A STUDY OF THE APPLICATION AND EFFECTIVENESS OF GERMICIDAL LAMPS FOR REDUCING THE NUMBER OF MICRO-ORGANISMS ON DAIRY UTENSILS

by

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B. S. in Agricultural Engineering
University of Tennessee
1939

A MAJOR THESIS

Submitted in Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE IN AGRICULTURAL ENGINEERING

Virginia Polytechnic Institute
Blacksburg, Virginia

June, 1940

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ACKNOWLEDGEMENT

The author wishes to express his appreciation for the cooperation of all who so willingly contributed toward making this study possible. Members of the Departments of Agricultural Engineering, Biology, and Dairy Husbandry contributed freely of their time and services toward the furtherance of this project. To the following men special acknowledgment is made.

In the Department of Agricultural Engineering: Professors Seitz, Weaver, and Potter.

In the Department of Biology: Professor Orcutt.

In the Department of Dairy Husbandry: Professor Reaves and Mr. Linkous.

Reference is also made to the Westinghouse Electric and Manufacturing Company of Roanoke who loaned equipment essential to this study.

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A STUDY OF THE APPLICATION AND EFFECTIVENESS OF GERMICIDAL LAMPS FOR REDUCING THE NUMBER OF MICRO-ORGANISMS ON DAIRY UTENSILS

INTRODUCTION

Unsterile milk utensils are the major contributing source of micro-organisms in normal market milk (26,36). As a public health protective measure, many health laws require pasteurization of milk, treatments to reduce the number of organisms on milk utensils, and various other precautions which tend to induce sanitation. The dairyman is interested in sanitation from an economic standpoint. High quality milk, which has a low bacterial count, not only controls a higher market price, but through the sale of sanitary milk the dairyman may expect an increased customer consumption.

Milk furnishes ideal conditions for the growth and multiplication of most bacteria. The more desirable bacteria keep certain undesirable bacteria inactive and from their by-products warn the consumer against the use of milk unfit for human consumption. Some of the undesirable types decompose milk and produce bad flavors and odors, while others are harmful from the standpoint of their ability to produce diseases. Large numbers of bacteria tend to reduce the keeping qualities of milk.

In order to keep the bacteria on milk utensils at a minimum, two methods have been used in general dairy practice, namely: (1) chemicals and (2) heat. Chemicals are often used in small dairies where a large initial investment in heating equipment cannot be afforded. They are especially recommended for use on various complicated equipment where heat cannot be practically applied (26). Although some chemicals have a comparatively high germicidal power, it is hard to prevent small amounts left on utensils from being carried over into milk and causing disagreeable tastes. Heat, for treating dairy utensils, is usually applied in the form of hot water, steam, hot dry air, or humidified air. The heat treatment is much preferred to the chemical treatment because it has little corrosive action on the utensils, is much more effective for killing micro-organisms imbedded in particles of organic matter and in the crevices of the utensils, and leaves the utensils clean and free from flavors and odors that might be carried into the milk.

For over 50 years it has been generally known that ultra-violet light possesses a germicidal action (31). Rays from the sun contain a portion of the ultra-violet spectrum and have proved effective in controlling various species of micro-organisms (50). Salle (45) states that ultra-violet light rays have a toxic action on bacteria and that the growth of an organism may be retarded or inhibited entirely, depending upon the intensity and length of exposure to the rays. Hammer (26) states that ultra-violet rays have no selective action on organisms but that there is a greater effect on vegetative cells than on spores. Henrici (28) states that rays between 2,800 and 2,540 angstrom units show the greatest germicidal action. Chick and Browning (18) show that the limit of bactericidal action occurs at a wave-length of 2,960 angstrom units and extends to from 2,400 to 2,150 angstrom units.

Economical means of producing artificial ultra-violet rays have been known for only a few years, but now there are several types of germicidal lamps on the market that are proving effective in controlling micro-organisms under various conditions (1, 3, 4, 5, 6, 7, 9, 16, 17, 19, 21, 22, 23, 25, 26, 27, 30, 31, 33, 35, 44). Most of the germicidal lamps emit the majority of their rays in the 2,537 angstrom band which has proved to be the most effective under practical conditions (31). An additional quality is that the lamp has a low power requirement and operates at low cost. Several institutions have recognized the possibilities of this lamp and are investigating some of its possible applications. With the idea of furthering the assembly of practical information on the possibilities of this lamp and making some contribution toward a more economical electrical method of reducing the number of micro-organisms on dairy utensils this study was originated.

OBJECTIVES

With the foregoing facts in mind this project was planned to accomplish the following objectives:

1. To design and construct an apparatus suitable for applying and utilizing the rays of germicidal lamps for the ultra-violet germicidal treatment of dairy utensils.
2. To determine the effectiveness of germicidal lamps for reducing the number of micro-organisms on dairy utensils.
3. To compare the performance of the germicidal lamp with present practices for treating dairy utensils.

FACILITIES

Germicidal lamps (and accessories) were available in several sizes and in sufficient number to allow consideration of several different arrangements and designs of equipment.

The funds for making this study were supplied as a cooperative agreement between the Bureau of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture and the Department of Agricultural Engineering of the Virginia Polytechnic Institute.

CHARACTERISTICS OF GERMICIDAL LAMP USED

The lamps and their accessories used in this study were a product of the Westinghouse Electric and Manufacturing Company of Bloomfield, New Jersey. Hibben and Blackburn (25) give the following description of the germicidal lamps.

> The Sterilamp* consists of an evacuated tube some one-half inch in diameter and of varying lengths into the ends of which are sealed special metallic electrodes coated with such electron emitting material as barium and strontium oxides, designed to minimize voltage drop. Into the tube is inserted a small quantity of inert gas, or a mixture of gases, which permits ionization at normal room temperatures and thus allows the arc discharge to become established instantaneously when the electric power is applied to the tube terminals, and at reasonable voltage. This starting voltage is in general also a function of the tube length, ranging in the commercial product from some 400 to 800 volts.
>
> In addition, the tube contains mercury vapor at a pressure of from four to ten millionths of an atmosphere-- a pressure which results in the emission of a negligible amount of radiant energy in the visible spectrum but produces the well-known ultraviolet mercury lines, chiefly the 2,537- and 3,650-Angstrom wave lengths. The quality of the special glass of this lamp is carefully selected so as to obtain maximum transmission of wave lengths longer than some 2,000 Angstroms (65 per cent at 2,637 Angstroms) but to ablsorb rather definitely such shorter wave lengths as the 1,850- and 1,940-Angstrom bands.
>
> One of the problems has been to limit the amount of radiations known to react on the atmosphere (oxygen) to produce ozone. This gas in turn may react unfavorably on the membranes of the nasal passages, or have a toxic effect, or may be absorbed by certain materials such as fats and hasten oxidation, or develop objectionable odors and rancidity. It will prevent the transmission of 2,537-Angstrom radiation. Neither are wave lengths much longer than 3,000 Angstroms useful, because such are not as abiotic or would be required in much too great a volume to do the same kind of work as the radiations of shorter wave length...

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* Trade Mark, Reg. U. S. Pat. Off.

Hence it has been logical to restrict the ultraviolet lamps to a low power consumption, usually about six watts per foot of tubing. Moreover, the small diameter of the arc stream relative to its length, and the carefully chosen mercury-vapor pressure, restricts to a negligible amount the output having wave lengths longer than the strong 2,537-Angstrom band. The commercial lamps normally consume 0.03 to 0.05 ampere, or an average of 35 milliamperes. A 20-inch tube operating at 375 volts thus may consume approximately 12 watts, with the temperature of no part rising more than five to ten degrees centigrade above the ambient temperature. The energy emitted in the visible spectrum is of a pleasant light blue color but negligible for any illumination purposes. At some 18 inches from a typical tube the illumination is no more than one foot-candle...

The volume of ultraviolet emission from any particular unit or group of tubes may be controlled by varying the current input through a change of transformer taps, or by the number of tubes in series on one transformer. An uncontrollable influence is that of very cold surrounding air since a condensation of mercury vapor (the pressure approximately 0.4 micron at zero degrees Fahrenheit) normally will reduce ultraviolet output. The vapor pressure is optimum and the radiation is most abiotic when the wall temperature of the lamp is slightly in excess of 45 degrees Fahrenheit. The lamp is designed so that at refrigerated-air temperatures of some 40 degrees Fahrenheit or higher, the output is satisfactory.

As with any gaseous-discharge lamp, these tubes possess negative resistance, requiring a current-limiting device to be used in series. Since the lamp requires a transformer that will deliver a voltage high enough to start the discharge, the current-limiting feature can be incorporated into one unit. From one to four lamps may be operated in series from the secondary of such a transformer, although naturally the current through each tube will vary with the number of tubes. Since the open-circuit secondary voltage in a cold-cathode lamp may be in excess of 1,000 volts, it has been advisable to develop dee porcelain sockets to protect the metal ends of the lamps and to supply a power unit in which is incorporated an undercurrent relay to de-energize the primary circuit upon any interruption of the lamp circuit. For stability of operation, the voltage drop across the lamps represents approximately two-thirds of the equivalent supply voltage.

When dealing with extra-short-wave radiations, reflecting and absorbing materials must be chosen critically. Polished or oxidized aluminum is practically the only suitable reflector, with a coefficient of some 60 per cent at 2,500 Angstroms. Chromium is about equally as efficient. Most ordinary glasses are opaque. Some of the fungi or spores can be killed through several inches of clear water, but for bactericidal purposes the penetration in slightly turbid liquids is extremely shallow.

PROCEDURE

The first step in this study was that of assembling and arranging into a bibliography all available subject matter of germicidal lamps and various processes of treating dairy utensils. The result was a varied assortment of experimental bulletins, textbooks, articles from journals, and manufacturers' literature. Much of this information was available in the college libraries; other material was furnished by manufacturers.

Design of Germicidal Lamp Cabinet

The first objective of this project was that of designing a suitable germicidal lamp cabinet. A number of requirements were kept in mind during the design of the cabinet. Aside from high germicidal efficiency it was considered important to build the apparatus to satisfy the following requirements as much as was practicable:

1. Safe operation and free from fire hazard.
2. Low initial and operating cost.
3. Proper size to provide treatment and storage for the amount of equipment used by the dairy farmer.
4. Sturdy construction.
5. Ease and convenience of operation.

Because the ultra-violet radiation from these lamps was considered harmful to the eyes and skin, it was necessary to install and operate the lamps under conditions which provided adequate protection for the eyes and minimized the time of direct exposure to the skin. To accomplish this protection a cabinet was constructed of plywood. The lamps were arranged and mounted inside the cabinet. A glass observation window was placed in the cabinet to enable the operator to determine the operation of the lamps. Number 14 wire, which had a 5000-volt protective insulation, was used throughout the secondary circuit. Care was taken in wiring all circuits to see that proper connections were made and that no wires were left exposed. All wires inside the cabinet were protected with half-inch rigid conduit to meet the code requirements set up by the National Board of Fire Underwriters. Ordinary 4-inch utility boxes were used as junction boxes for mounting the lamp terminals. A switch was mounted in a handy position on the cabinet so that the lamps could be easily turned on or off. A door switch was placed in the circuit to turn off the lamps when the lid was opened.

The power unit was made up of two transformers, a single pole relay, and a start and stop switch all arranged and conveniently mounted in a suitable metallic box. The primary terminals were arranged for using 110- and 120- volt, 60-cycle alternating current. The secondary terminals were designed to handle a maximum of 3000 volts and 50 milliamperes. This unit was capable of operating as many as eight of the largest size (30-inch) lamps. The proper voltage was controlled by the number of lamps connected in series, and the current was regulated automatically by a device incorporated within the transformer.

The size of the cabinet was adapted to a practical size for the average dairy farmer. This apparatus was designed to treat in one operation two 10-gallon milk cans and several smaller utensils such as lids, pails, and cream separator parts.

Ultra-violet rays coming directly from the lamps are more germicidal than reflected rays; thus it was desirable to design the apparatus so that a maximum amount of utensil surface was exposed to the rays. Rocklath, with a layer of aluminum foil bonded to one side, was used to line the inside walls of the cabinet so that all rays emitted would be reflected within the cabinet. It was believed that milk cans, because of their size, shape, and smallness of neck would offer the most difficult problem of any utensils to be treated; consequently, it was desirable to arrange a scheme for inserting a lamp into each can. Two 20-inch lamps were supported in a vertical position for milk can treatment.

Directly beneath the compartment for treating milk cans a space was provided for treating small dairy utensils. Four 30-inch lamps were installed for this purpose. Two of the lamps were mounted directly beneath the lower tray and about one inch from the bottom of the cabinet. The two upper lamps were mounted about 20 inches higher and gave additional exposure to the milk cans and also aided in treating the small utensils in the space below the lamps.

Two doors were built for the cabinet. One was placed on top and hinged to the back side of the cabinet which provided a means for inserting milk cans into the cabinet. The other door was placed on the front side near the bottom of the cabinet. This opening gave entrance for small utensils into the cabinet.

For complete details of construction see drawings in appendix.

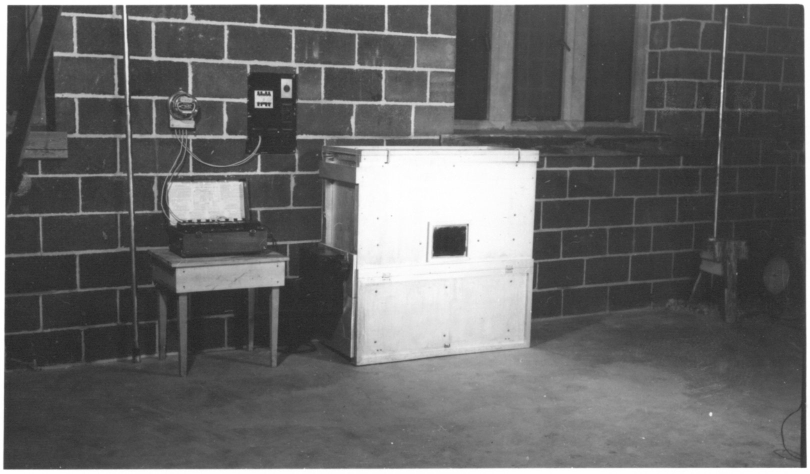

Fig. 1. Cabinet, enclosing six germicidal lamps, for treating dairy utensils.

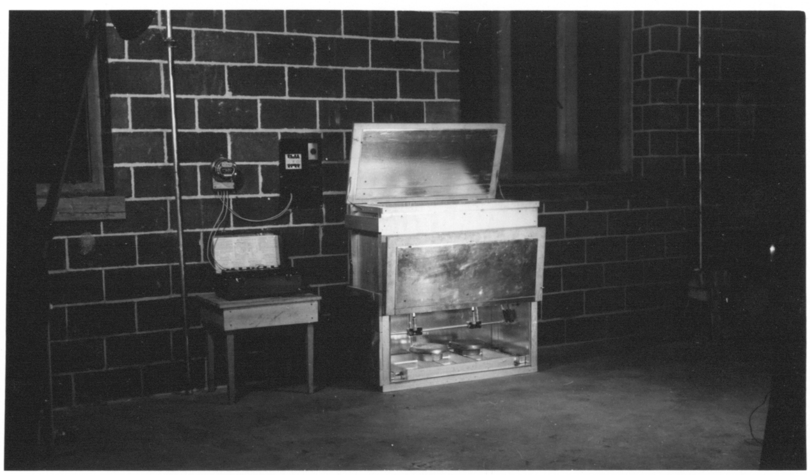

Fig. 2. Cabinet with lid and bottom door raised to show openings for inserting dairy utensils.

Fig. 3. Front of cabinet removed to show location and arrangement of germicidal lamps.

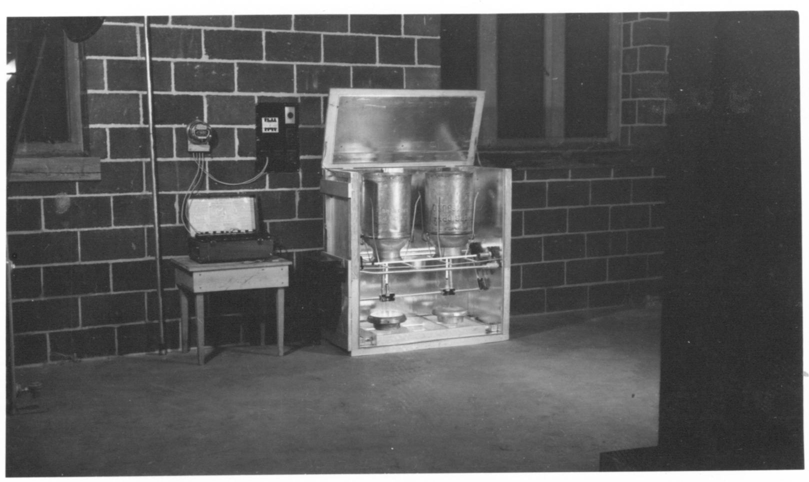

Fig. 4. Front removed to show arrangement of utensils.

Experimental Tests

The second objective of this project was to test the effectiveness of the germicidal lamps for reducing the number of microorganisms on several of the typical dairy utensils. Following preliminary tests, as outlined below, it was believed necessary to duplicate all succeeding tests a number of times in order to get more accurate results. The short time allotted permitted tests only on 10-gallon milk cans. Arrangements were made whereby ordinary milk cans in daily use at the V. P. I. Creamery were obtained for treatment in all tests.

The germicidal lamp cabinet was set up in a small room having a floor drain. This permitted wetting of the floor and walls prior to each test. The purpose of this was to reduce the number of airborne bacteria and to diminish the likelihood of recontaminating the utensils after the ultra-violet treatment and prior to rinsing with sterile water.

Bacteriological Examination of Milk Cans. The methods used in the bacteriological examination were those recommended by the American Public Health Association (10). Following is the procedure recommended for rinsing cans and collecting the rinse solution:

> Insert 100 cc. of sterile water into the can to be testes. Tightly replace the can cover. Lay the can on its side on the floor. Grasp the can under the cover with one hand and under the bottom rim with the other and shake rapidly back and forth ten times through a distance of about 18 inches. Replace the can on the floor, giving it a quarter turn and repeat the shaking process twice more after giving the can quarter turns in the same direction... Collect rinse solution in a sterile container for transfer to the laboratory.

The rinse solution was diluted by transferring one cc. quantities to 9 cc. and 99 cc. sterile water blanks. Likewise, one cc. of the diluted solution was plated using Bacto trypton-glucose-extract-milk agar as recommended by the American Public Health Association (10). The pates were incubated at 37 degrees C. for 48 hours and then counted.

Preliminary Tests. Milk cans, for the preliminary tests, were obtained from the creamery immediately after they had been returned from the milk route. These cans, without further contamination, were washed with warm, soapy water in the usual manner of washing utensils in the creamery and carried to the test room for the ultra-violet treatment. The varied time of exposure and results of the bacteriological examination for these cans are contained in Table I.

Performance Tests. Milk cans, for the performance tests, were divided into two groups. Following is the treatment given each group prior to the ultra-violet treatment.

Group A. The cans in this group were washed with warm, soapy water and treated over a steam jet for 20 seconds. After the cans cooled, a pint of raw milk was added to each, and the cans were allowed to set for 48 hours at an average room temperature of 74 degrees F. At the end of the contamination period, the cans were emptied and washed with warm, soapy water and rinsed with tap water. Table II includes the results of the tests and of the bacteriological examination of this group.

Group B. The milk cans for this group were taken from the

V. P. I. Mess Hall immediately after the noon meal. They, too, were washed with warm, soapy water before the ultra-violet treatment. Results of tests on this group are also shown in Table II.

TABLE I

RESULTS OF PRELIMINARY TESTS ON 10-GALLON MILK CANS

Date of Test	Number of Tests	Length of Exposure (Minutes)	Number of Cans	Standard Method Plate Count* (Ave. of all cans)
4/10-17/40	2	0	2	33,000,000
4/10-17/40	2	3	4	439,800
4/10-17/40	2	5	4	397,800
4/19/40	1	7	1	270,000
4/19/40 -5/4/40	1	10	2	166,700
4/19/40 -5/4/40	1	15	2	36,200
4/19/40	1	30	1	5,600

* Estimated number of organisms per 100 cc. of sterile water used for rinsing each can.

TABLE II

RESULTS OF PERFORMANCE TESTS ON 10-GALLON MILK CANS

Kwhr Meter Reading
Begin 0.0
End 0.9

Date	Test No.	No. of Utensils in test	Treatment prior to Exposure[1]	Length of Exposure (Minutes)	Room Conditions[2]		Electrical Readings			Standard Plate Count[3]	REMARKS
					Temp.	Hum.	Volts	Amps.	Watts		
4/27/40	1	4	A	5	80	30	117.0	2.70	127	2,200,000	Untreated cans in group A had an average std. plate count of 46,000,000 per can.
4/27/40	2	4	A	10	79	28	117.0	2.66	127	418,000	
4/27/40	3	4	A	15	79	33	118.0	2.80	130	443,000	
4/27/40	4	4	A	20	79	31	118.0	2.70	130	1,950,000	
4/27/40	5	4	A	30	78	29	118.0	2.80	130	656,000	
5/10/40	6	1	B	10	86	60	117.0	2.75	127	228,000	Untreated cans in group B had an average std. plate count of 33,000,000 per can.
5/10/40	7	1	B	15	86	60	118.0	2.70	130	35,000	
5/10/40	8	1	B	20	86	60	118.0	2.78	130	94,500	
5/10/40	9	1	B	25	86	60	118.0	2.70	130	14,000	
5/13/40	10	1	B	10	85	60	118.0	2.75	122	326,000	
5/13/40	11	1	B	15	85	60	117.0	2.80	122	43,200	
5/13/40	12	1	B	20	85	60	117.5	2.75	130	39,800	
5/13/40	13	1	B	25	85	60	117.5	2.78	130	18,000	
5/14/40	14	2	B	10	86	35	117.5	2.70	130	273,000	
5/14/40	15	2	B	15	86	35	117.5	2.75	132	33,300	
5/14/40	16	2	B	20	86	35	117.5	2.73	132	36,000	
5/14/40	17	2	B	25	86	35	117.5	2.75	132	9,800	
5/20/40	18	2	B	10	87	64	118.0	2.76	132	540,000	
5/20/40	19	2	B	15	87	64	117.5	2.71	130	423,000	
5/20/40	20	2	B	20	87	64	117.5	2.71	130	99,000	
5/20/40	21	2	B	25	87	64	117.0	2.66	130	38,500	

1. See page 15 ; 2. Temp. (**F°**) and Rel. Hum. (%) during period of exposure; 3. Estimated number of micro-organisms per 100 cc. of rinse water.

DISCUSSION OF RESULTS

Before commenting on the more pertinent facts of this investigation, the author wishes to call attention to the inaccuracies common to investigations of this nature. With the presence of such variable factors as turbidity of wash water, rusty spots on cans, dust film on germicidal lamp tubes, and individual technique in bacteriological examinations, results are not always consistent.

It is interesting to note that the effectiveness of the germicidal lamps for treating milk utensils depends primarily upon the method of applying the rays so that all the interior utensil surface will receive a sufficient amount of ultra-violet rays, during the exposure period to kill the micro-organisms present. In the apparatus studied, the two vertical lamps used for treating the interior of milk cans could probably not give their maximum effectiveness because of the shading effect of the support paralleling each lamp. It was believed in designing the apparatus that a U-shaped lamp would have proved more effective for treating interior milk can surfaces; however, Garrett and Arnold (25) had favorable results with the lamp across the mouth of the can. It was not known until after the cabinet was constructed that U-shaped lamps could be purchased; because of the delay necessary and the fact that no gurantee was made that additional lamps of this shape could be purchased, the attempt to use them in this study was abandoned.

The purpose of the preliminary tests run on 10-gallon milk cans was to obtain some idea of the performance of the germicidal lamps.

The milk cans were exposed to the rays for varying lengths of time, the results of which show that the bacterial reduction is proportionate to the length of time of exposure.

All of the results from the performance tests show that there is a definite germicidal action of the ultra-violet rays on micro-organisms residing on milk cans. The plate counts of the cans which were artificially contaminated (Group A) were very inconsistent but showed that the rays had a germicidal action. This inconsistency was probably caused by contamination which occurred during the bacteriological examination. The milk cans which had been in use under actual dairy operations (Group B) gave very consistent results. Cans in this group which were exposed for 25 minutes gave an average standard plate count of 20,000 organisms. The American Public Health Association (10) states that 10-gallon milk cans should not have an average standard plate count higher than 40,000.

Another interesting feature shown in the performance tests is the low power consumption. The total wattage of all lamps in the cabinet was approximately 130. In one group of tests the lamps were on 405 minutes and consumed 0.9 kilowatt-hours, which shows that the lamps will operate 7.5 hours on one kilowatt-hour of electricity.

Comparison of Ultra-violet Treatment With Other Methods

A number of physical and chemical agents have been used for treating dairy utensils, but at present the most widely used treatments probably are steam, hot water, hot air, and chlorine compounds. The effect of the germicidal lamp on bacteria is considerably different from either the heat treatment or the chemical treatment; nevertheless, it is classified as a physical agent (15, 45, 50) and consequently has certain characteristics in common with many types of apparatus for treating dairy utensils with heat. In making a comparison of the performance factors of the ultra-violet method of treating dairy utensils with the other methods it is seemingly appropriate to consider the following points:

Requirements of Apparatus for Reducing the Number of Micro-organisms on Dairy Utensils. Theophilus and Atkeson (51) suggest that any apparatus for treating dairy utensils should meet the following requirements:

1. High sterilizing* efficiency.
2. Low operating cost.
3. Sturdy construction.
4. Low original cost.
5. Easily cleaned and operated.
6. Sterilizing process completed quickly.
7. Leave the utensils dry at the end of the sterilization process.
8. Produce no undesirable odors or dirt.
9. Produce hot water for washing purposes.
10. Proper size for amount of equipment to be sterilized.
11. Safe and free from fire hazard.

Swink and Beane (49) made a comparative study of electric equipment for treating dairy utensils. Their comments are summarized as follows:

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* Sterilizing, as used in this quotation, indicates the reduction of bacteria to an insignificant number.

1. Humidified hot air sterilizer.

    (a) The sterilizer is simple in construction and fool-proof in operation, assuring a positive job of sterilization.
    (b) Commercially manufactured models are comparatively high priced, ranging from $175 for the four can size upward.
    (c) The simplicity of design and construction make it possible for any carpenter or tinsmith to build a sterilizer of this type at the place where it is to be operated.
    (d) Efficient in operation.
    (e) Provides ideal storage space for utensils.
    (f) Does not provide means of heating water.
    (g) Flexible in size so that the sterilizer can be built to suit the needs of any size dairy.
    (h) If homemade, the cost is comparatively low.

2. Combination electic dairy water heater and sterilizer.

    (a) Takes care of two separate and necessary jobs at the dairy: heating water and sterilizing equipment.
    (b) Comparatively low in first cost. (Can be built for $60.00 locally or $125.00 commercially.)
    (c) The size of the equipment limits its use to retail dairies of not over 12 cows, and wholesale dairies of not over 20 cows.
    (d) Not so efficient in operation.
    (e) Can be automatically operated by a thermostat to assure proper sterilization temperature but the utensils must be removed while hot for drying.

3. Electric heated steam boiler.

    (a) Provides hot water for washing and steam for sterilizing.
    (b) First cost $175.00 and up, depending on size.
    (c) Not manufactured in the east at present.
    (d) Cannot be built at the dairy advisedly because of dangers involved in high steam pressures.
    (e) Requires long period of time for making steam, therefore, would not provide for emergency demand.

4. The steam generator.

    (a) The sterilizer, as it is, can be used for single utensils such as buckets, cans, etc.
    (b) Its use must be limited to small wholesale dairies, or as an auxiliary sterilizer in larger dairies.
    (c) Purchase cost is low, cost is $18.50, complete.
    (d) Cheap to operate.
    (e) Requires no special wiring.
    (f) Can be used for heating small quantities of water.

5. Humidified hot air sterilizer (home-made).

   (a) The controlled humidity type sterilizer does a positive job of sterilizing utensils.
   (b) The size of the sterilizer can be varied and designed to meet the needs of any size dairy.
   (c) The cost of materials for constructing the sterilizer built for this study was approximately $58.00.
   (d) An operating temperature of 180 degrees maintained for 30 minutes is the most practical and economical and will insure thorough sterilization.
   (e) This type of sterilizer does not provide means of heating water...

Eight commercially manufactured sterilizers and water heaters and one home-made sterilizer were studied by Theophilus and Atkeson (51). They summarize their findings as follows:

> All proved efficient in sterilization when operated according to directions. Cabinet or steam box types were most efficient for all types of utensils, but were limited in capacity. Steam jet sterilizers were not as limited in capacity for such utensils as cans and pails, but were not well adapted to the sterilization of strainers, separator parts, and other smaller utensils. A combination of the cabinet and open jet had the widest adaptation.
>
> Electricity, compressed natural gas, gasoline, and kerosene were sources of heat involved in the study. Electricity proved to be most convenient, cleanest, freest from odors, and to have the least fire hazard, but the electric sterilizer was the highest in cost of operation. Compressed natural gas was cheaper and quicker in operation than electricity and ranked next to electricity in the other factors mentioned. Gasoline and kerosene were the cheapest sources of heat, but the sterilizers produced objectionable fumes, were harder to clean and represented greater fire hazard. Gasoline as a source of heat was superior to kerosene...
>
> Chemical sterilization is suggested as an alternative method or supplement to steam sterilization.

Fosson and Notis (42) discuss various methods of treating dairy utensils. They state the following in relation to the steam jet:

> Utensils such as cans and pails may be treated to kill bacteria by inverting them over a steam jet, but this system is not recommended because there is no way of knowing the temperatures reached and thus making sure that the heat applied has been sufficient to kill bacteria. More care must be taken in drying the utensils, and there is more temptation for the operator to slight his work...
>
> The effectiveness of the steam jet depends upon the steam pressure used, the size of the opening through which the steam is ejected and the length of time the utensils are steamed. It usually requires about half a minute to steam a 10-gallon can thoroughly if the steam pressure is 20 to 25 pounds. If a steam jet is used, the utensils should be steamed until they are too hot to handle with the bare hands. After treatment in this manner they will become dry from their own heat if placed right side up and left uncovered for a few minutes before they are inverted on the rack.

With the available information and data on methods and equipment for killing bacteria on dairy utensils the following table is arranged.

TABLE III

COMPARISON OF ULTRA-VIOLET TREATMENT WITH OTHER METHODS

Method	Costs		Effectiveness	Safety and Convenience	Hot Water Production	Adaptation to Average Farm	Storage Space	Power Requirements
	Initial	Operating						
Humidified Hot Air Sterilizer	$175	High	High	Good	No	Yes	Yes	1.5 kw.
Comb. Water Heat. & Sterilizer	125	Med.	Med.	Good	Yes	Yes	Yes	3 to 5 kw.
Elec. Steam Boiler	175	Med.	High	Good	Yes	Yes	Yes	1.5 to 2 kw.
Steam Generator	18.50	Low	Poor	Fair	Limited	No	No	1 kw.
Humidified Hot Air Sterilizer (Home-made)	115	Med.	High	Good	No	Yes	Yes	3 kw.
Chlorine Comp.	None	Low	Med.	Fair	No	Yes	No	None
Germicidal Lamps	125	Very low	Med.	Fair	No	Probable	Yes	130 Watts

CONCLUSIONS

In formulating conclusions from this study of the performance of germicidal lamps for treating dairy utensils, it is admitted that possibly in some instances only tendencies are indicated and that further investigations on certain phases of the problem are necessary to warrant definite statements of fact. Particular attention is directed to the inconsistency of the bacterial reductions by the ultra-violet rays. The present study, however, seemingly warrants the following conclusions:

1. The bactericidal effectiveness of the lamps depends principally upon the design of the apparatus for applying the lamp rays.
2. Exposure periods of 25 minutes reduce the number of micro-organisms below the maximum that is suggested by the American Public Health Association. Periods shorter than this do not reduce the organisms sufficiently.
3. One of the disadvantages of the ultra-violet treatment is that it has little penetrative power and possibly is not very effective in killing bacteria imbedded in milk particles and crevices of the can.
4. Although germicidal lamps have the advantage of very low operating costs, they have the disadvantage of high initial costs.

5. From this study it was believed that a more practical design could be built which would be more convenient to use.
6. Germicidal lamp tubes should be cleaned frequently with a moist paper towel because a thin film of dust on the tubes reduces their germicidal action a considerable amount.
7. Replacement of the vertical lamps with U-shaped lamps will probably give a more favorable reduction of organisms and cut down on the length of the period of exposure.

SUGGESTIONS FOR FUTURE STUDIES

There is a very definite need for more information relative to the application, peration, and effectiveness of the ultra-violet process of reducing the number of micro-organisms on dairy utensils. With the facilities already on hand, it appears that further studies are justifiable. The author wishes to suggest the following as possible investigations:

1. Study of designs more applicable to practical dairy farm conditions.
2. Study of the reliability of the ultra-violet process of reducing the number of micro-organisms on dairy utensils.
3. The effect that rust spots, unsoldered seams, and other utensil blemishes have on the reduction process.
4. The practicability of using a U-shaped lamp for treating the interior of certain dairy utensils.

APPENDIXES

APPENDIX I

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BIBLIOGRAPHY

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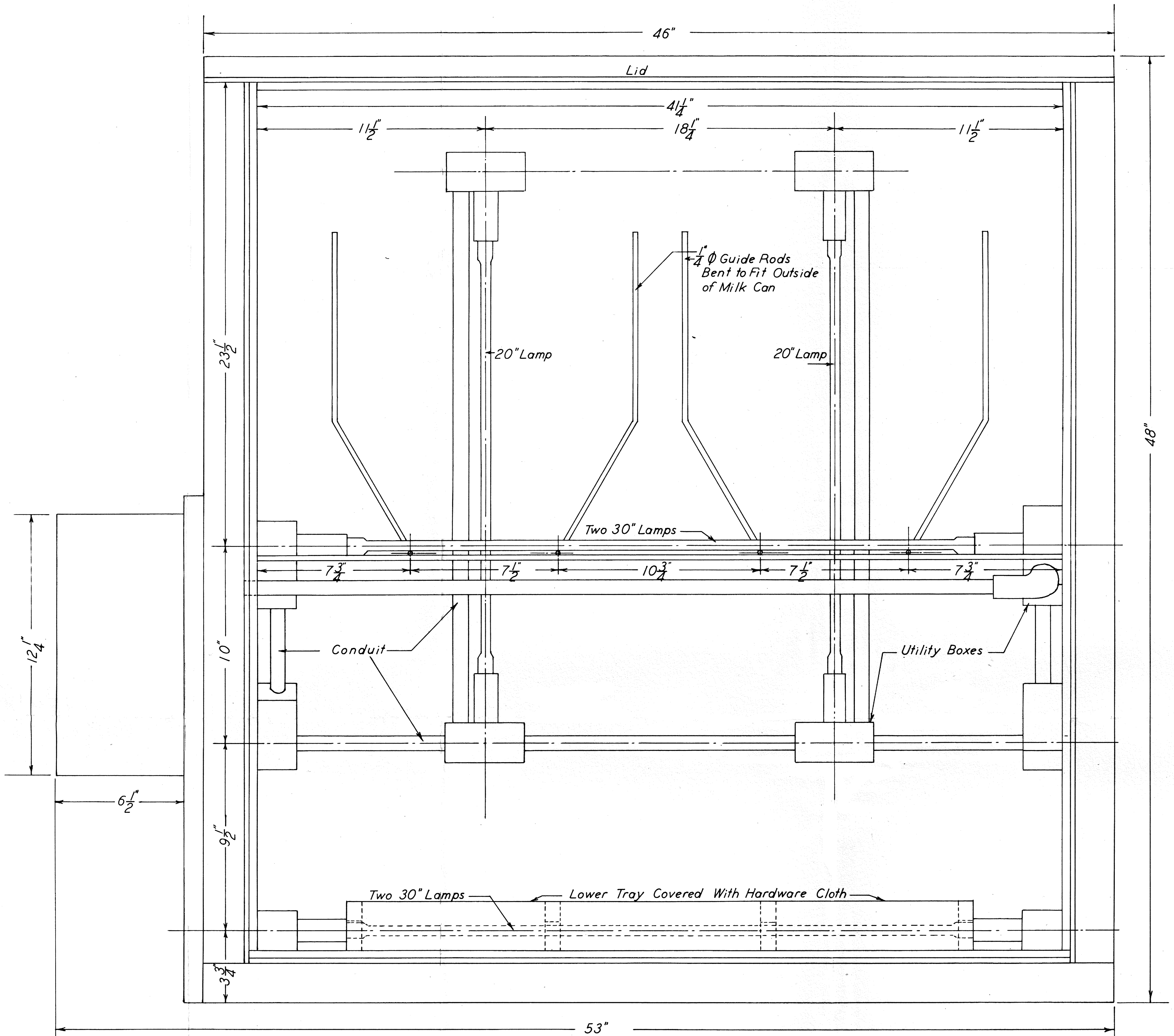
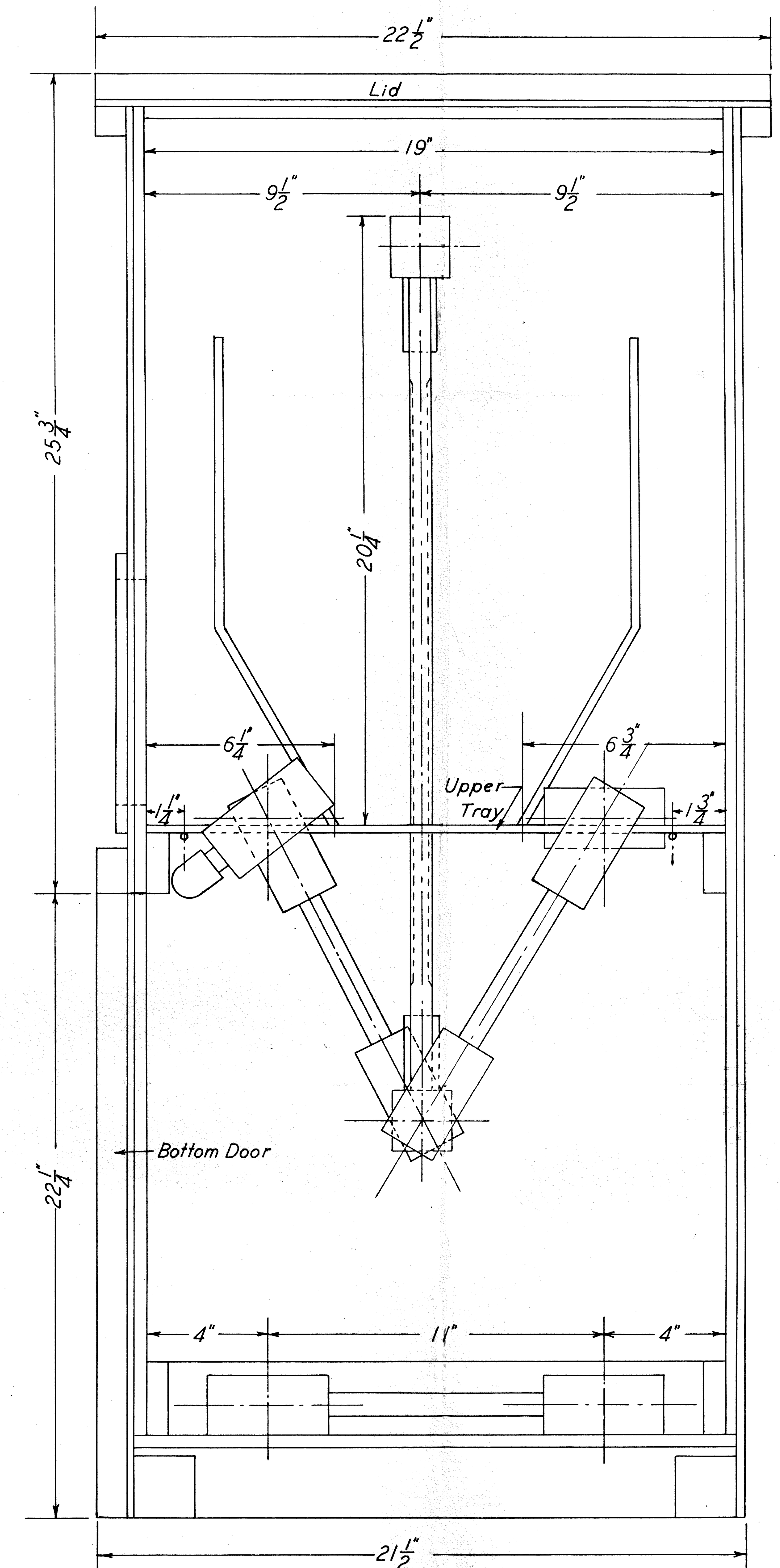
APPENDIX II

WORKING DRAWINGS OF GERMICIDAL LAMP CABINET

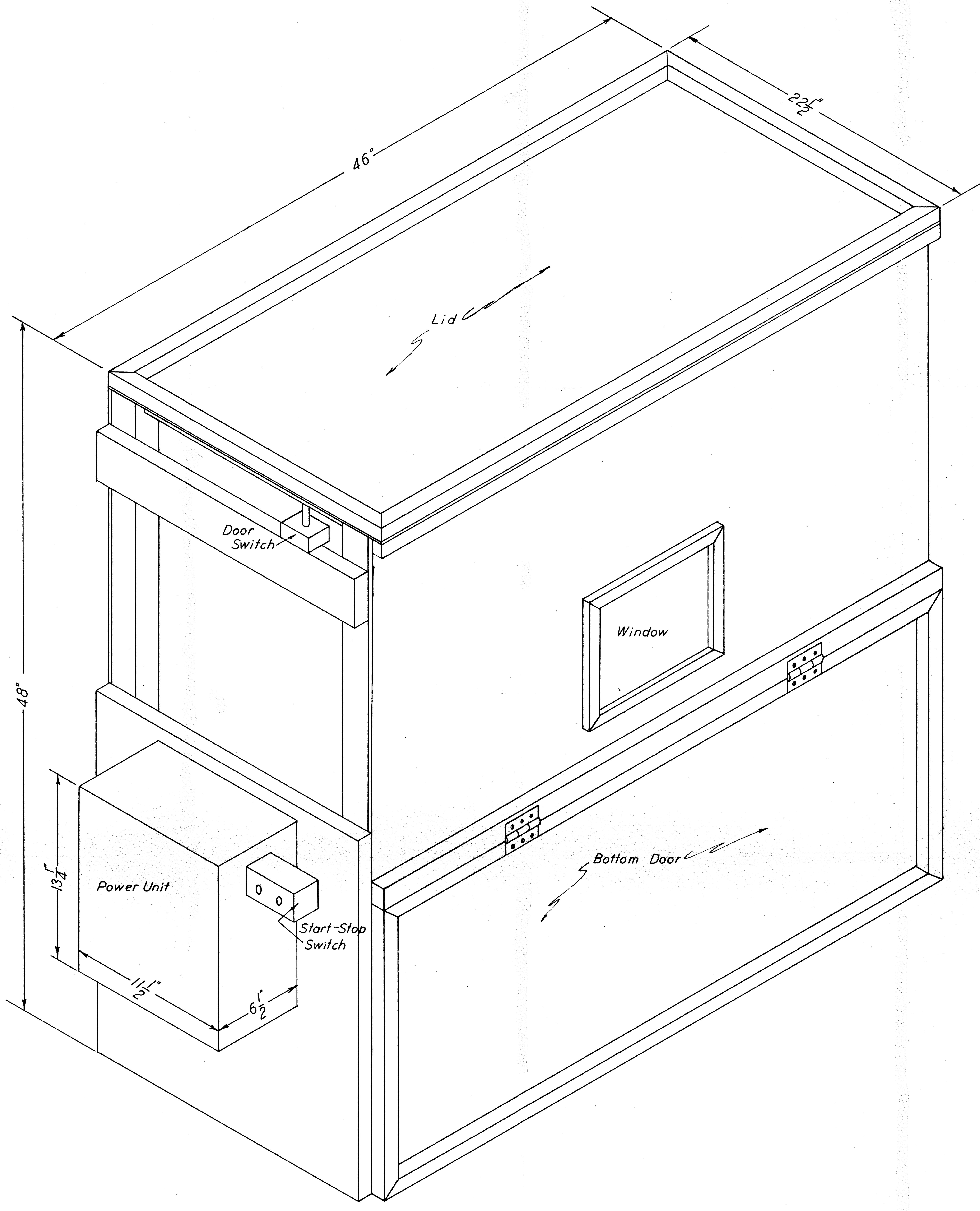


INTERIOR FRONT VIEW
Scale: 3/8" = 1"



INTERIOR RIGHT END VIEW
Scale: 3/8" = 1"

DETAILS OF GERMICIDAL LAMP CABINET	AGRICULTURAL ENGINEERING DEPT. VIRGINIA POLYTECHNIC INSTITUTE BLACKSBURG, VIRGINIA.		
	Drawn: C.G.B. Traced: C.F.W.	Sheet 1 of 2	May 28, 1940



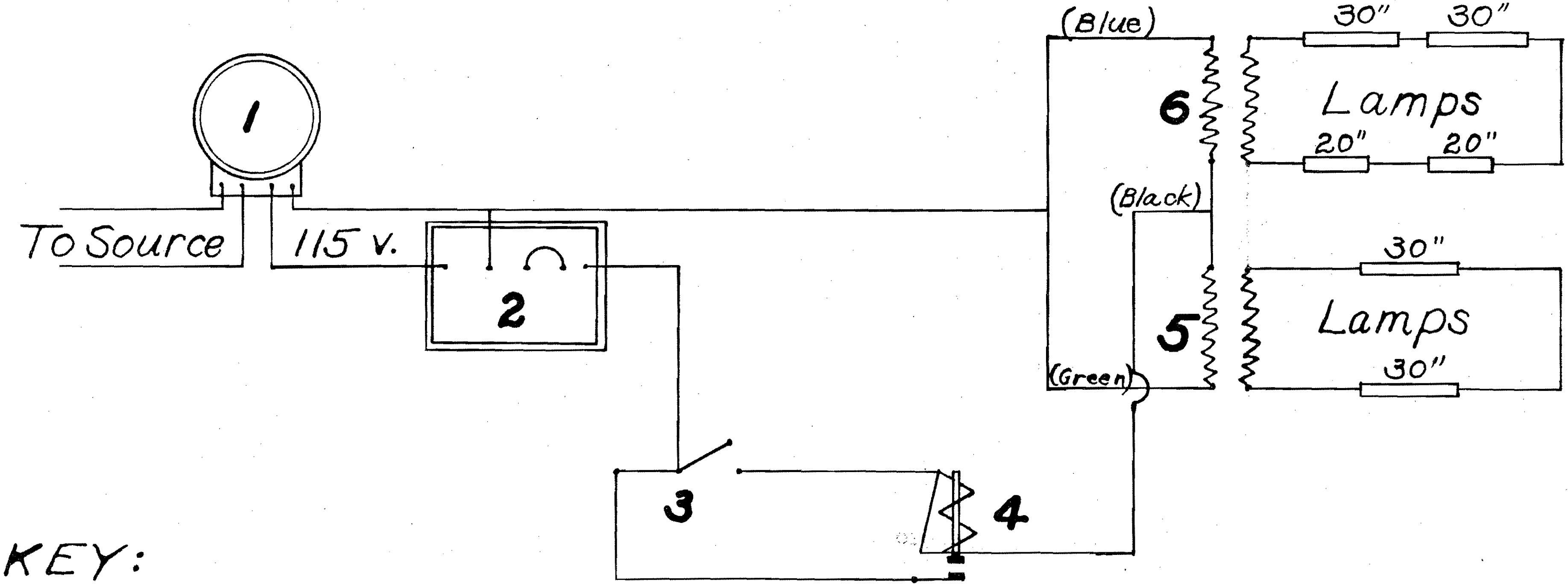
EXTERIOR ISOMETRIC VIEW
Scale: 1/4" = 1"

ISOMETRIC VIEW OF GERMICIDAL LAMP CABINET	AGRICULTURAL ENGINEERING DEPT. VIRGINIA POLYTECHNIC INSTITUTE BLACKSBURG, VIRGINIA.		
	Drawn: C.G.B. Traced: C.F.W.	Sheet 2 of 2	May 28, 1940

APPENDIX III

WIRING DIAGRAM

WIRING DIAGRAM



KEY:

1. Kilowatt-hour meter.
2. Industrial analyzer.
3. Start-Stop switch.
4. Single-pole magnetic relay
5. & 6. Transformers.

Dairy Utensil Sanitization
With Germicidal Lamps
Drawn By
Charles G. Burress
May 13, 1940