6	4.0		2 (8%)	19 (79%)	2 (8%)	1 (4%)						24
	4.4			14 (71%)	6 (25%)	3 (12%)				1 (4%)		24
	4.9		1 (4%)	3 (12%)	12 (50%)	7 (29%)				1 (4%)		24
	5.4			1 (4%)		14 (61%)	4 (17%)	3 (13%)	1 (4%)			23
	5.9				1 (4%)	5 (21%)	7 (30%)	8 (33%)	3 (12%)			24
	6.5					1 (4%)	2 (8%)	8 (33%)	12 (50%)	1 (4%)		24
	7.2			1 (4%)				2 (9%)	8 (35%)	11 (44%)	2 (9%)	23
	8.0					1 (4%)			3 (13%)	19 (83%)		23

This table shows the number and percentage of lesions of each degree of severity for the stated radiant exposure at 0.5 sec. exposure time when the average skin temperatures were either 36.7 and 30.6° C.

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Table 3a

The 50% Effective Exposure and 0.95 Confidence Interval of Radiant Energy for 2+ and 3+ Burns, Produced in Skin at the Temperature Indicated

Laboratory Grade	Skin Temperature °C.		50% Effective Exposure (cal/cm ²)	0.95 Confidence Interval (cal/cm ²)
	Range	Average		
2+	> 36	36.7	3.9	3.7 - 4.1
	< 32	30.6	4.9	4.7 - 5.1
3+	> 36	36.7	5.8	5.5 - 6.1
	< 32	30.6	6.4	6.2 - 6.6

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TABLE 4

RESULTS OF MICROSCOPIC EVALUATION

Skin Temp. (°C)	Radiant Energy (cal/cm ²)	No Burn	Epidermal Damage	Transepidermal Damage		Dermal Damage		Total No. of Exposures	Percent Complete Transepidermal Damage or More
				Focal	Complete	Superficial	Mid		
36.7	3.3	1 (4%)	8 (35%)	14 (61%)				23	
	3.6	1 (5%)	6 (30%)	13 (65%)				20	0%
	4.0	1 (4%)	4 (17%)	18 (75%)	1 (4%)			24	4%
	4.5		2 (9%)	18 (82%)	1 (5%)	1 (5%)		22	10%
	5.1			9 (43%)	9 (43%)	3 (14%)		21	57%
	5.8	1 (4%)		5 (22%)	10 (44%)	7 (30%)		23	74%
	6.6			3 (14%)	4 (18%)	7 (32%)	8 (37%)	22	86%
	7.5				6 (27%)	10 (45%)	6 (27%)	22	100%
30.6	4.0		8 (35%)	15 (65%)				23	0%
	4.4		4 (15%)	17 (65%)	3 (12%)	2 (8%)		26	20%
	4.9		2 (9%)	17 (74%)	2 (9%)	2 (9%)		23	18%
	5.4		1 (4%)	17 (74%)	3 (13%)	2 (9%)		23	22%
	5.9			11 (46%)	5 (21%)	7 (29%)	1 (4%)	24	54%
	6.5		1 (4%)	2 (9%)	12 (52%)	6 (26%)	2 (9%)	23	87%
	7.2		1 (4%)	2 (9%)	9 (39%)	10 (44%)	1 (4%)	23	87%
	8.0				5 (24%)	12 (57%)	4 (19%)	21	100%

This table shows the number and percentage of lesions of each degree of severity as judged by depth of damage for the stated radiant exposure at 0.5 exposure time when the average skin temperatures were either 36.7 or 30.6° C.

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Table 4a

The 50% Effective Exposure and 0.95 Confidence Interval of Radiant Energy for Complete Transepidermal Burns, Produced in Skin of Skin Temperatures Indicated.

Average Skin Temperature (°C.)	50% Effective Exposure (cal/cm ²)	0.95 Confidence Interval (cal/cm ²)
36.7	5.3	5.0 - 5.6
30.6	5.7	5.4 - 6.0

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Figure 12

THIS FIGURE SHOWS THE 50% EFFECTIVE EXPOSURES AND 0.95 CONFIDENCE INTERVAL FOR THE GRADE INDICATED WHEN THE AVERAGE SKIN TEMPERATURE WAS 30.6°C. OR 36.7°C.

PART III

THE INFLUENCE OF SKIN TEMPERATURE ON THE PRODUCTION OF
CUTANEOUS BURNS IN SWINE AT DIFFERENT EXPOSURE TIMES.INTRODUCTION

In the foregoing section it was shown that when the average skin temperature prior to burning was decreased 6°C . more energy was required to produce 2+ and 3+ burns at 0.5 sec. exposure times.

It is of interest (1) to determine whether this result is true also for longer exposure times, and (2) to estimate further increase in energy required when the initial skin temperature is even lower.

Our purpose was primarily to investigate the effect of two different skin temperatures at exposure times of 0.5, 1.0 and 4.0 sec. on the production of 2+ burns.

METHODSEquipment and Material

These are the same as previously described in Part II with the exception that the sides of the animals were divided into three columns and ten rows to provide 30 subareas. In addition to the Dial, animals were given 15 mgm Chlorpromazine intramuscularly.

Experimental Design

Six animals designated group A, were put into a constant temperature room at 15.5°C . one-half to three-quarters hour following induction of anesthesia. The temperature in each of the subareas were measured at frequent intervals and when the skin temperatures in all were below 29°C .

burns were produced in those designated by randomization to receive the exposure.

With the completion of the burns of the cool skin, the ambient temperature was raised to 32° C. When the skin temperatures at the remainder of the subareas rose to 35.8° C. or greater, the remainder of the burns were produced.

In five other animals designated group B, the procedure was reversed, i. e., the subareas were first burned when the skin temperatures were above 35.9° C., and secondly when the skin temperatures were below 29° C. In some cases warming and cooling was accelerated by use of a rubber blanket through which water could be circulated.

Five radiant exposures at each of three times of 0.5, 1.0 and 4.0 sec. and at each of the skin temperature levels were used to determine the 50% effective exposure for 2+ burns. The resulting 30 combinations were replicated 24 times. Each combination fell once on each side of the pig. By systematic randomization there was an equal probability of any combination falling in any subarea.

Evaluation

The burns were graded by the criteria previously described in Part II. In evaluation of the depth of damage histologically, the criterion of transepidermal damage was divided further into four subgroups depending upon the extent of epidermal-dermal separation observed. Separation up to 1/4, 1/2 and 3/4 of the burned area denotes mild, moderate and severe respectively. When almost all the epidermis was separated from the dermis the damage was termed complete transepidermal.

RESULTS

I. The Conditions Existing at Time of Burn Production

Table 5 shows the skin temperatures existing and the time after anesthesia during the period of burning. From this table it is seen that in group A, burns were produced from 1-3/4 to 3-1/4 hours after induction of anesthesia at which time the skin temperatures were below 29° C.; the average skin temperature, 26.5° C.; the average rectal temperature 26.6° C. In the same animals a period of from 4-1/4 to 9 hours after anesthesia elapsed before the skin temperatures rose to above 35.8° C. with change in the ambient temperature from 15.5° to 32° C. At time of burning the average skin temperature was 36.4° C.; the average rectal temperature was 37.7° C.

In the group B burns were produced from 1 hour to 3 hours 50 minutes after anesthesia, at which time the skin temperatures were above 35.9° C., the average skin temperature 36.4° C., the average rectal temperature 37° C. In the same animals from 4-1/2 hours to 8 hours after anesthesia elapsed before the skin temperatures fell to below 28° C. with change in ambient temperature from 32° to 15.5° C. At time of burning the average skin temperature was 26.9° C., the average rectal temperature was 29.9° C.

II. The Effect of Skin Temperature on Burn Production

In tables 6 and 7 are shown numbers and percentages of lesions of a given severity for any radiant exposure, time and average skin temperature. Table 6 shows the results in group A; table 7, group B.

The 50% effective exposures and 0.95 confidence intervals were computed for each group separately. No confidence interval could be determined in group B for the exposure of 0.5 sec. when the average skin temperature was 36.4°C. , because only 0 and 100% responses were observed. The data is summarized in table 8. Groups A and B differ by the sequence of burning. In group A, animals were first burned when the average skin temperature was 26.9°C. and secondly when 36.4°C. In group B, the first burns were produced in subareas of 36.4°C. and secondly in subareas of 26.9°C. In five cases out of six no significant difference in the 50% effective exposures could be detected as a result of the sequence in which burning was done.

When burns were produced in skin of surface temperature of 26.5 or 26.9°C. , 1-3/4 to 3-1/4 or 4-1/2 to 8 hours after anesthesia at exposure time of 0.5 and 4.0 sec., there was no significant difference at the 0.95 level of confidence in the 50% exposures required. There was a significant difference at 1.0 sec. exposures however. When burns were produced in skin of surface temperature of 36.4°C. either 4-1/4 to 9 or 1 to 4 hours after anesthesia, there was no significant change in the 50% effective exposures required. Therefore, in five cases of six no significant difference in 50% effective exposures could be detected as a result of different length of time elapsing following anesthesia in group A or group B. With this evidence, it was felt, justifiable to combine the data of group A and B.

The combined data is shown in table 9, listing the number and percentage of lesions of any given severity for the radiant exposure and average skin temperature existing at the time of burning.

The 50% effective exposures and 0.95 confidence intervals are shown in table 9a and figure 13. It is clearly indicated that there is a significant difference in the 50% effective exposure required to produce a 2+ burn when the average skin temperature is either 26.7° C. or 36.4° C. at each of the exposure times tested. Thirty to forty percent more energy is required to produce a 2+ burn when the initial skin temperature is 26.7° C. than when it is 36.4° C. This can be expressed as the potency ratio of the 50% effective exposures required at the initial skin temperature of 26.7° C. to that at 36.4° C. These are shown in table 10 which indicates that there is no significant difference in these ratios at the 0.95 level of confidence in respect to three exposure times.

Table 10

Exposure Time (sec)	Potency Ratio (0.95 Confidence Interval)
0.5	1.395 (1.22 - 1.59)
1.0	1.31 (1.25 - 1.38)
4.0	1.41 (1.33 - 1.48)

The results of evaluation of biopsied lesions are shown in table 11, listing the number and percentage of lesions of any given severity for the radiant exposure and the average skin temperature existing at the time of burning. The 50% effective exposures and the 0.95 confidence intervals required for the grade of moderate transepidermal damage are shown in table 11a and figure 14. There is a significant difference in the 50% effective exposure required to produce this degree of

injury when the skin temperature is either 26.7 or 36.4° C.; 29 to 36% more energy is required to produce the same degree of damage when the initial skin temperature is 26.7° C. than when it is 36.4° C. This can be expressed as the potency ratio of the 50% effective exposure required at the initial skin temperature of 26.7° C. to that at 36.4° C. These ratios are shown in table 11, which shows the variation from 1.29 to 1.36. However, there is no significant difference in them at the 0.95 level of confidence with respect to time. These results of evaluation of biopsied lesions closely follow those determined by surface appearance.

Table 12

Exposure Time (sec)	Potency Ratio (0.95 Confidence Interval)
0.5	1.33 (1.24 - 1.43)
1.0	1.29 (1.23 - 1.35)
4.0	1.36 (1.36 - 1.43)

DISCUSSION

At the three exposure times, 0.5, 1.0 and 4.0 sec. there is a 30 to 40% increase in 50% effective exposure for 2+ burns with a 10° C. fall in skin temperature. This represents a 3 to 4% increase in energy requirements for each degree Centigrade fall in skin temperature prior to burning in the range studied, although this may not be a linear relationship. These findings were paralleled by the results of evaluation of biopsied lesions. Conversely with an equal amount of energy incident of the skin of two surface temperatures, a much less severe

burn may be expected in the skin of lower skin temperature. The 50% effective exposure to produce a 2+ burn at 0.5 sec. with skin temperature of 26.7°C . is 6 cal/cm^2 , which is ordinarily considered above the 50% effective exposure for 3+ burns (8). By the lowering of skin temperature the severity therefore would be decreased from 3+ to 2+.

The skin temperature conditions existing at the time of burning has made a large difference in the amount of energy required to produce an equivalent burn and is essential information in the laboratory and field studies of thermal burns. The skin temperature variable may be controlled by (1) keeping the ambient temperature constant or (2) measuring the skin temperature prior to burning.

The results of this experiment are not readily explainable. If more energy must be applied merely to raise the initial skin temperature at 26.7°C . to that at 36.4°C ., disregarding exposure time there would be a constant arithmetical difference between the 50% effective exposures for the specified skin temperatures at each of the three exposure times. But this is not so. The difference is 1.7, 1.6 and 2.8 cal/cm^2 for 0.5, 1.0 and 4.0 sec. respectively for 2+ burns and 1.4, 1.6 and 2.5 at these times for moderate transepidermal damage as determined by microscopic examination. Yet, it is reasonable that more energy would be required with the skin of lower temperature than that of higher temperature as shown experimentally, if some maximum temperature must be attained in any position in the skin at any exposure time to produce a 2+ burn.

The protection afforded exposed hands and face in cold climates from burns of atomic explosions as a result of lowering skin temperatures may be considerable. However, it should be remembered that these findings

are in anesthetized pigs and that the rectal temperatures of the animals were also changed. In the conscious state a different set of conditions would exist. Therefore the results of this experiment are not directly referable to humans under combat conditions.

SUMMARY AND CONCLUSIONS

1. (a) The skin temperature of six anesthetized animals given Chlorpromazine fell below 29°C . in 1-3/4 to 3-1/4 hours after anesthesia at an ambient temperature of 15.5°C . With change of room temperature from 15.5° to 32°C . skin temperatures rose to above 35.8°C . in 4-1/4 to 9 hours after anesthesia.

(b) The skin temperatures of five anesthetized animals given Chlorpromazine rose to above 35.9°C . from 1 to 4 hours after anesthesia in an ambient temperature of 32°C . With change of room temperature from 32° to 15.5°C . the skin temperatures fell to below 28°C . from 4-1/2 to 8 hours after anesthesia.

2. When the skin temperature was greater than 35.8°C . or less than 29°C ., the average was 36.4° or 26.7°C . respectively.

3. (a) When 2+ burns were produced in skin of surface temperature below 29°C . either 1-3/4 to 3-1/4 hours or 4-1/2 to 8 hours after anesthesia at exposure times of 0.5 and 4.0 sec., there was no significant change in the 50% effective exposure.

(b) When 2+ burns were produced in skin of surface temperature of 36.4°C . either 4-1/4 to 9 hours or 1 to 4 hours after anesthesia, there was no significant change in the 50% effective exposure required.

(c) Furthermore, the sequence in which burning was done had little effect on the 50% effective exposure of 2+ burns at 0.5, 1.0 and 4.0 sec.

4. (a) There is a 30 to 40% difference in the 50% effective exposure for 2+ burns in anesthetized pigs at exposure times of 0.5, 1.0 and 4.0 sec. when the average skin temperature prior to burning was either 36.4° or 26.7° C. More energy is required when the skin temperatures are lower.

(b) There is a 29 to 36% difference in the 50% effective exposures to produce burns judged moderate transepidermal damage, when the skin temperature is either 36.4° or 26.7° C.

(c) For each degree Centigrade fall in skin temperature there is a 3 to 4% increase in the energy required to produce 2+ burns.

5. Control of skin temperature is of considerable importance in the study of radiant energy burns in the laboratory. Furthermore, a knowledge of the ambient temperature and its effect on skin temperatures is necessary for the proper evaluation of thermal burn studies in the field.

Table 5

Group	Pig	Time of Burning Hrs. Min.	Skin Temperature °C		Rectal Temperature °C	Time of Burning Hrs. Min.		Skin Temperature °C		Rectal Temperature °C
			Range	Average				Range	Average	
A	647R	2 15	27.6-29.0	28.4	31.0	4 15		36.1-36.5	36.3	37.0
	647L	2 30	25.9-27.4	26.9	30.2	4 30		36.0-36.1	36.1	37.0
	648R	1 45	26.1-27.7	26.9	32.0	8 00		36.1-36.9	36.6	38.0
	648L	2 00	25.2-27.1	26.2	32.0	8 15		36.1-36.7	36.4	38.0
	651R	2 30	25.3-26.6	25.8	30.2	9 00		36.2-36.8	36.5	38.0
	651L	2 45	25.0-26.7	26.2	30.2	9 15		36.2-36.8	36.4	38.0
	650L	3 00	25.9-26.9	26.2	30.2	8 15		35.8-36.6	36.2	38.0
	650R	3 15	25.8-26.9	26.3	29.2	8 00		36.1-36.8	36.4	38.0
	654R	1 45	25.5-28.0	26.3	32.0	8 55		36.4-37.1	36.7	38.2
	654L	2 00	24.8-25.9	25.4	30.5	8 35		36.0-36.8	36.3	38.0
	655R	2 15	26.2-27.9	27.0	30.8	8 00		36.1-36.5	36.4	37.2
	655L	2 30	25.0-26.6	25.9	29.5	8 15		36.0-36.4	36.2	37.5
B	659R	1 45	36.2-36.6	36.4	37.0	4 30		26.4-27.1	27.0	29.1
	659L	1 30	36.1-36.7	36.5	37.0	4 40		26.2-27.6	27.1	29.1
	660R	1 15	36.6-37.2	36.9	37.6	5 00		26.1-26.7	26.4	27.7
	660L	1 00	36.7-37.3	36.9	37.6	4 50		26.5-26.9	26.8	27.7
	664R	3 15	36.0-36.6	36.3	36.7	6 30		26.0-27.5	26.8	30.2
	664L	3 00	36.0-36.3	36.1	36.7	6 00		25.8-28.4	26.9	30.8
	665R	2 45	36.1-36.8	36.5	36.7	5 45		26.3-27.9	27.4	29.3
	665L	2 30	36.0-36.4	36.2	36.5	5 30		26.5-27.6	27.1	29.3
	670R	3 40	35.9-36.3	36.1	37.3	7 15		25.6-28.0	26.9	33.0
	670L	3 50	36.0-36.4	36.2	37.3	8 00		26.0-28.0	27.0	32.8

This table shows the time after anesthesia of burning, the average and the range of skin temperatures existing, and the rectal temperature observed in two groups of pigs studied under different ambient temperature conditions at different time intervals after anesthesia.

Table 6
RESULTS OF EVALUATION OF SURFACE APPEARANCE
(Group A)

Skin Temp. (°C)	Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+		Total No. of Exposures
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	
36.4	0.5	3.3	3 (25%)	7 (58%)	2 (17%)						12
		3.6		10 (83%)	1 (9%)	1 (9%)					12
		4.0		6 (50%)	4 (33%)	2 (17%)					12
		4.5		1 (9%)	4 (33%)	5 (42%)	1 (9%)	1 (9%)			12
		5.1		1 (9%)		4 (33%)	1 (9%)	3 (25%)	3 (25%)		12
26.5	0.5	5.0	1 (9%)	8 (67%)	2 (17%)	1 (9%)					12
		5.6		6 (46%)	4 (31%)	1 (8%)	1 (8%)	1 (8%)			13
		6.0		4 (33%)	4 (33%)	3 (25%)	1 (9%)				12
		6.5		5 (42%)		3 (25%)	2 (17%)		2 (17%)		12
		7.0		2 (17%)		4 (33%)		3 (25%)	2 (17%)	1 (9%)	12
36.4	1.0	4.0	1 (9%)	10 (83%)	1 (9%)						12
		4.5	1 (9%)	5 (42%)	6 (50%)						12
		5.0		2 (17%)	5 (42%)	5 (42%)					12
		5.5		2 (18%)	1 (9%)	4 (36%)	1 (9%)	2 (18%)		1 (9%)	11
		6.0			2 (17%)	5 (42%)	3 (25%)	2 (17%)			12
26.5	1.0	6.0		10 (83%)	2 (17%)						12
		6.5		8 (67%)	3 (25%)	1 (9%)					12
		7.0		6 (50%)	2 (17%)	3 (25%)			1 (9%)		12
		7.5		3 (25%)	2 (17%)	2 (17%)	4 (33%)	1 (9%)			12
		8.0		2 (17%)	1 (9%)	3 (25%)	3 (25%)	3 (25%)			12
36.4	4.0	6.0		4 (33%)	7 (58%)	1 (9%)					12
		6.4		2 (17%)	7 (58%)	3 (25%)					12
		7.0		1 (9%)	3 (25%)	6 (50%)	2 (17%)				12
		7.5			2 (17%)	7 (58%)	2 (17%)		1 (9%)		12
		8.0			1 (9%)	2 (17%)	2 (17%)	4 (33%)	2 (17%)	1 (9%)	12
26.5	4.0	8.5		7 (58%)	5 (42%)						12
		9.0		3 (25%)	4 (33%)	4 (33%)	1 (9%)				12
		9.5	1 (9%)	4 (33%)	6 (50%)	1 (9%)					12
		10.0		1 (9%)	6 (50%)	2 (17%)	2 (17%)	1 (9%)			12
		10.5		2 (17%)	2 (17%)	5 (42%)	2 (17%)	1 (9%)			12

This table shows the number and percentage of burns of indicated severity for each combination of skin temperature, exposure time and radiant exposure, produced in the order of cold subareas first, then the warm.

Table 7

RESULTS OF EVALUATION OF SURFACE APPEARANCE
(Group B)

Skin Temp. (°C)	Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+		Total No. of Exposures
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	
36.4	0.5	3.3		9 (90%)		1 (10%)					10
		3.6		8 (80%)	2 (20%)						10
		4.0		8 (80%)	2 (20%)						10
		4.5				2 (20%)	6 (60%)	1 (10%)	1 (10%)		10
		5.1				4 (40%)	4 (40%)	1 (10%)	1 (10%)		10
26.9	0.5	5.0	1 (11%)	6 (67%)		1 (11%)	1 (11%)				9
		5.6	1 (10%)	7 (70%)	1 (10%)			1 (10%)			10
		6.0		2 (22%)	1 (11%)	4 (44%)	2 (22%)				9
		6.5		1 (10%)	1 (10%)	3 (30%)	2 (20%)	2 (20%)		1 (10%)	10
		7.0			1 (9%)	2 (18%)	3 (27%)	2 (18%)	2 (18%)	1 (9%)	11
36.4	1.0	4.0	2 (20%)	8 (80%)							10
		4.5	1 (10%)	7 (70%)	1 (10%)	1 (10%)					10
		5.0		2 (20%)	4 (40%)	4 (40%)					10
		5.5		1 (10%)	3 (30%)	3 (30%)	2 (20%)			1 (10%)	10
		6.0				7 (70%)	3 (30%)				10
26.9	1.0	6.0	2 (20%)	2 (20%)	2 (20%)	3 (30%)	1 (10%)				10
		6.5		4 (40%)	1 (10%)	5 (50%)					10
		7.0	1 (10%)	2 (20%)	1 (10%)	5 (50%)		1 (10%)			10
		7.5	1 (10%)		1 (10%)	1 (10%)	4 (40%)	3 (30%)			10
		8.0		1 (10%)		2 (20%)	3 (30%)	3 (30%)	1 (10%)		10
36.4	4.0	6.0	1 (10%)	1 (10%)	7 (70%)	1 (10%)					10
		6.4	1 (10%)	2 (20%)	4 (40%)	3 (30%)					10
		7.0			3 (30%)	5 (50%)	2 (20%)				10
		7.5			2 (20%)	5 (50%)	3 (30%)				10
		8.0				1 (10%)	5 (50%)		2 (20%)	2 (20%)	10
26.9	4.0	8.5	1 (10%)	3 (30%)	1 (10%)	4 (40%)	1 (10%)				10
		9.0		1 (10%)	5 (50%)	3 (30%)	1 (10%)				10
		9.5	1 (10%)		1 (10%)	5 (50%)	2 (20%)		1 (10%)		10
		10.0		1 (10%)	1 (10%)	4 (40%)	3 (30%)		1 (10%)		10
		10.5			3 (30%)	1 (10%)	3 (30%)	3 (30%)			10

This table shows the number and percentage of burns of indicated severity for each combination of skin temperature, exposure time and radiant exposure, produced in the order of warm subareas first, then the cold.

Table 8

Exposure Time (sec)	Group A			Group B			Significant Difference in 50% Effective Exposure Between A and B
	Average Skin Temperature (°C)	Time After Anesthesia of Burning (hrs)	50% Effective Dose (0.95 Confidence Interval) (cal/cm ²)	Average Skin Temperature (°C)	Time After Anesthesia of Burning (hrs)	50% Effective Dose (0.95 Confidence Interval) (cal/cm ²)	
0.5	26.5	1.75-3.25	6.2 (5.9-6.5)	26.9	4.5-8.0	5.9 (5.6-6.3)	No
	36.4	4.25-9.0	4.4 (4.1-4.7)	36.4	1.0-4.0	4.2	No
1.0	26.5	1.75-3.25	7.4 (7.1-7.7)	26.9	4.5-8.0	6.5 (6.1-6.9)	Yes
	36.4	4.25-9.0	5.1 (4.7-5.5)	36.4	1.0-4.0	5.2 (4.8-5.6)	No
4.0	26.5	1.75-3.25	10.0 (8.5-11.8)	26.9	4.5-8.0	8.4 (7.2-9.8)	No
	36.4	4.25-9.0	6.8 (6.5-7.1)	36.4	1.0-4.0	6.5 (5.9-7.2)	No

This table shows the 50% effective exposures and 0.95 Confidence Intervals for 2+ burns produced at the time after anesthesia stated and the average skin temperature indicated in groups A and B separately. The last column states whether or not there is any significant difference in the 50% effective exposures between the two groups.

Table 9
RESULTS OF EVALUATION OF SURFACE APPEARANCE
(Groups A and B)

Skin Temp. (°C)	Time (sec)	Radiant Exposure (cal/cm ²)	1+			2+			3+		Total No. of Exposures
			Mild	Mod	Sev	Mild	Mod	Sev	Mild	Mod	
36.4	0.5	3.3	3 (14%)	16 (72%)	2 (9%)	1 (5%)					22
		3.6		18 (82%)	3 (14%)	1 (5%)					22
		4.0		14 (63%)	6 (27%)	2 (9%)					22
		4.5		1 (5%)	6 (27%)	11 (50%)	2 (9%)	2 (9%)			22
		5.1		1 (5%)		8 (36%)	5 (23%)	4 (18%)	3 (14%)	1 (5%)	22
26.7	0.5	5.0	2 (10%)	14 (67%)	2 (10%)	2 (10%)	1 (5%)				21
		5.6	1 (4%)	13 (57%)	5 (22%)	1 (4%)	1 (4%)	2 (9%)			23
		6.0		6 (29%)	5 (24%)	7 (33%)	3 (14%)				21
		6.5		6 (27%)	1 (5%)	6 (27%)	4 (18%)	2 (9%)	2 (9%)	1 (5%)	22
		7.0		2 (9%)	1 (4%)	6 (26%)	3 (13%)	5 (22%)	4 (17%)	2 (9%)	23
36.4	1.0	4.0	3 (14%)	18 (82%)	1 (5%)						22
		4.5	2 (9%)	12 (54%)	7 (32%)	1 (5%)					22
		5.0		4 (18%)	9 (41%)	9 (41%)					22
		5.5		3 (14%)	4 (19%)	7 (33%)	3 (14%)	2 (10%)	1 (5%)	1 (5%)	21
		6.0			2 (9%)	12 (54%)	6 (27%)	2 (9%)			22
26.7	1.0	6.0	2 (9%)	12 (54%)	4 (18%)	3 (14%)	1 (5%)				22
		6.5		12 (54%)	4 (18%)	6 (27%)					22
		7.0	1 (5%)	8 (36%)	3 (14%)	8 (36%)		1 (5%)	1 (5%)		22
		7.5	1 (5%)	3 (14%)	3 (14%)	3 (14%)	8 (36%)	4 (18%)			22
		8.0		3 (14%)	1 (5%)	5 (23%)	6 (27%)	6 (27%)	1 (5%)		22
36.4	4.0	6.0	1 (5%)	5 (23%)	14 (63%)	2 (9%)					22
		6.4	1 (5%)	4 (18%)	11 (50%)	6 (27%)					22
		7.0		1 (5%)	6 (27%)	11 (50%)	4 (18%)				22
		7.5			4 (18%)	12 (54%)	5 (23%)		1 (5%)		22
		8.0			1 (5%)	3 (14%)	7 (32%)	4 (18%)	4 (18%)	3 (14%)	22
26.7	4.0	8.5	1 (5%)	10 (45%)	6 (27%)	4 (18%)	1 (5%)				22
		9.0		4 (18%)	9 (41%)	7 (32%)	2 (9%)				22
		9.5	2 (9%)	4 (18%)	7 (32%)	6 (27%)	2 (9%)		1 (5%)		22
		10.0		2 (9%)	7 (32%)	6 (27%)	5 (23%)	1 (5%)	1 (5%)		22
		10.5		2 (9%)	5 (23%)	6 (27%)	5 (23%)	4 (18%)			22

This table combines the data of table 5 and table 6, showing the number and percentage of burns of indicated severity for each combination of skin temperature, exposure time and radiant exposure.

9a

The 50% Effective Exposure and 0.95 Confidence
Interval for 2+ Burns

Exposure Time (sec)	Initial Skin Temperature (°C.)	
	36.4	26.7
0.5	4.3 (3.7-5.0)	6.0 (5.8-6.2)
1.0	5.4 (5.2-5.5)	7.0 (6.7-7.3)
4.0	6.8 (6.6-7.1)	9.6 (9.2-10.0)

Table 11
RESULTS OF MICROSCOPIC EVALUATION
Experiment 2 (Groups A and B)

Skin Temp. (°C)	Time (sec)	Radiant Exposure (cal/cm ²)	Epidermal Damage	Transepidermal Damage				Dermal Damage	Total No. of Exposures
				Mild	Mod	Severe	Complete		
36.4	0.5	3.3	7 (37%)	9 (47%)	3 (16%)				19
		3.6	4 (22%)	11 (61%)	3 (17%)				18
		4.0	2 (11%)	12 (63%)	5 (26%)				19
		4.5	1 (5%)	8 (36%)	10 (45%)	2 (9%)	1 (5%)		22
		5.1	1 (6%)	1 (6%)	6 (33%)	5 (28%)	4 (22%)	1 (5%)	18
26.7	0.5	5.0	4 (19%)	10 (48%)	7 (33%)				21
		5.6	1 (5%)	9 (45%)	7 (35%)	1 (5%)		2 (10%)	20
		6.0	1 (5%)	9 (45%)	8 (40%)			2 (10%)	20
		6.5		4 (18%)	9 (41%)	3 (14%)	1 (5%)	5 (23%)	22
		7.0		2 (10%)	9 (43%)	3 (14%)	1 (5%)	6 (29%)	21
36.4	1.0	4.0	11 (52%)	9 (43%)	1 (5%)				21
		4.5	7 (30%)	15 (65%)	1 (4%)				23
		5.0	4 (19%)	11 (52%)	6 (29%)				21
		5.5	1 (5%)	4 (19%)	7 (33%)	5 (24%)	1 (5%)	3 (14%)	21
		6.0		5 (26%)	9 (47%)	1 (5%)	3 (16%)	1 (5%)	19
26.7	1.0	6.0	5 (26%)	11 (58%)	3 (16%)				19
		6.5	3 (15%)	14 (70%)	3 (15%)				20
		7.0	1 (4%)	8 (35%)	12 (52%)		2 (9%)		23
		7.5	2 (10%)	4 (20%)	8 (40%)	6 (30%)	1 (5%)	1 (5%)	22
		8.0		4 (18%)	14 (64%)	2 (9%)		2 (9%)	22
36.4	4.0	6.0	3 (15%)	11 (55%)	4 (20%)	1 (5%)	1 (5%)		20
		6.4	6 (30%)	9 (45%)	5 (25%)				20
		7.0	2 (11%)	5 (28%)	10 (56%)	1 (6%)			18
		7.5	1 (5%)	5 (25%)	12 (60%)	1 (5%)	1 (5%)		20
		8.0		3 (14%)	4 (19%)	5 (24%)	7 (33%)	2 (10%)	21
26.7	4.0	8.5	3 (17%)	11 (61%)	4 (22%)				18
		9.0	1 (6%)	9 (50%)	8 (44%)				18
		9.5	2 (9%)	4 (17%)	14 (61%)		1 (4%)	2 (9%)	23
		10.0	2 (10%)	6 (30%)	9 (45%)	2 (10%)	1 (5%)		20
		10.5	1 (5%)	7 (32%)	11 (50%)	1 (5%)		2 (9%)	22

This table shows the number and percentage of burns of indicated severity for each combination of skin temperature, exposure time and radiant exposure shown.

11a

The 50% Exposure and 0.95 Confidence Interval
for Moderate Transepidermal Damage

Exposure Time (sec)	Initial Skin Temperature (°C.)	
	36.4	26.7
0.5	4.2 (3.9-4.5)	5.6 (5.3-5.9)
1.0	5.4 (5.1-5.7)	7.0 (6.7-7.3)
4.0	6.9 (6.6-7.3)	9.4 (9.1-9.8)

58

Figure 13

THIS FIGURE SHOWS THE 50% EFFECTIVE EXPOSURE AND 0.95 CONFIDENCE INTERVALS FOR 2+ BURNS PRODUCED WHEN THE AVERAGE SKIN TEMPERATURE WAS 26.7°C. OR 36.4°C.

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Figure 14

THIS FIGURE SHOWS THE 50% EFFECTIVE EXPOSURE AND 0.95 CONFIDENCE INTERVALS FOR TRANSEPIDERMAL BURNS (MODERATE) WHEN THE AVERAGE SKIN TEMPERATURE WAS 26.7°C. OR 36.4°C.

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