80
2/14/80
ENERGY

DR. 947

SAN-1166-1

LITEK LAMP EVALUATION PROGRAM

MASTER

October 1978
Date Prepared

Work Performed Under Contract No. EY-76-C-03-1166

Lighting Technology Corporation
Burlingame, California

U. S. DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy \$8.00
Microfiche \$3.00

LITEK LAMP EVALUATION PROGRAM
Contract EY-76-C-03-1166 Mod A003

Prepared:
October, 1978

Submitted:
July, 1979

Prepared By:

LIGHTING TECHNOLOGY CORPORATION
801 Mahler Road
Burlingame, CA 94010

ef
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

Section Title	Page
Summary of Program Results	1
Experimental Study	4
Lampmaking	16
Lamp Efficiency Measurements	18
Lumen Maintenance Measurement	21
Harry Diamond Laboratory Data	28
Lamp Emission Observation	31
Conclusions	38
Appendix A: RFI Test Report	A
Appendix B: Part 18, FCC Rules and Regulations	B

ILLUSTRATIONS

Figure	Title	Page
1	Experimental Observation of Lumen Output Versus Input RF Power	3
2	Original Experimental System	5
3	Calibration of Transmission Line System	9
4	Transmission Line System Calibration Curve	11
5	Photographs of Sphere Assembly	12
6	Initial Observation of RF Efficiency	15
7	Superposition of HDL and Litek Observations	17
8	Expanded Test Results	20
9	Views of Lumen Maintenance Facility	22
10	Schematic of Lumen Maintenance Facility	23
11	Lumen Maintenance Observation	25
12	Lumen Maintenance Curves	24
13	Incandescent Lamp Operating Characteristics	27
14	HDL Lumen Output Versus RF Power	29
15	HDL Luminous Efficacy Versus RF Power	30
16	HDL Relative UV Output Versus RF Power	32
17	Photographic View of Shielded Test Fixture	35
18	Photographic View of Isolation Network	36

FINAL REPORT

Contract No. EY-76-C-03-116

October 6, 1978

Summary of Program Results

As has been reported earlier, many severe technical problems have caused considerable delay in obtaining any early results from this technical effort. Toward the end of July it was recognized that repeated lamp failures and consistently observed poor lamp efficiencies as well as the non-reproducibility of experimental observations were, at least in part, synergistically related symptoms of a more basic problem. Specifically, the transmission line connecting the rf generator to the plasma induction circuitry within the integrating sphere was necessarily of considerable length because of the physical layout of that part of the laboratory in which the sphere is located. This long line was found to take part in the resonance phenomena taking place at its terminal end. Indeed, the line reactance was found to dominate the determination of the discharge characteristics which were the subject of the measurement.

The transmission system was re-examined in terms of what the actual experimental requirements were. It was then redesigned and reinstalled in the sphere and found to perform satisfactorily. The system was then calibrated and subsequently was in continuous use until the end of this program.

The test results have been much better than those forecast. Electrodeless lamp efficiencies have been measured with values ranging between roughly seventy to ninety lumens per watt of rf power delivered to the lamp's resonant induction coil, over a range in rf power between about ten and thirty-five watts. The interesting portion of the lumens versus power curve (i.e. between 1500 and 1760 lumens) contains reproducible data points

above 85 lumens per watt and only a few points below 80 lumens per watt. In this region the scatter in data is less than $\pm 10\%$ from the value at 85 lumens per watt. These experimental data are graphically presented in Figure 1.

Lumen maintenance observations were recorded over an 1800 hour period and yielded a depreciation of less than ten percent, indicating that the LITEK lamp is not as heavily loaded as it once was believed to be. Projections based on these observations indicate total feasibility of LITEK lamp operation both at the original design goal of 1500 lumens and at the higher level of 1750 lumens, over periods up to 10,000 hours.

The development of 400 volts MOSFETs by at least three semiconductor manufacturers has made it possible to consider LITEK lamp system operation feasible at 70%-80% electronic efficiency. Thus, while this program excluded any circuit development activities, it did enable some component evaluation which clearly indicated a high success potential for these new high voltage field effect transistors in the LITEK lamp application.

An evaluation of the FCC Rules and Regulations applicable to the LITEK lamp was performed and the lamp itself was tested for RFI by an independent FCC approved testing laboratory. The results showed that the interference potential of the LITEK lamp is relatively small and the lamp almost qualifies for operation outside the ISM bands at the present time.

From these observations these conclusions have been drawn:

1. A properly coated and filled electrodeless fluorescent lamp is intrinsically efficient.
2. There is not, nor has there been, a coupling problem except when a long transmission line was improperly employed. Then, the line dominated the observation.

46 0703

K&E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFTEL & ESSER CO. MADE IN U.S.A.

Output
Lumen
Total

FIGURE 1: EXPERIMENTAL OBSERVATION OF LUMEN OUTPUT VERSUS INPUT RF POWER.

3. Operation of a LITEK lamp at 1500 lumens output with less than 25 watts of raw AC input is inevitable. Further, operation is highly probable at or near the 1760 lumen level with 25 watts input; or equivalently, at the 1500 lumen level with about 21 watts input.

4. The lumen maintenance of an A-25 LITEK lamp will be superior to the lumen maintenance of a common "heavily loaded" fluorescent lamp; thus, a preliminary estimate of LITEK lamp (i.e., glass part) life can be inferred from fluorescent lamp data: 9000-10,000 hours.

5. The interference potential of a LITEK lamp is low. Operation in the ISM band at 13.56 Mhz is appropriate and legal. Bulb shielding by means of a tin oxide coating is effective.

Experimental Study

The original experimental system is schematically depicted in Figure 2. The poor lamp performance reported by this organization during this program was observed with this system. As reported, the key symptoms were measured efficiencies on the order of 40-50 lumens per rf watt, and evidence of poor coupling. For example, a lighted lamp going dim when one's hand touches it is evidence of very strong capacitive effects being present when no such effects should be present, hence very poor coupling must exist to the magnetically excited discharge.

Although an impedance match, as evidence by negligible observable power reflections on the transmission line, could be effected by the proper choice of suitable L-C combinations at almost any level of applied power, it became obvious that the poor efficiency observed with the test lamps in the distributed system resulted from a cause other than a simple impedance mismatch.

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF LIGHTING TECHNOLOGY CORPORATION, AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, LIGHTING TECHNOLOGY CORPORATION RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THERETO.

LITEK

LIGHTING TECHNOLOGY CORP.

PREPARED BY	DATE	PREPARING ACTIVITY	PROJECT OR MODEL
CHECKED BY	DATE	TITLE OR SUBJECT	
APPROVED BY	DATE	Original Experiment 1 System - Fig 2	SHEET OF DOCUMENT OR REPORT NO.

The problem, which was not recognized by LITEK personnel for a very long time, had been that the transmission line connecting the rf power supply system to its lamp load is identically part of the resonant load circuit, such that measurements of lamp rf efficiency were inclusive of transmission line effects, source-line-load impedance variations, as well as the anticipated L-C and coupling efficiency effects.

It was found that the transmission line effects dominated the measurement of lamp efficiency because of impedance variations along the length of transmission line between source and load. The results obtained depended on line length, frequency and the L-C ratio employed, and to a less than desirable extent, upon the lamp.

A series of "superficial" tests employing a small transmitter coupled to the lamp load through a transmission line made from RG8/U Cable, which was made progressively shorter yielded the result that lamp efficiency improved, at fixed input power, as the line length was decreased, even though the L-C cable termination and frequency remained fixed. Then, when the power input to the lamp was varied with a fixed length transmission line the data in the following table were obtained:

P_i	P_r	ΔP	FC	L	LPW
32.5	18.5	14	79.0	796.3	58.99
35	21	14	83.5	841.7	62.35
40	25	15	89.4	901.2	62.58
45	29.9	15.1	94.5	952.6	65.70
50	33	17	98.6	993.9	61.73
30	16.5	13.5	75.3	759.0	58.38

where:

P_i = Indicated Incident power

P_r = Indicated Reflected power

$\Delta P = P_i - P_r$

FC = Detector reading (footcandles)

L = Total lumens

LPW = Luminous efficacy

The only significant change taking place with an increase of applied power at the cable/load interface is an increase in amplitude of the incident rf. Since the plasma load impedance depends on its exciting rf, it is clear that the total terminating impedance of the transmission line (i.e. the plasma load) must be varying with variations in the applied rf power level. Since the efficiency of power transfer to the lamp was shown as above to depend upon this impedance level, it became clear that the measurement being attempted included the transmission line as an integral part of the resonator, and the poor efficiencies that had been observed necessarily resulted from the long line dictated by the physical size of the integrating sphere. That is, large transmission line currents are necessary if the line is part of the resonant circuit, and large transmission line currents have associated fields which are detected by the in-line wattmeter, and such large currents (i.e., powers) involve substantial line losses. Such effects obviously are minimized when a short line is employed.

Additionally, it had been observed that the presence of outside skin currents was evidenced on the transmission line. Such currents result from use of a balanced load, such as the LITEK lamp, with an unbalanced line, and they are largely responsible for radiation losses from coaxial systems. Since it is virtually impossible to quantify such radiation losses in terms of power, load efficiency measurements such as those attempted in this exercise involved inclusion of the radiation loss in power delivered to the load, as the skin currents cannot be detected by the in-line wattmeter. The following symptoms were reviewed:

- a. Large transmission line losses;
- b. Evidence of radiation loss from the coaxial line;
- c. Evidence of transmission line participation in the actual determination of the effective values of resonator capacitance and Q ;

- d. Evidence of strong capacitive effects in the lighted electrodeless lamp (i.e., visible dimming when one's hand touches the lamp);
- e. Very poor observed efficiency in lamp light output.

During this study it became quite clear that the transmission line was dominating the experiment by its very presence. A brief but intensive review of the properties of transmission lines suggested that employment of a half wave section of line would enable the transfer of the load impedance effectively to the source end of the line where presumably a shunt stub could be employed to properly adjust the effective impedance level of the load end of the line. This "solution" only made the problem worse; indeed, so much capacitance was introduced by the $\lambda/2$ line that no value of series capacitor could be found which would simultaneously enable lamp ignition (through quasi-series resonance) while resonating at 13.56 Mhz.

The problem was clearly one of isolation of the load from the line and the elimination of unbalanced line to balanced load skin currents on the coaxial transmission line. An appropriate balun transformer (i.e., balun is a psuedo-acronym for a balanced line to unbalanced line transformer) was therefore specified. Excellent line-to-load isolation was required, and a unity impedance transformation appeared desirable because a considerable backlog of information was available which involved a Z_0 of 50Ω coupled to the electrodeless lamp load. An appropriate device was obtained and inserted in the line. The $\lambda/2$ line was retained.

Calibration of the feed system was effected by means of a flat, noninductive resistor (53.7Ω) connected to the line through the balun as in Figure 3. The peak-to-peak rf voltage across the resistor was recorded oscillographically for observed conditions of incident and reflected rf power. Data were reduced to form the quotient of the square of the RMS voltage across the resistor and the resistance value of 53.7Ω . This was plotted against the

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF LIGHTING TECHNOLOGY CORPORATION, AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, LIGHTING TECHNOLOGY CORPORATION RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THERETO.

LITEK

LIGHTING TECHNOLOGY CORP.

PREPARED BY	DATE	PREPARING ACTIVITY
CHECKED BY	DATE	TITLE OR SUBJECT
APPROVED BY	DATE	Fig 3 - Calibration of Transmission Line System

PROJECT OR MODEL

SHEET
OF

DOCUMENT
OR REPORT NO.

difference between indicated incident and reflected rf power, as shown in Figure 4. The observed relationship was found to be linear, and can be expressed by

$$P = 0.552 (W + 2.6)$$

where W is the indicated difference between incident and reflected rf power, and P is the actual dissipation. Scope traces were measured with a pair of dividers, taking values between voltage peak extremes to assure that any measurement errors would be on the high side. Likewise, the skin depth in the resistor at the calibration frequency was such that the whole resistor volume is known to have participated in the recorded dissipation. The total uncertainty in the final power calibration is distributed as follows:

Value of resistance	0.6Ω	1.117%
Wattmeter reading	0.25 watts	1.400% @ 20W actual
Scope trace (total)	0.10 divisions	2.128% @ 20W actual
Total uncertainty.		4.645%

This calibration indicated that the balun transformer is quite inefficient, in general agreement with the opinions of several amateur radio operators who were familiar with similar devices. It also proved that the former experiments had little meaning in terms of light production efficiency because of the profound influence of the line on the laboratory observation of rf power.

The transmission line/balun assembly was transferred to the integrating sphere. A Y-shaped structure was fabricated to accommodate the electrodeless lamp on one branch and an incandescent standard on the other branch, as shown in Figure 5. The sphere containing the structure was calibrated via NBS 9380 and NBS 10144 incandescent standards at the following illumination levels.

NBS 9380	.517ADC	120VDC	80.7FC	867L
NBS10144	.827ADC	120VDC	144.6FC	1537L

FIGURE 4: TRANSMISSION LINE SYSTEM CALIBRATION.

FIGURE 5 Photographs of Sphere Assembly

The uncertainty in this calibration is distributed as follows:

Ammeter readings	0.25%
Voltmeter readings	0.25%
Illumination meter	2.00%
Standard uncertainty	1.00%
TOTAL	3.5%

The calibration factors determined above were as follows:

869 Lumens	80.7 FC	10.7683 L/FC
1537 Lumens	144.6 FC	10.6293 L/FC

In view of the above 3.5% overall uncertainty, the sphere transfer function was chosen intermediate to the above values: 10.70 lumens per foot candle.

The test set up contains an inductance of $3.75\mu\text{H}$ formed by 13.5 turns of AWG#20 enameled copper wire on a Teflon form of 0.925" diameter with a pitch of 20 T/inch. A combination of silver mica capacitors yielded 37.75 pf. which was wired in series with the inductance across the balun output. The ringing frequency $f_0 = 13.4$ Mhz of these elements was increased to 13.56 Mhz by the discharge. There was no evidence of skin currents on the transmission line, nor were capacitive effects observed when the lighted lamp was touched.

The initial experimental observation employing this system configuration is presented in Table I. Applied power ranged from 12 watts to 37.1 watts with lumen outputs observed between 923 and 2066 lumens respectively. The maximum efficiency was observed at 14.6 watts: 77.5 lumens per rf watt. The total uncertainty in these figures is 8.15%. The experimental record is presented in Figure 6.

TABLE I
INITIAL TEST DATA, LAMP #282

P ₁	P ₂	A P	P	FC	L	LPW
38	1.5	36.5	21.5	138.2	1478.7	68.8
34	1.25	32.75	19.5	129.3	1383.5	70.9
31	1.25	29.75	17.8	122.6	1311.8	73.7
27	1.5	25.5	15.5	109.2	1168.44	75.4
22	3	19	12	86.3	923.4	77.0
25.5	1.75	23.75	14.6	105.7	1131.0	77.5
30	1 ⁺	29	17.5	120.8	1292.6	73.9
36	1.25 ⁺	34.75	20.6	134.9	1443.4	70.1
40	1.5	38.5	22.6	143.2	1532.2	67.8
42	1.75	40.25	23.5	148.2	1585.7	67.5
44	2	42	24.5	151.0	1615.7	65.9
46	2	44	25.6	155.5	1663.9	65.0
48	2	46	26.7	160.0	1712.0	64.1
50	2.25	47.75	27.7	163.8	1752.7	63.3
52	2.25	49.75	28.8	167.5	1792.3	62.2
54	2.50	51.50	29.9	169.4	1812.6	60.6
56	2.50	53.5	31.0	172.3	1843.6	59.5
58	3 ⁺	55	31.8	177.2	1896.0	59.6
60	3.75	56.25	32.5	180.9	1935.6	59.6
65	4.5 ⁺	61.5	35.4	187.0	2000.9	56.5
70	5.5	64.5	37.1	193.1	2066.2	55.7
25	2	23	14.2	99.0	1059.3	74.6
26	1.75	24.25	14.9	103.6	1108.5	74.4
28	1.5 ⁺	26.5	16.1	111.0	1187.7	73.8
30	1.5	28.5	17.2	116.9	1250.8	72.7

Calibration:

NBS 9380	0.517A	120V	80.7FC	869L	10.77 L/FC
NBS 10144	0.827A	120V	144.6FC	1537L	10.63 L/FC

The lamp employed in this initial measurement was lamp No.282, a test lamp fabricated during the initial ERDA contract. It was fabricated at the same time as were the lamps provided by Dr. Colin Willet of Harry Diamond Laboratories, and the performance of this group of lamps is expected by LITEK to be approximately equal. The data from this measurement are superposed on the data supplied by HDL in Figure 7. The agreement is seen to be quite good, the widest difference (on a watt-for-watt basis) being about 6% at 37 watts input. The HDL data were verified by the National Bureau of Standards so the above close agreement serves as an excellent independent check in the calibration of LITEK's experiment.

Lampmaking

The earlier lamps, fabricated in Southern California, were formed of hard glass and coated with an equal mixture of Cool White and Warm White phosphors in an ethyl cellulose lacquer. Lamps fabricated in the new facility in the Bay Area are made of standard ribbon blown soft glass forms and employ Cool White Phosphors in a nitrocellulose lacquer. As is known, many problems have existed in our lamp fabrication activity since the move to Burlingame took place. Indeed, only a few good lamps have been made in the new facility.

The actual cause for this was isolated by elimination of all other probable causes. Essentially, for purposes of economy in this program at the time of its redirection on June 10, 1977, the lamp fabrication activity had to be given a low priority by this organization because lampmaking was not a significant part of the redirected program. The expense of an air conditioned and dehumidified lampmaking facility could not be justified within the constraints of the funding available, since no particular effort toward the perfection of the lampmaking procedure was called for in the new contract modification.

FIGURE 7: SUPERPOSITION OF HDL AND LATEX OBSERVATIONS

HDL Δ

LATEX ○

It is now realized that the priority placed on the lampmaking activity was altogether too low. Most current lamps evolve water vapor when operated with even moderate loading. The water is transferred into the lamp during its coating process through both ad-and absorption processes in the Al_2O_3 binding agent employed to aid phosphor adhesion to the glass wall. Normal lehring does not remove all the water. Sorption proceeds continuously in the high relative humidity of LITEK's glass laboratory.

The lamps employed in the test program thus far were found to be moderately free from sorbed water. They are all imperfect in this respect. However, they are the best lamps available at the present time and are about twenty percent more efficient than the earlier samples formed of hard glass.

Lamp Efficiency Measurements

All lamps in this testing sequence were operated identically and no variations in experimental procedure are known to exist.

A lamp under test was placed on the Teflon coil form within the integrating sphere and operated at a level of 12 to 13 watts of input rf power for a period of thirty minutes before any test data were taken. This established the baseline thermal environment for the experiment for both amalgam lamps and pure mercury lamps. This procedure was chosen because any of the lamps thus far examined has a range of operating levels where efficiency is highest. It is believed to be very important to enforce comparative measurements to begin at the same operational level, in order that reproducibility of data be possible.

Input power was advanced in small increments, most often in steps of two watts (indicated). The incident and reflected power levels were recorded, as was the reading (in footcandles) of the sphere's photodetector. Power increases were provided until the meter readings indicated that the lamp efficiency had decreased to a value no longer of interest. Both the wattmeter and the

balun corrections to the observed power difference (i.e., incident minus reflected power) had been placed in a HP-65 program, as had been the integrating sphere transfer function, so the observational data were numerically reduced. Previously, hand calculations confirmed the accuracy of the numerical reduction.

The overall results of these measurements were presented in Figure 1. For better visibility the interesting part of these observations is presented in greatly expanded form in Figure 8. To aid in visualization of these results the loci of three constant efficacy relations have been superposed at 70, 80, and 90 lumens per rf watt. Also two of the Harry Diamond Lab supplied data points, and LITEK's equivalent data are included to demonstrate that, in spite of the lampmaking problems experienced during the recent year, a significant measured improvement in lamp performance has been derived from the present effort.

An examination of Figure 8 in the region between 1500 lumens and 1760 lumens will show that almost all of the observational data fall in an efficiency band between 80 and 90 lumens per rf watt. This is highly significant because the cool white phosphors employed in all of the test lamps are not particularly efficient, as is well known, and this performance was observed with lamps known to be flawed because of the sorption of water discussed previously. Additionally, no attempt was made to operate any lamp at its optimum loading, although an optimum operating point is known to exist for any electrodeless lamp, because time was not available to discover the "optimum" operating point for any of these lamps. Thus, the inescapable conclusion must be drawn that the efficiencies reported herein are at least what one can expect from an electrodeless fluorescent lamp. It is quite probable that, once the contamination of water vapor is removed from the lamp, a serious effort to enhance lamp performance can be undertaken. Earlier work suggested that, with cool white or similar phosphors, the realizable efficiency should be of the order of 118 lumens per rf watt. It would appear that such performance is within reach

FIGURE 8: EXPANDED TEST RESULTS.

Lumen Maintenance Measurement

Lumen maintenance of an electrodeless lamp was evaluated for a test duration of 1800 hours between 17 July, 1978 and 30 September, 1978. Lamp No. 280, which was one of the handblown lamps from the original program and which contained a mercury-indium charge with a 1.25 torr backfill of argon, was employed for this test.

Power was supplied by a Gonset transmitter which fed a series L-C load in which the inductance was 7.70 μ H and the capacitance was 18.0 pf. Feeding was through a length of RG 8/U coaxial cable in which was inserted a Bird in-line directional wattmeter.

Throughout the observation period the indicated power (incident power minus reflected power) was held fixed at 14.5 rf watts. The discharge was maintained within a light-tight box of dimensions 16" X 16" X 24" with a thick interior coating of MgO, and an opaque baffle was positioned between the lamp and the detector so that direct illumination of the detector was prevented. Photographic views of the facility are presented in Figure 9, and the experiment is schematically shown in Figure 10.

The box and detector were calibrated against NBS Standard Lamp No. 9380, and its transfer function was determined to be 22.06 lumens per indicated footcandle.

During the observational period data were collected on a daily basis during the work week, and often on weekends and holidays.

Toward the end of August the system was shut down to enable the upgrading of its performance. Shortening of the transmission line to 24" and retuning of the system were found to enhance light output by 18%. The test was continued at the improved performance level. Prior to the shut down the detected illumination indicated a light output of about 618 lumens with an indicated input power of 14.5 watts. Afterwards, the indicated light output was 728 lumens at 14.5 watts input.

FIGURE 9 Views of Lumen Maintenance Facility

THE INFORMATION DISCLOSED HEREIN WAS ORIGINATED BY AND IS THE PROPERTY OF LIGHTING TECHNOLOGY CORPORATION, AND EXCEPT FOR RIGHTS EXPRESSLY GRANTED TO THE UNITED STATES GOVERNMENT, LIGHTING TECHNOLOGY CORPORATION RESERVES ALL PATENT, PROPRIETARY, DESIGN, USE, SALE, MANUFACTURING AND REPRODUCTION RIGHTS THERETO.

PREPARED BY	DATE	PREPARING ACTIVITY	LITEK LIGHTING TECHNOLOGY CORP.	
CHECKED BY	DATE	TITLE OR SUBJECT		
APPROVED BY	DATE	Fig. 10 Schematic of Lumen Maintenance Test Facility	SHEET OF	DOCUMENT OR REPORT NO.

The observed lumen maintenance is plotted in Figure 11. Actual observations are indicated by open circles. The early observations were adjusted to enable correlation with the observations made after August 29. These adjusted data points are indicated by crosses.

The digital readout of the illumination meter consisted of only two digits, hence the precision of the measurement was only one footcandle out of about thirty-five. It was found that a loss of 66 lumens out of an initial 772 occurred after 1800 hours of operation, or roughly 9%.

The total phosphor coated surface area of lamp No. 280 is 43.41 in². The indicated arc watts per unit surface area is 0.33. Figure 12 presents lumen maintenance curves for typical cool white fluorescent lamps. From Figure 12b it is seen that 0.33 watts per square

Fig. 12. Lumen maintenance curves for typical fluorescent lamps as a function of: (a) hours operations and (b) incident radiant power density on the phosphor surface.

inch falls between "medium" and "heavy" loading, and one would expect lumen depreciation of about 13% after 3000 hours of operation. Extrapolation backwards from the 87% point at 3000 hours in Figure 12a indicates a loss of about 9% at 1800 hours, in agreement with the depreciation observed with lamp No. 280.

The developmental LITEK lamp employs the common cool white mixture of calcium halophosphate phosphors because such phosphors are inexpensive and easy to obtain. No decision has been made regarding the choice of phosphors for the production model of the LITEK lamp, although it has become apparent that the new narrow band phosphors* may be ideally suited to this application, yielding both higher efficacy and better color rendering than the halophosphates, and also being amenable to higher-than-usual loading during operation to enable a longer lamp life under heavy loading.

The LITEK lamp is a moderately loaded fluorescent lamp if the bulb is selected to be of the A-25 size and operation is such that 17.5 rf watts produces the 1500 lumen design goal. The total phosphor coated surface area of the ribbon blown A-25 LITEK lamp, including the internal reentrant section, is 45.69 in², and the phosphor loading at the design operating point is 0.38 arc watts per square inch of phosphor surface.

With reference to Figure 12b the 1500 lumen LITEK lamp is seen to fall at about the 84% point. Thus, the light output of a LITEK lamp after 3000 hours of operation would be expected to be 84% of its initial value, or about 1260 lumens, roughly that of a 75 watt incandescent lamp.

*L.E. Vrenken, Real Energy Saving Fluorescent Lamps, Jour. IES 7, 154 (1978)

Elevation of LITEK lamp initial lumen output to 1750 lumens has been shown to be easily done. In this case the arc watts must increase to 20.6 watts and the phosphor loading will rise to 0.45 arc watts per square inch. The 3000 hour light output will then be 82% of the initial value, or 1435 lumens, and the 10,000 hour value will be 1103 lumens.

An interesting comparison between projected LITEK lamp lumen depreciation and that of the garden variety incandescent lamp is afforded by examining Figure 13, in which the lumen output of an incandescent lamp is pre-

sented as a function of the burning time of the lamp. In the case of the common, short life 100 watt lamp it is seen that at the 750 hour point (i.e., at 100% of the rated life) the lamp's lumen output is reduced to about 82%, or about 1420 lumens. The longer

life lamps (1480 lumens, 2500 hour), which are now becoming popular in the residential sector, will be producing 1214 lumens at 2500 hours, while at 750 hours (i.e., at 30% of the rated life) the lumen depreciation is only 8%, yielding 1306 lumens, which is hardly distinguishable from the 750 hour value of 1420 lumens of the short life lamp.

FIGURE 13

Typical operating characteristics of incandescent lamps as a function of burning time.

Harry Diamond Laboratory Data

HDL submitted a draft report to DOE in September, 1978, describing their efforts on this program. This HDL report is not available for inclusion in the present document, however. The following information was supplied verbally by Dr. Colin Willet of Harry Diamond Laboratory.

Electrodeless lamp light output was measured by HDL as a function of rf power input to the lamp. Power was supplied by a Heathkit transmitter which fed a tuned load through a Bird in-line directional wattmeter. The values of the load L-C components were: $C=45\text{pf}$, $L=3.9\mu\text{H}$ (1" diameter form). For Lamp No. 235 the following data were reported:

rf power (watts)	lamp output (lumens)
12.0	980
21.0	1450
22.0	1500
30.0	1880
34.0	2050
36.5	2180
37.0	2200
40.0	2250
41.5	2270
42.5	2300

These data are presented in Figure 14. The ratio of lamp output to rf power input at any point is a measure of the rf efficiency of the lamp under test as a function of applied rf power. This has value of 81.7 lumens per rf watt at 12 rf watts input and 59.5 lumens per rf watt at 37 rf watt input. The curve tends to flatten out at higher input power levels and efficiency falls off significantly with additional power input. The efficiencies taken from the above table are plotted in Figure 15. The change in efficiency at input power in excess of 37 watts is prominent.

FIGURE 14

FIGURE 15

HDL also investigated the relative ultraviolet output of an uncoated quartz lamp in an attempt to explain the fall-off in coated lamp efficiency with increasing rf power. The observation was such that reversal of the emission group at $\lambda 2537$ could be identified. The reported relative intensity at $\lambda 2537$ and the applied rf power are tabulated below:

Power (rf watts)	Relative intensity
12.5	0.60
14	0.64
15	0.65
23	8.84,1
27	1.10
30	1.24
35	1.37
38	1.50

These data appear in Figure 16. The discontinuity in relative UV output at 23 watts input is not understood, but the data points at the higher input powers are either linearly related, as indicated, or form a curve which is slightly concave upward. In either case the UV production efficiency does not appear to degrade with increasing rf power, hence the decrease in light production efficiency with increasing power in the previous observation of lamp No. 235 must be due to phosphor related effects; specifically, the sharp decrease in lamp efficiency at 37 watts input could be indicative of the saturation of the phosphors by the incident UV at the indicated power level.

Lamp Emission Observation

Tests, as prescribed in Volume II, Parts 15 and 18 of the FCC Rules and Regulations, were conducted toward the end of this program on various LITEK lamp structures by Electro-Service Manufacturing Corporation, an independent testing laboratory authorized by both the FCC and the UL. The tests, originally scheduled for late August, were delayed for reasons given in the cover letter appended to the Electro-Service test report which was received by Lighting Technology Corporation on September 28, 1978.

FIGURE 16

The regulations governing all applications such as the LITEK lamp are contained in the FCC Rules and Regulations, Volume II, Part 18: Industrial, Scientific and Medical Equipment. This document is appended hereto for convenience in reference. Particular attention is called to the definitions in Paragraph 18.3(d) and (f); the assigned ISM frequencies listed in Paragraph 18.13; Subpart H: Miscellaneous Equipment; and Subpart E: Medical Diathermy Equipment, in which the specific rules and requirements for the LITEK lamp are stated.

From the above, the basic requirements for LITEK lamp operation at 13.56 Mhz are as follows:

frequency stability: $\pm$ 6.78 KHz

spurious emission: 25 μ v/m @ 1000 ft.

At an operating frequency of 13.56 Mhz, it is seen that operation of a LITEK lamp may be without regard to the type of power of emission being radiated, and likewise for the first two harmonics respectively at 27.120 Mhz and 40.680 Mhz. The next and all higher harmonics must be constrained to produce less than 25 μ v/m at a distance of 1000 feet or more, as are any spurious emissions.

The Electro-Service test report, appended hereto in its entirety, indicates that, for the LITEK lamp devices tested, all signals investigated would meet the limitations specified in Part 18 of the FCC Rules and Regulations, except the fundamental, independent of the fact that an assigned ISM frequency was employed. Thus, the devices tested are legal in their present form, if the frequency tolerance of 0.05% is maintained at the ISM frequency of 13.56 Mhz.

The shielding effectiveness of the various coatings on the electrodeless lamp envelopes tested appears to be fairly well established by Electro-Service's measurements, but the proper grounding of a shielded lamp's surface was found to be essential. For example, lamp No. 386 had a relatively wide mouth, and therefore didn't

fit properly into the base to enable its tin oxide coating to be grounded. This lamp was seen to radiate a full 25% more fundamental frequency energy than the uncoated reference lamp No. 276. The cause for this, while not known with total certainty at this time, most likely is due to capacitive coupling of rf energy to the lamp's outer equipotential surface, and the resulting creation of a larger more efficient electric dipole antenna than was the induction coil itself. The lamp with a copper film coating, on the other hand, produced less than half the fundamental frequency emission produced by the uncoated reference lamp. Indeed, the fundamental frequency emission from this lamp (1335 v/m @ 25') was only 33.5% higher than the FCC limit for spurious emission.

Emission measurements employing the shielded fixture yielded an emission observation at the fundamental frequency approximately ten percent lower than that observed with the standard fixture, when unshielded lamps were employed. Harmonic radiation, however, was higher at every observed frequency. This well-shielded fixture is shown in Figure 17, and its isolation network is

presented in Figure 18. The electronics package of this unit was one of the original unpackaged discrete units supplied by Beckman Instruments which may be somewhat rich in harmonics.

The observation of emission from a coil excited by an external rf source indicated that five to six times the radiation is produced by this apparatus in excess of that observed to emit from a packaged power supply. Roughly one third of this derives from the balun transformer, as indicated by the balun radiation measurement. The reported results suggest no concrete reason why the coaxially driven system should be a more efficient radiator than is the packaged system. However, the effects of reflected energy from the balanced load into the balun may be a significant contributor to the high observed emission in view of the fact that an impedance mismatch was indicated by the presence of reflected power during the lamp-associated measurement that was absent during the resistive load calibration.

FIGURE 17: PHOTOGRAPHIC VIEW OF SHIELDED TEST FIXTURE.

FIGURE 18: PHOTOGRAPHIC VIEW OF ISOLATION NETWORK.

It is believed that, although no LITEK system was available that was assembled with emission suppression in mind, DOE's suggestion of this RFI test was a very good idea because baseline figures are now available with which to scope the extent of RFI potential of the LITEK lamp. The use of a conductive film over the lamp's surface was found to be quite effective in the suppression of emission when the film is properly grounded. Otherwise, in the absense of a properly grounded film, the coating appears to enhance emission. It therefore is recognized that a properly coated lamp must be conductively attached to its shielded base to be effective.

The relatively low value of emission observed in the case of the standard fixture employing the well grounded lamp is very encouraging because it suggests that there is much less of an RFI problem than had earlier been anticipated. That is, except for the lamp coating, nothing had been done to this system to suppress interference, and the system, as is, was found to almost satisfy the FCC requirements outside the ISM band.

The effects of harmonics, on the other hand, have not yet been adequately examined. The shielded fixture is known to be free of line conduction effects, yet the attenuation of emission from a standard lamp using this fixture was only about 10% relative to the emission value observed in the case of the standard fixture and standard lamp. The rich harmonic content of the signal generated by the shielded fixture suggests that the source of this emission must be within the electronics package, because the harmonics are generated in the circuit, not in the lamp. The substitution of the screw-in socket within the shielded fixture for the Beckman power supply and the replacement of this supply with the standard LITEK fixture should have been done, but the importance of this additional measurement was not recognized until the data were being examined, after the tests were completed.

Conclusions

During the period between June 10, 1977 and September 30, 1978 the credibility of the LITEK lamp was severely and thoroughly examined, both within this project and elsewhere.

The program at Lighting Technology Corporation was intended to prove or disprove the veracity of the LITEK principle through the results of a series of relatively uncomplicated, simple experimental measurements that were suggested by the Department of Energy. This program yielded results that are very favorable to the LITEK lamp.

The parallel program at Harry Diamond Laboratories, also supported by the Department of Energy, had an identical purpose and yielded similar results.

The conclusions drawn from this study were presented in the Summary and are repeated below:

1. A properly coated and filled electrodeless fluorescent lamp is intrinsically efficient.

2. There is not, nor has there been, a coupling problem except when a long transmission line was improperly employed. Then, the line dominated the observation.

3. Operation of a LITEK lamp at 1500 lumens output with less than 25 watts of raw AC input is inevitable. Further, operation is highly probable at or near the 1760 lumen level with 25 watts input; or equivalently, at the 1500 lumen level with about 21 watts input.

4. The lumen maintenance of an A-25 LITEK lamp will be superior to the lumen maintenance of a common "heavily loaded" fluorescent lamp; thus, a preliminary estimate of LITEK lamp (i.e., glass part) life can be inferred from fluorescent lamp data: 9000-10,000 hours.

5. The interference potential of a LITEK lamp is low. Operation in the ISM band at 13.56 Mhz is appropriate and legal. Bulb shielding by means of a tin oxide coating is effective.

APPENDIX A

Electro-Service Manufacturing Corporation

240 MAIN STREET-P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

Sept. 28, 1978

Mr. Donald D. Hollister
LIGHTING TECHNOLOGY CORPORATION
801 Mahler Road, Suite D
Burlingame, California 94010

Gentlemen:

Attached herewith you will find the documented results of testing performed at our facility on your RF excited light bulb(s). I believe you will find the results favorable.

It should be noted that all signals investigated would meet the limitations specified in Part 18 of the F.C.C. Rules and Regulations, except the fundamental. Also, it should be noted that the shielded bulbs we tested did not provide any means of grounding the envelope shield. It would be my guess that this will significantly alter the radiation characteristics of these units in a manner which would prove them to be more favorable.

One of the priority test modes was one in which the envelope was excited by the standard LITEK coil, driven by an external RF source. While the results of this test are of concern and interest, I question the validity of the results. The actual circuit impedance, made up of the LITEK coil and its associated tuning capacitor, is unknown, and hence, to properly match it to a standard 50 ohm line through a 1:1 balun, may or may not provide optimum results. As indicated in the last test, the balun and coaxial line are quite capable of radiating considerable energy, even when terminated in a matched load. Possibly a more effective test would be to completely shield the balun, which currently has no shielding, in an effort to reduce the error produced by this element. Also of great interest, would be a test bed made up of the LITEK standard shielded supply, in combination with several shielded envelopes, this time utilizing an effective grounding scheme. This test would effectively provide what could be considered optimum results.

Sincerely yours,

Steven R. Pease
Chief Engineer

Electro-Service Manufacturing Corporation

- P. O. BOX 1289 - SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

Sept. 28, 1978

Mr. Donald Hollister
Lighting Technology Corp.
801 Mahler Road, Suite D
Burlingame, California 94010

Gentlemen:

We wish to take this opportunity to explain the rather lengthy delay encountered in obtaining this test report.

Unfortunately, ours is a very seasonal business. As we do a large portion of our business certifying consumer products, radio receivers, walkie talkies, CB radios, etc., our work flow is greatly influenced by seasonal buying habits. With the upcoming Christmas season, many of our clients are preparing new models and designs for both the Christmas season as well as the Winter CES. Due to this great influx of work, and because we must work on a first-come-first-serve basis, we were forced to refuse testing of your product when we were approached and requested to do so.

Add to this problem the fact that both the company President, and myself took very late vacations, my fiance' refused to allow me to move our wedding up two months, and you find that we have compounded an already self-compounding problem. Please understand that this is the first time such a situation has arisen, generally we can provide services within two days of the date we are contacted, but this year we were forced into the exception.

Rest assured that in the future, we at Electro Service will make every attempt to provide you with our usual prompt service.

Sincerely yours,

Steven R. Pease
Chief Engineer

SRP/pl

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Standard Fixture with Standard Envelope # 276

Test Setup : See attached diagram Figure 1A

Test Date : 9-26-78

Test Results:

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	33	39 db	1.0	2937 uv/m
27.120 MHz	"	11	38 db	"	891 "
40.680 MHz	"	150	1.1 X	"	165 "
54.240 MHz	"	500	1.4 X	"	700 "
67.800 MHz	"	225	1.7 X	"	383 "
81.360 MHz	"	300	2.0 X	"	600 "

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Standard Fixture with Shielded Envelope # 327

Test Setup : See attached diagram Figure 1A

Test Date : 9-26-78

Test Results:

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	30	39 db	1.0	2670 uv/m
27.120 MHz	"	6	38 db	"	486 "
40.680 MHz	"	200	1.1 X	"	220 "
54.240 MHz	"	700	1.4 X	"	980 "
67.800 MHz	"	325	1.7 X	"	552 "
81.360 MHz	"	200	2.0 X	"	400 "

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Standard Fixture with Shielded Envelope No I.D. # (Copper)

Test Setup : See attached diagram Figure 1A

Test Date : 9-27-78

Test Results:

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	15	39 db	1.0	1335 uv/m
27.120 MHz	"	2	38 db	"	162 "
40.680 MHz	"	125	1.1 X	"	138 "
54.240 MHz	"	500	1.4 X	"	700 "
67.800 MHz	"	90	1.7 X	"	153 "
81.360 MHz	"	240	2.0 X	"	480 "

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements, the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Standard Fixture with Shielded Envelope # 386

Test Setup : See attached diagram Figure 1A

Test Date : 9-27-78

Test Results:

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	41	39 db	1.0	3649 uv/m
27.120 MHz	"	10	38 db	"	810 "
40.680 MHz	"	190	1.1 X	"	209 "
54.240 MHz	"	400	1.4 X	"	560 "
67.800 MHz	"	200	1.7 X	"	340 "
81.360 MHz	"	215	2.0 X	"	430 "

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Shielded Fixture with Standard Envelope # 431

Test Setup : See attached diagram Figure 1A

Test Date : 9-26-78

Test Results:

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	30	39 db	1.0	2670 uv/m
27.120 MHz	"	15	38 db	"	1215 "
40.680 MHz	"	1000	1.1 X	"	1100 "
54.240 MHz	"	650	1.4 X	"	910 "
67.800 MHz	"	400	1.7 X	"	680 "
81.360 MHz	"	700	2.0 X	"	1400 "

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements, the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Coil as Excited From an External RF Source w/Standard Envelope # 437

Test Setup : See attached diagram Figure 1A (Schematic 2A Applicable)

Test Date : 9-27-78

Test Results:

Wattmeter Readings: 26 Watts For.
4 Watts Rev.

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	190	39 db	1.0	16910 uv/m
27.120 MHz	"	22	38 db	"	1782 "
40.680 MHz	"	290	1.1 X	"	319 "
54.240 MHz	"	170	1.4 X	"	238 "
67.800 MHz	"		1.7 X	"	
81.360 MHz	"		2.0 X	"	

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Coilas Excited From an External RF Source w/Shielded Envelope # 386

Test Setup : See attached diagram Figure 1A (Schematic 2A Applicable)

Test Date : 9-27-78

Test Results:

Wattmeter Readings: 26 Watts For.
4 Watts Ref.

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	200	39 db	1.0	17800 uv/m
27.120 MHz	"	25	38 db	"	2025 "
40.680 MHz	"	315	1.1 X	"	347 "
54.240 MHz	"	160	1.4 X	"	224 "
67.800 MHz	"		1.7 X	"	
81.360 MHz	"		2.0 X	"	

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Coil as Excited from an External RF Source w/Shielded Envelope # 327

Test Setup : See attached diagram Figure 1A (Schematic Diagram 2A Applicable)

Test Date : 9-27-78

Test Results:

Wattmeter Readings: 26 Watts For.
4 Watts Rev.

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	190	39 db	1.0	16910 uv/m
27.120 MHz	"	20	38 db	"	1620 "
40.680 MHz	"	300	1.1 X	"	330 "
54.240 MHz	"	200	1.4 X	"	280 "
67.800 MHz	"		1.7 X	"	
81.360 MHz	"		2.0 X	"	

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements, the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: LITEK Coil as Excited from an External RF Source w/Copper Shielded Envelope

Test Setup : See attached diagram Figure 1A (Schematic Diagram 2A Applicable)

Test Date : 9-27-78

Test Results:

Wattmeter Readings: 26 Watts For.
4 Watts Rev.

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	175	39 db	1.0	15575 uv/m
27.120 MHz	"	20	38 db	"	1620 "
40.680 MHz	"	450	1.1 X	"	495 "
54.240 MHz	"	200	1.4 X	"	280 "
67.800 MHz	"		1.7 X	"	
81.360 MHz	"		2.0 X	"	

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

REPORT of MEASUREMENTS

Test Sample: KLM Balun Terminated into Sierra 50 Coaxial Termination

Test Setup : See attached diagram Figure 1A (Schematic 2B Applicable)

Test Date : 9-27-78

Test Results:

Wattmeter Readings: 26 W. For
Ø W. Ref

Frequency of Emission	Distance feet	Meter Reading uv	Antenna Correction Note 1	Distance Correction X	Field Strength in uv per meter at 25 feet
13.560 MHz	25	60	39 db	1.0	5340 uv/m
27.120 MHz	"		38 db	"	
40.680 MHz	"		1.1 X	"	
54.240 MHz	"		1.4 X	"	
67.800 MHz	"		1.7 X	"	
81.360 MHz	"		2.0 X	"	

Note 1- For fundamental and 2nd harmonic measurements, the LP105 antenna correction is given as a voltage ratio in db and is added to the meter reading. For all other measurements, the 91865-2 antenna correction is given as a direct multiplication factor.

Measurements were made to determine the field strength of radio frequency energy generated by the above referenced device(s). Measurements were made in accordance with standard engineering procedures. An approved type of field strength meter using a loop pickup was used for measurements below and including 27.120 MHz. A doublet antenna was utilized for measurements on frequencies above 27.120 MHz.

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

Figure 1A

ELECTRONIC EQUIPMENT DESIGNED AND MANUFACTURED

Electro-Service Manufacturing Corporation

P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

NOTES TO FIGURE 1A

- Note 1- Standard AC line cord to utility lines located at screened room approximately 25 feet from the Unit under Test. This line was in place only for the duration of the tests requiring an AC supply to the unit under test. The line is filtered twice. First at the screened room through massive transformers and line decoupling networks. Then, at the test fixture by two Singer LISN's.
- Note 2- 50 ohm coax cable to the RF Power Amplifier located within the screened room approximately 25 feet from the Unit under Test. This line was in place only for the duration of the tests requiring an external RF source.
- Note 3- The antenna(s) were raised and lowered vertically from 1 to 10 meters in an attempt to obtain the maximum field intensity. The antenna(s) were rotated on a vertical axis from 0 to plus and minus 90 degrees in an attempt to obtain the maximum field intensity. The antenna(s) were rotated on a horizontal axis from 0 to plus and minus 180 degrees to obtain the maximum field intensity.
- Note 4- The Unit Under Test was located on a wood platform approximately one meter above the ground.

Electro-Service Manufacturing Corporation

-P. O. BOX 1289-SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

Figure 2A

Figure 2B

Electro-Service Manufacturing Corporation

- P. O. BOX 1289 - SAN MATEO, CALIFORNIA 94401
TELEPHONE: (415) 344-8400 TELEX/TWX: 9103742841

EQUIPMENT LISTING

Instrument	Model No.	Serial No.	Mfr.
Wattmeter	43	100348	Bird
Plug	100H	N/A	Bird
RF Section	8554B	1614A02564	HP
IF Section	8552B	1616A10450	HP
Mainframe	141A	544-03395	HP
Coaxial Termination	197A-a	154	Sierra
Dipole Antenna	91865-2	N/A	Stoddart
Loop Antenna	LP105	N/A	Empire
Osc/Power Amp	327-3	114	Collins
Balun	3-60	N/A	KLM
LISN	91221-1	0383	Singer
LISN	91221-1	0384	Singer

APPENDIX B

RULES AND REGULATIONS

Part 18

*Industrial, Scientific, and
Medical Equipment*

SEPTEMBER 1972

FEDERAL COMMUNICATIONS COMMISSION

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Contents—Part 18

Subpart A—General

- Sec.
18.1 Statement of basis and purpose.
18.3 Definitions.
18.11 Full information; inspection by Commission representatives.
18.13 ISM frequencies and frequency tolerances.
18.14 Operation on microwave frequencies.
18.17 Interference from ISM equipment.
18.21 When license is required.
18.22 Showing required.
18.23 Applications for station licenses.
18.24 Full information.
18.25 License period.
18.26 Renewal of license.
18.27 Station license, posting of.
18.28 Operator requirements.
18.29 Cessation of operation pursuant to license.

Subpart B—[Reserved]

Subpart C—Ultrasonic Equipment

- 18.71 Operation without a license.
18.72 Technical limitations.
18.73 Type approval.
18.74 Identification of type approved equipment.
18.75 Effect of certificate of type approval.
18.76 Changes in type approved equipment.
18.77 Withdrawal of certificate of type approval.
18.78 Measurement of field strength.
18.79 Location of equipment.
18.80 Certification attesting compliance with rules.
18.81 Renewal of certification.
18.82 Certification after maintenance work.
18.83 Prototype certification permitted.
18.84 Effective date.

Subpart D—Industrial Heating Equipment

- 18.101 Operation without a license.
18.102 Technical limitations.
18.105 Inspection of industrial heating equipment.
18.106 Renewal of certificate.

- Sec.
18.107 Measurement of field strength.
18.108 Location of equipment.
18.109 Report of radiation measurements.
18.111 Form of certificate.
18.112 Certification regarding operation.
18.113 Certification regarding radiation.
18.114 Prototype certification permitted.
18.115 Compliance with installation instructions.
18.116 Certificate to be filed with Commission.
18.117 Copy of certificate with equipment.
18.118 Rejection of certificate.
18.119 Elimination and investigation of harmful interference.
18.120 Interference to a radionavigation or safety service.
18.121 Interference to other radio services.
18.122 Report of interference investigation.
18.125 Prototype certification procedure.
18.126 Information to be filed for prototype certification.

Subpart E—Medical Diathermy Equipment

- 18.141 Operation on assigned frequencies.
18.142 Operation on unassigned frequencies.
18.143 Measurement of field strength.
18.144 Procedure for type approval.
18.145 Effect of certificate of type approval.
18.146 Withdrawal of certificate of type approval.

Subpart F—RF Stabilized Arc Welders

- 18.181 Technical specifications.
18.182 Certification requirements.
18.183 Location of certificate.

Subpart G—[Reserved]

Subpart H—Miscellaneous Equipment

- 18.261 Miscellaneous equipment.
18.262 Existing epilation equipment.

AUTHORITY: §§ 18.1 to 18.262 issued under secs. 4(1), 303(r), 48 Stat. 1086, 1082, as amended; 47 U.S.C. 154(1), 303(r). Interpret or apply sec. 301, 48 Stat. 1081; 47 U.S.C. 301.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUBPART A—GENERAL

§ 18.1 Statement of basis and purpose.

(a) Section 301 of the Communications Act of 1934, as amended, provides for the control by the Federal Government over all the channels of interstate and foreign radio communication and further provides, in part, that no person shall use or operate apparatus for the transmission of energy, communications, or signals by radio when the effects of such operation extend beyond state lines or cause interference with the transmission or reception of energy, communications or signals, of any interstate or foreign character by radio, except under and in accordance with the Communications Act and a license granted under the provisions of that act. The operation in the industrial, scientific and medical service of medical diathermy equipment, industrial heating equipment and miscellaneous equipment of a type which emits radio frequency energy upon frequencies within the radio spectrum constitutes a serious source of interference to authorized radio communication services operating upon the channels of interstate and foreign communication unless precautions are taken which will prevent the creation of any substantial amount of such interference.

(b) The following rules and regulations are designed to have a twofold effect:

(1) They set forth the conditions under which the operation of the equipment in question is not regarded as a cause of interference to the authorized radio communication services and is therefore not required to be operated pursuant to license under the Communications Act.

(2) They provide a procedure for the licensing of medical diathermy, industrial heating and miscellaneous equipment which in operation constitute a source of interference to authorized communication services, directly affect the control of the Federal Government over the channels of interstate and foreign radio communication, and are therefore required to be licensed.

§ 18.3 Definitions.

For purposes of the provisions of this part the following definitions in the industrial, scientific, and medical service shall be applicable:

(a) "Radio frequency energy" shall include electromagnetic energy generated at any frequency in the radio spectrum between 10 kHz and 30,000 MHz.

(b) "Medical diathermy equipment" shall include any apparatus (other than surgical diathermy apparatus designed for intermittent operation with low power) which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for therapeutic purposes.

(c) "Industrial heating equipment" shall include any apparatus which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for or in connection with industrial heating operations utilized in a manufacturing or production process.

(d) Miscellaneous equipment shall include apparatus other than that defined in or excepted by paragraphs (b) and (c) of this section in which radio frequency energy is applied to materials to produce physical, biological, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal and acceleration of charged particles, which do not involve communications or the use of radio receiving equipment.

(e) Ultrasonic equipment shall include any apparatus which generates radio frequency energy and utilizes that energy to excite or drive an electromechanical transducer for the production of sonic or ultrasonic mechanical energy for industrial, scientific, medical or other noncommunication purposes.

(f) "Industrial, scientific and medical equipment" (ISM equipment). Devices which use radio waves for industrial, scientific, medical or any other purposes including the transfer of energy by radio and which are neither used nor intended to be used for radio-communication.

(g) "Harmful interference." Any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this chapter.

(h) "ISM frequency." A frequency assigned by this part for the use of ISM equipment. A specified tolerance is associated with each ISM frequency. (See § 18.13.)

§ 18.11 Full information; inspection by Commission representatives.

Upon request by the Commission the owner or operator of any medical diathermy equipment, industrial heating equipment, or miscellaneous equipment shall promptly furnish the Commission with such information as may be requested concerning the operation of such equipment. The premises in which medical diathermy, industrial heating, or miscellaneous equipment are operated, and any license or certification required hereby, shall be available for inspection by representatives of the Commission at all reasonable hours.

§ 18.13 ISM frequencies and frequency tolerances.

The following frequencies are allocated for use by ISM equipment with the tolerance limits specified:

ISM frequency:	Frequency tolerance
13,560 kHz-----	± 0.78 kHz.
27,120 kHz-----	±160.0 kHz.
40,680 kHz-----	± 20.0 kHz.
915 MHz ¹ -----	± 13.0 MHz.
2,450 MHz ¹ -----	± 50.0 MHz.
5,800 MHz ¹ -----	± 75.0 MHz.
24,125 MHz ¹ -----	±125.0 MHz.

¹ The use of this frequency is subject to the conditions in § 18.14.

[§ 18.13 footnote 2 deleted *eff.* 5-5-75; II(72)-6]

§ 18.14 Operation on microwave frequencies.

Except for industrial heating equipment which is regulated by §§ 18.101 through 18.122, inclusive, ISM equipment may be operated on the microwave frequencies (915 MHz, 2450 MHz, 5800 MHz and 24,125 MHz) subject to the following conditions:

(a) The emission of radio frequency energy resulting from such operation shall be on the particular frequency and must not exceed tolerance limits associated with each such frequency as set forth in § 18.13.

(b) The energy radiated and the bandwidth of emissions shall be reduced to the greatest extent practicable.

(c) No harmful interference shall be caused to authorized communication services from spurious or harmonic radiation. In the event of such harmful interference, operation of the ISM equipment causing such harmful interference shall cease and shall not be resumed until steps necessary to eliminate such interference have been taken.

§ 18.17 Interference from ISM equipment.

(a) Subject to the exceptions in paragraphs (b) and (c) of this section and irrespective of whether the equipment otherwise complies with the rules in this part, the operator of ISM equipment that causes harmful interference to any authorized radio service shall promptly take steps as may be necessary to remedy the interference.

(b) The provisions of paragraph (a) of this section shall not apply in the case of interference to an authorized radio station operating on an ISM frequency (including tolerance).

(c) The provisions of paragraph (a) of this section shall not apply in the case of interference to a receiver arising from direct intermediate frequency pickup by the receiver of the fundamental frequency emissions of ISM equipment operating on an ISM frequency (including tolerance) and otherwise complying with the requirements of this part.

§ 18.21 When license is required.

(a) Any medical diathermy equipment, industrial heating equipment or miscellaneous equipment which complies with the provisions of this part may be operated without a station license. A license is required for any such equipment operated otherwise.

(b) No medical diathermy equipment, industrial heating equipment or miscellaneous equipment which does not comply with this part shall be operated except pursuant to a station license issued by the Commission authorizing such operation.

(c) Whenever the Commission on complaint or on its own motion determines that medical diathermy equipment, industrial heating equipment or miscellaneous

equipment is not in fact operating in compliance with the provisions of this part and so advises the operator of such equipment, further operation of such equipment without a station license shall be unlawful unless within 10 days of the receipt of such notice, or within such further time as the Commission may for good cause allow, the operator of such equipment shall file with the Commission a certificate of a competent engineer stating that the equipment is now capable of complying with the requirements of the rules.

§ 18.22 Showing required.

A station license for the operation of medical diathermy equipment, industrial heating equipment or miscellaneous equipment will be granted upon proper application therefor in accordance with the provisions of this part and a showing that in the light of the following considerations the public interest, convenience, and necessity would be served by such a grant: (a) The purpose for which the equipment sought to be licensed will be used; (b) the reasons why the equipment involved may not be operated in compliance with the provisions of this part for the operation of such equipment without a license; and (c) the nature and extent of interference that may be caused to authorized communication services by the operation of such equipment.

§ 18.23 Applications for station licenses.

Each applicant for a station license authorizing the operation of medical diathermy, industrial heating equipment, or miscellaneous equipment, or requesting the modification or renewal of such a license, shall file with the Commission in Washington, D.C., three copies of each application on the appropriate form designated by the Commission and a like number of any exhibits and other papers incorporated therein and made a part thereof. Application for a license shall be made upon the appropriate form prescribed by the Commission, and separate application should be made for each unit of equipment for which a license is sought. Application for modification or renewal of a license shall also be upon appropriate form prescribed by the Commission.

§ 18.24 Full information.

Each application for a license authorizing the operation of medical diathermy, industrial heating equipment or miscellaneous equipment shall contain full and complete information concerning all matters and things required to be disclosed by the application form.

§ 18.25 License period.

Each station license authorizing the operation of medical diathermy, industrial equipment or miscellaneous equipment will expire at the hour of 3 a.m. and will be issued for a normal license period of five years

or such other period as the Commission may specify upon consideration of the facts in a particular case. Each such license shall be nontransferable.

§ 18.26 Renewal of license.

Unless otherwise directed or permitted by the Commission, applications for renewal of a station license for the operation of medical diathermy, industrial heating equipment or miscellaneous equipment shall be filed with the Commission upon prescribed forms at least 60 days prior to the expiration date of such license.

§ 18.27 Station license, posting of.

The original of each station license shall be posted in the room in which the equipment is operated. Licenses covering equipment not used in a fixed place shall be attached to the equipment itself.

§ 18.28 Operator requirements.

Equipment for which a station license is issued pursuant to the provisions of this part may be operated by persons who do not hold an operator license or permit issued by this agency.

§ 18.29 Cessation of operation pursuant to license.

If any equipment for which a license has been issued hereunder shall cease to be operated pursuant to such license, or is transferred, sold, assigned, leased, loaned, stolen, destroyed, or otherwise removed from the possession of the licensee, the licensee shall within five days of such occurrence notify the Commission thereof and, where possible, include in such notification the name and address of the recipient of such equipment.

SUBPART B—[RESERVED]

SUBPART C—ULTRASONIC EQUIPMENT

§ 18.71 Operation without a license.

Ultrasonic equipment may be operated without a license: *Provided*, The design and operation complies with the technical limitations for such equipment: *And provided further*, That the equipment has been type approved by the Commission or has been certified pursuant to the requirements of §§ 18.71 to 18.84 and the certificate is attached to the equipment or is prominently posted in the room in which the equipment is being operated; except that ultrasonic equipment operating on frequencies below 90 kHz and generating less than 500 watts of radio frequency power may be operated without license, type approval or certification, if such equipment complies with all other applicable provisions of §§ 18.71 to 18.84.

§ 18.72 Technical limitations.

(a) Ultrasonic equipment shall be designed and constructed in accordance with good engineering practice with sufficient shielding and filtering to provide

adequate suppression of emissions on frequencies outside the ISM frequency bands.

(b) Except for ultrasonic measurement equipment that operates over a continuous band of frequencies, the fundamental frequency of operation shall fall outside the frequency bands 490–510 kHz, 2170–2194 kHz, and 8354–8374 kHz.

(c) The varying conditions under which ultrasonic equipment is operated shall not result in radiation exceeding the following limits:

Frequency	Distance Feet	Field μV/m
Up to and including 490 kHz.....	1,000	2400 Frequency in kHz
Over 490 kHz up to and including 1600 kHz.	100	24000 Frequency in kHz
Over 1600 kHz exclusive of frequencies in the ISM frequency bands.	100	15

(d) The operation of ultrasonic equipment on frequencies below 490 kHz using radio frequency power in excess of 500 watts shall be in compliance with the requirements of this section except that the maximum radiated field permitted may be increased as the square root of the ratio of the generated radio frequency power to 500 watts: *Provided*, That the radiated field shall in no case exceed the field permitted industrial heating equipment: *And provided further*, That equipment used in predominantly residential areas shall not be permitted the increase in field with power as indicated in this paragraph.

(e) On any frequency above 490 kHz, the radio frequency voltage appearing on each power line shall not exceed 200 microvolts. On any frequency below 490 kHz, the radio frequency voltage appearing on each power line shall not exceed 1000 microvolts. Measurement shall be made from each power line to ground with the equipment itself both grounded and ungrounded.

NOTE: One method of making conducted interference measurements is described in "Military Specification for Interference Measurement" MIL-I-16910 (SHIPS) dated January 14, 1952, available from the Commanding Officer, Naval Supply Depot, Scotia, New York, 12302. Note that this procedure calls for grounding the equipment under test, whereas these rules call for measurements with the equipment both grounded and ungrounded.

§ 18.73 Type approval.

(a) Manufacturers of ultrasonic equipment desiring to obtain type approval for their equipment may request permission to submit such equipment to the Commission for testing by following the procedure set out in Part 2 of this chapter. The request shall include a statement that at least five units of the model to be submitted are scheduled for manufacture.

(b) To be acceptable for type approval, ultrasonic equipment must meet the following requirements:

(1) The equipment must comply with the technical limitations for ultrasonic equipment.

(2) The design and construction of the equipment must give reasonable assurance of compliance with the rules in this part for at least 5 years under normal operation and with average maintenance.

(c) Additional rules relative to type approval will be found in Part 2 of this chapter.

§ 18.74 Identification of type approved equipment.

(a) Equipment for which a certificate of type approval has been issued shall be identified by the insertion of the FCC Type Approval Number on the nameplate of the equipment.

(b) In addition to the nameplate, the manufacturer shall furnish each user of type approved equipment a certificate setting forth the conditions under which such equipment shall be operated.

§ 18.75 Effect of certificate of type approval.

A certificate of type approval issued by the Commission constitutes a recognition that, on the basis of the tests made, the equipment appears to be capable of complying with the technical limitations in the rules in this part, provided such equipment is properly installed, maintained and operated, and no change whatsoever is made in the construction of equipment sold under the certificate of type approval except on specific prior approval by the Commission to any changes made.

§ 18.76 Changes in type approved equipment.

No changes whatsoever may be made in ultrasonic equipment for which a certificate of type approval has been issued except on specific prior approval by the Commission.

§ 18.77 Withdrawal of certificate of type approval.

(a) A certificate of type approval may be withdrawn if the type of equipment for which it was issued proves defective in service and under usual conditions of maintenance and operation such equipment cannot be relied on to meet the conditions set forth in this part for the operation of the type of equipment involved, or if any change whatsoever is made in the construction of equipment sold under the certificate of type approval issued by the Commission, without the specific prior approval of the Commission.

(b) The procedure for withdrawal of the certificate of type approval shall be the same as that prescribed for revocation of a radio station license pursuant to the provisions of the Communications Act of 1934, as amended.

(c) In the case of withdrawal of a certificate of type approval the manufacturer shall make no further sale of equipment under such certificate.

(d) When a certificate of type approval has been withdrawn for unauthorized changes or for failure to comply with technical requirements, the Commission will consider that fact in determining whether the manufacturer in question is eligible to receive any new certificate of type approval.

§ 18.78 Measurement of field strength.

Measurements to determine the field strength of radio frequency energy including both fundamental and spurious (including harmonic) emissions, generated by the ultrasonic equipment shall be made in accordance with standard engineering procedures and shall include the following:

(a) A field strength meter using loop pickup shall be used for measurements on frequencies up to and including 18 MHz, and such a meter with a doublet antenna shall be used for measurements on frequencies above 18 MHz.

(b) The radiation shall be determined along at least 5 radials approximately 72° apart. A smooth curve shall be drawn through the measurements when plotted and the value of field strength determined from these curves.

§ 18.79 Location of equipment.

For the purpose of measurements required in order to execute a certification of compliance, the location of the ultrasonic equipment may be considered to be the actual physical location of the equipment, or, where several such units are grouped within a circle of 200 feet radius or less, the several units may at the election of the certifying engineer be considered as a single unit, located at the center of the smallest enclosing circle. If the certification includes several units treated as one equipment, the distance of 1,000 feet at which the maximum permissible radiation is determined shall be decreased by the radius of the smallest circle that encloses the several units.

§ 18.80 Certification attesting compliance with rules.

(a) A certification attesting compliance with the rules in this part may be affixed or posted for any ultrasonic equipment.

(b) The certification shall be based on an inspection of the equipment and measurements taken at the place of use after the ultrasonic equipment has been assembled and is ready for operation: *Provided however*, That the certifying engineer may, in lieu of measuring the radio frequency voltage on the power lines, base the certification on specifications for the power line filter and test data regarding the radio frequency voltage on the power lines furnished by the manufacturer of the ultrasonic equipment.

(c) The certification may be executed by any engineer skilled in making and interpreting field strength measurements. The Commission may require such engineer to present proof of his qualifications to make such measurements.

(d) The certification shall contain the following information:

(1) Type and serial number, or other positive identification of the ultrasonic equipment being certificated.

(2) Conditions under which the certificated equipment shall be operated.

(3) Brief description of the engineering tests and a summary of the measured data upon which the certification is based.

(4) If the radio frequency voltage on the power line is not measured, a statement that, based on an inspection of the equipment and study of such test data and specifications as may be furnished by the manufacturer, the equipment can reasonably be expected to meet the requirements for radio frequency voltage on the power lines.

(5) A statement certifying that under the described condition of operation, the certificated equipment may reasonably be expected to meet the requirements of the rules in this part. This statement shall include the period of time over which the equipment may reasonably be expected to comply with the rules in this part.

(6) Date the measurements were made.

(7) Date of certification.

(8) Signature of certifying engineer.

(9) Name and address of employer of certifying engineer, if any.

§ 18.81 Renewal of certification.

The certification required by §§ 18.71 to 18.84 does not require renewal. However, when the Commission has reason to believe that operation of the equipment concerned may be inconsistent with §§ 18.71 to 18.84, it may require a new certification based on a new set of measurements.

§ 18.82 Certification after maintenance work.

It shall be the responsibility of the operator of the ultrasonic equipment to have such equipment recertified when changes have been made that might increase the radiated or conducted interference beyond the limits specified in §§ 18.71 to 18.84.

§ 18.83 Prototype certification permitted.

(a) Provision for prototype certification is made on the basis that production units can be expected to exhibit the same radiation characteristics as those of the prototype. Acceptance of prototype certification is based on representations and measurements made by the manufacturer of ultrasonic equipment.

(b) Ultrasonic equipment may be prototype certificated under the same procedure provided for industrial heating equipment in §§ 18.125 and 18.126. The technical limitations for ultrasonic equipment in § 18.72 shall apply, and the report of measurements shall include a showing of capability of compliance with the requirements of § 18.72(e).

(c) Certification of ultrasonic equipment which carries the manufacturer's prototype certification label shall be made pursuant to § 18.116 (a) and (b).

§ 18.84 Effective date.

(a) All ultrasonic equipment manufactured on or after July 1, 1955, must comply with the rules in §§ 18.71 to 18.84.

(b) Ultrasonic equipment manufactured prior to July 1, 1955, may be utilized until July 1, 1965, providing it complies either with the rules in §§ 18.71 to 18.84

or with the rules for miscellaneous equipment in § 18.261. After July 1, 1965, all such equipment must comply with the rules in §§ 18.71 to 18.84.

SUBPART D—INDUSTRIAL HEATING EQUIPMENT

§ 18.101 Operation without a license.

Industrial heating equipment may be operated without a license: *Provided*, The design and operation of the equipment complies with the technical limitations in this part for such equipment: *And provided further*, That the equipment has been certificated pursuant to the requirements of this part.

§ 18.102 Technical limitations.

(a) Industrial heating equipment shall be designed and constructed in accordance with good engineering practice with sufficient shielding and filtering to meet the requirements of this part.

(b) Industrial heating equipment may be operated on any frequency except frequencies in the bands 490–510 kHz, 2170–2194 kHz, and 8354–8374 kHz. Equipment operating on an ISM frequency may be operated with unlimited radiation on that frequency. Equipment operated on other frequencies must suppress radiation on the fundamental carrier frequency as well as other frequencies as required by this part.

(c) Industrial heating equipment designed for operation on an ISM frequency shall be adjusted to operate as close to that ISM frequency as practicable.

(d) Radiation of radio frequency energy from any industrial heating equipment on any frequency below 5725 MHz, except ISM frequencies, shall be suppressed so that the radiated field strength does not exceed 10 microvolts per meter at a distance of one mile or more from the equipment.

(e) Radiation of radio frequency energy from any industrial heating equipment on any frequency above 5725 MHz, except ISM frequencies, shall be reduced to the greatest extent practicable.

NOTE: The Commission will establish definite radiation limits for these frequencies as soon as information regarding equipment operating on these frequencies becomes available.

(f) Filtering between the industrial heating equipment and power lines must be provided to the extent necessary to prevent the radiation of energy from power lines on frequencies other than ISM frequencies with a field strength in excess of 10 microvolts per meter at a distance of one mile or more from the industrial heating equipment and at a distance of 50 feet from the power line.

§ 18.105 Inspection of industrial heating equipment.

(a) Industrial heating equipment shall be periodically inspected in order to reaffirm the validity of the certificate required by this part.

(b) Inspection shall be made at sufficiently frequent intervals to insure that each industrial heating

equipment is installed, maintained, and operated in a manner that provides compliance with the provisions of this part.

(c) A log shall be maintained of the inspections made. The inspector shall enter a brief note of his findings and shall date and sign each entry.

(d) The log shall be maintained at the same location as the certificate.

(e) The inspector shall require the equipment to be recertificated pursuant to the requirements of this part if he determines, as a result of his inspection, that such action is necessary in order to assure compliance with this part.

§ 18.106 Renewal of certificate.

(a) The certificate required to be exhibited by this part shall be renewed:

(1) When changes have been made that might increase the radiated interference beyond the limits specified in this part.

(2) When the inspector has determined that such action is necessary to assure compliance with the requirements of this part.

(3) When required by the Commission because it has reason to believe that operation of the equipment concerned may be inconsistent with the requirements of this part.

(b) The renewal of the certificate shall be based on measurements made at the point of installation.

(c) After April 30, 1961, the renewal certificate shall be executed on FCC Form 724.

§ 18.107 Measurement of field strength.

Measurements to determine the field strength of radio frequency energy generated by industrial heating equipment shall be made in accordance with standard engineering procedures and shall include the following:

(a) A loop antenna shall be used for measurements on frequencies below 18 MHz, and a doublet antenna shall be used for measurements on frequencies above 30 MHz. Either a loop or doublet antenna shall be used on frequencies between 18 MHz and 30 MHz. Appropriate techniques shall be resorted to for measurements in the microwave region of the spectrum.

(b) Prior to the determination of the maximum field strength at one mile, a sufficient number of measurements shall be made in the vicinity of the industrial heating equipment to enable plotting of the polar radiation pattern and to assure the correct determination of the major lobes. Where conditions permit, these measurements shall be made at intervals of not more than 20 degrees in azimuth directions and at distances not exceeding 1,000 feet from the location of the equipment. The measurements so obtained shall be reduced to equivalent field strength at 1,000 feet.

(c) The field strength measurements for the maximum field strength at one mile shall be made along the radial corresponding to the lobe of maximum radiation as determined from the polar radiation pattern. Sufficient

measurements shall be made along radials extending through all lobes which are within 15 dB of the apparent maximum lobe, as determined in paragraph (b) of this section to assure that the assumed lobe of greatest field strength is in fact the maximum lobe. If two or more lobes of radiation of approximately the same strength are present, measurements to determine field strength shall be made along the several radials for such lobes. Where possible, field strength measurements shall be made along each radial at intervals of not greater than 500 feet and an average curve drawn for measured field strength in microvolts per meter versus distance in feet. Where necessary, the average curve shall be extended to show the extrapolated field strength at one mile. In these cases where it is impractical to conduct measurements along the radial of maximum radiation a sufficient number of field strength measurements shall be made to clearly indicate the magnitude of the radiation field in the sector containing the lobe of maximum radiation.

(d) Where there is evidence of radiation from power lines, field strength measurements shall be made at not less than three points along the power line located approximately 1 mile from the location of the industrial heating equipment causing such radiation and to include a length of power line not less than 500 feet. One point of measurement shall lie within the 1-mile distance and the others beyond. At each of these points at least three measurements of field strength shall be made along a line normal to the power line and out to a distance from the power line not exceeding 50 feet measured horizontally along the ground from a point directly below the outermost conductor.

(e) The field strengths specified herein refer to the maximum field strengths, regardless of polarization, measured at a height of 12 feet above the immediate terrain or at such lower height at which the field strengths may exceed that at 12 feet. Measurements made at frequencies below 18 MHz may be made at any convenient height.

(f) The spectrum shall be investigated from the lowest frequency generated in the equipment up to the tenth harmonic of the fundamental frequency or to 5725 MHz whichever is lower.

§ 18.108 Location of equipment.

For the purpose of measurements required in order to execute a certification of compliance, the location of the industrial heating equipment may be considered to be the actual physical location of the equipment, or, where several such units are grouped within a circle of 500 feet radius or less, the several units may, at the election of the certifying engineer, be considered as a single unit, located at the center of the smallest enclosing circle. If the certification includes several units treated as one equipment, the distance of one mile at which the maximum permissible radiation is determined shall be reduced by the radius of the smallest circle that encloses the several units.

§ 18.109 Report of radiation measurements.

The report of radiation measurements shall contain the following information:

(a) A description of the equipment that was measured for radiation, including: manufacturer, type number, nominal operating frequency, and nominal power-rating.

(b) A listing of the measuring equipment used, including the serial numbers.

(c) A statement of the date when the measuring equipment was last calibrated.

(d) The date the measurements were made.

(e) The frequency range that was investigated.

(f) [Reserved]

(g) If the required range of investigation includes the following frequencies, indicate the magnitude of the field measured on these frequencies or in these frequency bands:

<i>MHz</i>
74.6 to 75.4
108.0 to 118.0
121.5
156.8
243.0
328.6 to 335.4
420.0 to 460.0

(h) A graph, taken at any convenient point, of field strength versus frequency as required by § 18.107(f). The graph shall also show the ambient noise level if the same exceeds 6 microvolts per meter. Label the graph to show where the measurements were made.

(i) A graph of the polar radiation pattern as required by § 18.107(b). Label the graph to show the frequency that was used.

(j) A graph of field strength versus distance along the radial of maximum radiation shown in the polar graph required by paragraph (i) of this section. Label the graph to show the frequency that was used.

(k) A statement of the operating conditions that must be observed to ensure that radiation during routine operation does not exceed, within reasonable limits, the radiation that was measured and is reported herein.

NOTE: In the graphs required by paragraphs (i) and (j), use the fundamental frequency when this frequency falls outside an ISM frequency band; however, if the fundamental is an ISM frequency, use the harmonic, falling outside an ISM frequency band, which has the highest measured radiation.

§ 18.111 Form of certificate.

(a) Certificates issued after April 30, 1961, for industrial heating equipment shall be executed on FCC Form 724 except as provided in paragraph (b) of this section.

(b) Where the industrial heating equipment is identical to a prototype which has been tested for radiation prior to April 30, 1961, the certificate heretofore issued by the manufacturer for such equipment may be substituted for Part III of FCC Form 724 until January 1, 1970.

§ 18.112 Certification regarding operation.

The certification required in Part I of FCC Form 724 shall be executed by the owner or lessee of the equipment, in the case of a proprietorship; by one of the partners, in the case of a partnership; or by an officer or authorized employee, in the case of a corporation. If Part I is signed by an authorized employee, Part II shall be executed either by an officer or a party with respect to whom there is on file with the Commission a letter from an officer of the corporation authorizing that party to execute Part II of FCC Form 724.

§ 18.113 Certification regarding radiation.

The certification required in Part III of FCC Form 724 shall be executed by an engineer skilled in making and interpreting field strength measurements. The Commission may require such engineer to furnish proof of his qualifications.

§ 18.114 Prototype certification permitted.

(a) Provision for prototype certification is made on the basis that production units can be expected to exhibit the same radiation characteristics as those of the prototype. Acceptance of prototype certification is based on representations and field strength measurements made by the manufacturer of industrial heating equipment.

(b) The procedure for prototype certification is set out in §§ 18.125 and 18.126.

§ 18.115 Compliance with installation instructions.

Where the certification regarding radiation (Part III of FCC Form 724) is based on measurements of a prototype, the equipment shall be installed in accordance with the instructions which the engineer certifying to Part III of FCC Form 724 has certified as being adequate to ensure reasonable expectation of compliance with the radiation limits in § 18.102.

§ 18.116 Certificate to be filed with Commission.

(a) Two copies of FCC Form 724 required by § 18.101 and § 18.111 shall be filed. The original shall be filed with the Secretary, Federal Communications Commission, Washington, D.C., 20554. A duplicate copy shall be filed with the Engineer in Charge of the field office having cognizance over the area in which the heater is located.

(b) For equipment which carries the manufacturer's prototype certification label, the certificate shall consist of Part I and Part II, if applicable, of FCC Form 724.

(c) For equipment which does not carry the manufacturer's prototype certification label, the certificate shall consist of Parts I, II, if applicable, and III of FCC Form 724 plus the report of radiation measurement pursuant to § 18.109. A facsimile copy of the properly completed and signed Part III of FCC Form 724 may be submitted in lieu of the original thereof.

§ 18.117 Copy of certificate with equipment.

A copy of the certificate filed with the Commission pursuant to § 18.116 shall be retained by the operator and shall be attached to the equipment. Alternatively, the copy of the certificate may be placed at any location where it will be conveniently available for inspection by authorized representatives of the Commission, provided there is attached to the equipment a notice stating where the copy of the certificate is located.

§ 18.118 Rejection of certificate.

(a) A certificate that is incomplete or otherwise does not meet the requirements of Subpart D of this part may be rejected.

(b) The certificate shall be considered accepted unless rejected in writing within 60 days of receipt by the Commission.

(c) In the event a certificate is rejected but with no harmful interference involved, the equipment may be operated for a period of 20 days from the date of the rejection notice pending the submission of an acceptable certificate.

(d) If the certificate is rejected after the second submission thereof, the equipment may not be operated until a certificate has been filed with and accepted by the Commission.

§ 18.119 Elimination and investigation of harmful interference.

(a) The operator of industrial heating equipment that causes harmful interference shall promptly take appropriate measures to eliminate the harmful interference.

(b) When notified by the Commission that his installation is causing harmful interference, the operator shall arrange for an engineer skilled in interference measurements and control techniques to make an investigation to ensure that the harmful interference has been eliminated. The Commission may require the engineer making the investigation to furnish proof of his qualifications.

(c) The results of the investigation required by paragraph (b) of this section shall be reported to the Commission's Engineer in Charge of the district office in accordance with the provisions of § 18.122.

(d) If the equipment has not been certificated or if renewal of the certificate is required, a certificate covering the equipment shall be filed in accordance with the provisions of § 18.116.

§ 18.120 Interference to a radionavigation or safety service.

(a) If the operator of industrial heating equipment is notified by the Commission that operation of such equipment is endangering the functioning of a radionavigation or a safety service, he shall immediately cease operating the equipment.

(b) Operation may be resumed on a temporary basis, with the permission of the Engineer in Charge of the district office, but only for the purpose of elimi-

nating the harmful interference, making the interference investigation, and obtaining or renewing certification if required. Requests for permission to operate on a temporary basis may be made and granted by telephone, but in that event the request and the grant shall be confirmed promptly in writing.

(c) If the results of the interference investigation demonstrate that the harmful interference has been eliminated, and if the field work involved in certification, when required, demonstrates that the equipment meets the requirements for certification, the operator may, with the permission of the Engineer in Charge of the district office, resume full operation for a period of 10 days pending preparation and submission of the final interference report required by § 18.122 and the certificate required by §§ 18.101 and 18.111. Requests for permission to operate under such circumstances may be made and granted by telephone, but in that event the request and the grant shall be confirmed promptly in writing.

(d) Operation may be resumed on a regular basis after the harmful interference has been eliminated and the interference report and certificate, if required, have been filed.

§ 18.121 Interference to other radio services.

(a) If the operator of industrial heating equipment is notified by the Commission that operation of such equipment is obstructing or repeatedly interrupting an authorized radio service other than a radionavigation or safety service, he shall take prompt measures to eliminate the harmful interference but need not cease operation unless ordered to do so by the Commission.

(b) If the operator is ordered to cease operation, he may resume operation on a temporary basis, with the permission of the Engineer in Charge of the district office, but only for the purpose of eliminating the harmful interference, making the interference investigation, and obtaining or renewing certification. Requests for permission to operate on a temporary basis may be made and granted by telephone, but in that event the request and the grant shall be confirmed promptly in writing.

(c) If the results of the interference investigation demonstrate that the harmful interference has been eliminated, and if the field work involved in certification, if required, demonstrates that the equipment meets the requirements for certification, the operator may, with the permission of the Engineer in Charge of the district office, resume full operation for a period of 10 days pending preparation and submission of the final interference report required by § 18.122 and the certificate required by §§ 18.101 and 18.111. Requests for permission to operate under such circumstances may be made and granted by telephone, but in that event the request and the grant shall be confirmed promptly in writing.

(d) Operation may be resumed on a regular basis after the harmful interference has been eliminated and the interference report and certificate, if required, have been filed.

§ 18.122 Report of interference investigation.

(a) An interim report on the investigation and of the corrective measures that were taken shall be filed with the Engineer in Charge of the local FCC office within 30 days of notification of harmful interference. The final report shall be filed with the Engineer in Charge within 60 days of notification.

(b) The date for filing the final report may be extended for 30 days by the Engineer in Charge when the operator has shown that he has been diligent in his efforts and that additional time is required to put into effect the corrective measures or to complete the investigation. The request for extension of time shall be accompanied by a progress report showing what has been accomplished to date.

(c) The final report on the interference investigation shall list each radio facility which was receiving harmful interference, shall describe the measures taken to eliminate harmful interference, and shall describe the tests made to ensure that harmful interference has been eliminated, together with the test results and the date and time of each test. In the case of interference to broadcast receivers, the final report shall list the location of each receiver that was checked and the name of the receiver owner, shall describe the steps taken to eliminate the harmful interference, and shall specify the date and time each receiver was checked to ensure that harmful interference has been eliminated.

§ 18.125 Prototype certification procedure.

(a) Manufacturers desiring to prototype certificate their equipment, must file all the information set out in § 18.126. A separate prototype certificate shall be filed for each type of equipment.

(b) Receipt of each prototype certificate will be acknowledged subject to review at a later date.

(c) After filing the required information, the equipment may be identified with a label carrying the following statement:

The (name of manufacturer) has prototype certificated this equipment to the FCC as complying with Part 18 of its rules.

(d) The identifying label may be part of the equipment nameplate. If separate therefrom, the label shall be attached to the equipment in the vicinity of the nameplate.

§ 18.126 Information to be filed for prototype certification.

(a) Original of Part III of FCC Form 724 properly completed and signed.

(b) Report of radiation measurements pursuant to § 18.109.

(c) Installation instructions to be furnished to purchaser of the equipment.

(d) A statement certifying that production will be adequately controlled to insure that all units produced are capable of operating in compliance with the technical requirements of this subpart. This statement shall be signed by a responsible official authorized to sign for the manufacturer and shall show his title.

SUBPART E—MEDICAL DIATHERMY EQUIPMENT

§ 18.141 Operation on assigned frequencies.

A station license is not required for the operation of medical diathermy equipment on assigned frequencies provided such operation meets the following conditions:

(a) Such operation must conform to the general condition set out in the guarantee or certificate required by paragraphs (c) and (d) of this section. Operation must be confined to one or more of the frequencies:

ISM frequency:	Frequency tolerance
13,560 kHz-----	± 6.78 kHz.
27,120 kHz-----	±160.0 kHz.
40,630 kHz-----	± 20.0 kHz.
915 MHz ¹ -----	± 13.0 MHz.
2,450 MHz ¹ -----	± 50.0 MHz.
5,800 MHz ¹ -----	± 75.0 MHz.
24,125 MHz ¹ -----	±125.0 MHz.

¹ The use of this frequency is subject to the conditions in § 18.14.

[§ 18.141(a) footnote 2 deleted eff. 5-5-75; II(72)-6]

(b) Such operation may be without regard to the type or power of emission being radiated. Spurious and harmonic radiations on frequencies other than those specified above shall be suppressed so that such radiations do not exceed a strength of 25 microvolts per meter at a distance of 1,000 feet or more from the medical diathermy equipment causing such radiations.

(c) With respect to equipment for which type approval has been received from the Commission in accordance with §§ 18.144 to 18.146, inclusive, there shall be affixed to each unit of equipment operated in accordance with paragraphs (a) and (b) of this section, or posted in the room in which such operation occurs, a dated certificate of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment, setting forth the F.C.C. type approval number for such equipment, the general conditions under which such equipment should be operated, and certifying that the equipment involved may reasonably be expected to meet the requirements of this section under the described conditions of operation for a period of at least three years. The certification required in this section shall describe with certainty the apparatus covered thereby.

(d) The owners or operators of equipment which has not received type approval but which is manufactured for operation without a license and designed to meet the technical requirements set forth under paragraphs (a) and (b) of this section shall have posted in the room in which such equipment is operated a dated certificate of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment, setting forth the general conditions under which such equipment should be operated and certifying that the equipment involved may reasonably be expected to meet the requirements of this section for a period of

at least three years under the described conditions of operation. The certification required by this section shall describe with certainty the apparatus covered thereby, and shall include a brief statement of the engineering tests upon which such certification is based and the results thereof. Field strength measurements in such tests shall be made in accordance with § 18.143.

(e) No regular renewal of certification is required for equipment covered in paragraph (c) of this section. The certification required in paragraph (d) of this section shall be renewed at intervals of three years. Notwithstanding the above provisions with respect to renewal of certification, the certification required by paragraph (c) or (d) of this section shall be renewed for particular equipment by such date as the Commission may specify if the Commission has reason to believe that the operation of such equipment may be inconsistent with provisions of this part or the source of interference to radio communication.

§ 18.142 Operation on unassigned frequencies.

A station license is not required for the operation of medical diathermy equipment on frequencies other than those specified in § 18.141(a) provided such operation is in accordance with the general conditions of operation set out in the certification required in paragraph (b) of this section, and meets the following conditions:

(a) The equipment used in such operation shall be provided with a rectified and filtered plate power supply, power line filters and shall be provided with sufficient shielding so that the emission of radio frequency energy generated by such operation, including spurious and harmonic emissions, shall not exceed a strength of fifteen microvolts per meter at a distance of 1,000 feet or more from the medical diathermy equipment on frequencies other than those specified in § 18.141(a) under any conditions of operation.

(b) There shall be affixed to each unit of equipment so operated, or posted in the room in which such operation occurs, a dated certification of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment setting forth the general conditions under which such equipment should be operated and certifying that under the described conditions of operation the requirements of this section may reasonably be expected to be met for a period of at least 3 years. The certification required by this section shall describe with certainty the equipment covered thereby, and shall include a brief statement of the engineering tests upon which the certification is based and the results thereof. Field strength measurements in such tests shall be made in accordance with the provisions of § 18.143.

(c) The certification required in paragraph (b) of this section shall be renewed every 3 years: *Provided*, That such certification shall be renewed for particular equipment by such earlier date as the Commission may specify if the Commission has reason to believe that the operation of such equipment may be inconsistent with the provisions of this part or a source of interference to radio communication.

§ 18.143 Measurement of field strength.

Measurements to determine the field strength of radio frequency energy generated by medical diathermy equipment shall be made in accordance with standard engineering procedures and shall include the following:

(a) An approved type of field strength meter using loop pickup shall be used for measurements on frequencies below and including 18 MHz, and such a meter with a doublet antenna shall be used for measurements for frequencies above 18 MHz. Appropriate techniques shall be resorted to for measurements in the microwave region of the spectrum.

(b) The field strength at 1,000 feet from the medical diathermy equipment, or at any other point at which it becomes necessary to determine such field strength shall be determined by measurements at approximately 100-foot intervals along 5 radials approximately 72° apart, provided that additional measurements shall be taken when necessary in particular cases. An average curve shall be drawn through the points obtained for each radial and then either (1) the field strength at 1,000 feet taken from the curve or (2) the curve extended to the 1,000-foot point to obtain the field strength at that point. If points of measurement along a radial are such that marked changes of field strength over short distances are noted because of standing waves, multipaths, etc., continuous measurements shall be made along any such radial at points 100 feet apart in order to obtain average values for such points.

(c) The field strength specified in this section refers to the maximum field strength regardless of polarization, measured at a height of 12 feet above the immediate terrain or at such lower height at which the field strength may exceed that at 12 feet.

(d) If due to the location of equipment in a large city, or for some other reason, measurements as outlined above are impractical because of shadows or shielding of large buildings or other objects, every effort should be made to obtain necessary measurements at clear locations such as atop adjacent buildings, etc., with the measurements corrected to the height specified in paragraph (c) of this section in accordance with best available engineering information.

§ 18.144 Procedure for type approval.

(a) Manufacturers of medical diathermy equipment designed to operate on the frequencies specified in § 18.141(a) may submit units of such equipment to this Commission for type approval upon the grant of request therefor made in writing by the manufacturer to the Secretary of the Commission. Such a request will not be granted unless at least 5 units of the model to be submitted are scheduled for manufacture and the manufacturer agrees to bear all forwarding and return charges in connection with the shipment of the unit to be tested between the Federal Communications Commission, Laboratory Division, Laurel, Maryland, and the manufacturer.

(b) Any such equipment which is submitted will be tested and a certificate of type approval will be issued to the manufacturer for each type of equipment which meets the following tests:

(1) The frequency at all times during the tests below shall be maintained within 70% of the tolerance specified in § 18.141(a), except for equipment operating on 915 MHz, for which it shall be maintained within 100% of the tolerance specified in § 18.141(a).

(i) From a cold start the machine will be operated continuously at full load for 6 hours, except that machines classified as portable will be subject to a 2-hour test.

(ii) From a cold start the machine will be operated at no load for 5 minutes and then the frequency deviation determined over a normal treatment cycle. A treatment cycle will be simulated by artificial varying loads and varying settings of the resonance and other operating controls. Similar treatment cycle tests will be conducted after periods of continuous full load operations up to 6 hours (2 hours for portable operation) to determine the maximum deviation. The number of such tests normally will be determined by the results of test (1): *Provided, however*, That equipment designed to operate on the frequencies set forth in § 18.141(a) may be granted type approval regardless of frequency stability, provided such equipment meets the other requirements hereof and contains a power cut-off mechanism which is effective in rendering the machine inoperative when the deviation from the assigned frequency exceeds 70 percent of the tolerance provided for.

(2) The equipment must be designed to prevent the emission of spurious and harmonic radiations to the extent required in § 18.141(b).

(3) The electrical and mechanical components of the machine and their installation must be such as to give reasonable assurance of compliance with the requirements of permissible frequency tolerance for at least 5 years.

NOTE: Medical diathermy equipment operated on 915 MHz, 2450 MHz, 5800 MHz or 24,125 MHz will be eligible for type approval upon a determination by the Chief Engineer of compliance with the requirements of the Commission's public notice and order of December 26, 1946, which requirements are set forth in § 18.14.

[§ 18.144(b)(1) amended eff. 5-5-75; II(72)-6]

§ 18.145 Effect of certificate of type approval.

A certificate of type approval constitutes a recognition that on the basis of the tests made the equipment appears to have the capability of functioning in accordance with the provisions of § 18.141 (a) and (b) provided such equipment is properly constructed, maintained and operated, and no change whatsoever is made in the construction of equipment sold under the Certificate of Type Approval issued by the Commission

except on specific approval by the Commission to any changes made.

§ 18.146 Withdrawal of certificate of type approval.

(a) A certificate of type approval may be withdrawn if the type of equipment for which it was issued proves defective in service and under usual conditions of maintenance and operation such equipment cannot be relied on to meet the conditions set forth in this part for the operation of the type of equipment involved, or if any change whatsoever is made in the construction of equipment sold under the certificate of type approval issued by the Commission, without the specific prior approval of the Commission.

(b) The procedure for withdrawal of a certificate of type approval shall be the same as that prescribed for revocation of a radio station license pursuant to the provisions of the Communications Act of 1934, as amended.

(c) In the case of withdrawal of a certificate of type approval the manufacturer shall make no further sale of equipment under such certificate.

(d) When a certificate of type approval has been withdrawn for unauthorized changes or for failure to comply with technical requirements, the Commission will consider that fact in determining whether the manufacturer in question is eligible to receive any new certificate of type approval.

SUBPART F—RF STABILIZED ARC WELDERS

§ 18.181 Technical specifications.

(a) The requirements of this part with respect to electric arc welding devices using radio frequency energy are suspended, subject to the provisions of paragraphs (b)-(e) of this section, until action is completed in the Docket No. 11467 proceeding with respect to these devices.

(b) In the event of interference from electric arc welding devices using radio frequency energy to any authorized radio service, steps to remedy such interference shall promptly be taken (except that, in case of interference to receivers arising from direct intermediate frequency pickup by such receivers of the fundamental frequency emissions of certified electric arc welding equipment using radio frequency energy, this provision with respect to interference shall not apply).

(c) Equipment manufactured after September 1, 1952, shall be subject to the same technical limitations and standards as set forth for industrial heating equipment in §§ 18.101 to 18.108, inclusive, except that such equipment need not be operated within a shielded room or space but in lieu thereof shall be operated with sufficient shielding to limit the radiation to the value prescribed in § 18.102.

(d) Radio frequency stabilized electric arc welding

equipment designed for operation on ISM frequencies may be type approved and operated in accordance with the provisions of § 18.261(c).

(e) Broad band type of emissions from arc welding equipment shall be measured by an instrument having performance characteristics similar to the "Proposed American Standards Specification for a Radio Noise Meter—0.15 to 25 Megacycles/second" dated March 1950, published by the American Standards Association Committee on Radio Electrical Coordination C63. Quasi-peak values of field strength shall be measured and used in determining compliance with § 18.102. Instruments not having characteristics similar to the above-mentioned standards may be used provided suitable correlation factors are used to adjust the field strength readings to values which would be obtained with an instrument having the desired characteristics.

§ 18.182 Certification requirements.

(a) The certification required by § 18.101 may be based upon field strength measurements made by the manufacturer of the equipment at locations other than the one where the equipment is in use provided such certification includes a statement by the operator of the equipment that the equipment covered thereby has been installed and is being operated in conformity to the instructions issued by the manufacturer.

(b) The certificate required for RF stabilized arc welders shall be executed by an engineer skilled in making and interpreting field strength measurements. The Commission may require such engineer to provide proof of his qualifications.

(c) The certificate for an RF stabilized arc welder measured at the location where it is in use shall contain the following information:

- (1) Type and serial number, or other positive identification, of the welder being certified.
- (2) Conditions under which the welder shall be operated and maintained.
- (3) Brief description of the engineering tests and a summary of the measured data upon which the certificate is based.
- (4) Date the measurements were made.
- (5) A statement certifying that the welder does meet and may reasonably be expected to continue to meet the requirements of this part.
- (6) Date of certification.
- (7) Signature of certifying engineer.
- (8) Name and address of employer of certifying engineer, if any.
- (9) If the certificate is based on measurement of a prototype at some other location:
 - (i) Detailed installation instructions which will insure that the welder may reasonably be expected to comply with the radiation limits in § 18.102, and
 - (ii) A statement signed by the person responsible for the operation of the welder, attesting that it has been installed in accordance with the installation instructions attached to this certificate.

§ 18.183 Location of certificate.

In general the certificate shall be attached to the equipment. Alternatively the certificate may be placed at any location where it will be conveniently available for inspection by authorized representatives of the Commission, provided there is attached to the equipment a notice stating where the certificate is located.

SUBPART G—[RESERVED]

SUBPART H—MISCELLANEOUS EQUIPMENT

§ 18.261 Miscellaneous equipment.

(a) The operation without a license of miscellaneous equipment, as defined in § 18.3(d), generating radio-frequency power of 500 watts or less, shall be in compliance with the provisions of this part for medical diathermy apparatus.

(b) Operation of such equipment generating radio-frequency power in excess of 500 watts shall be in compliance with the requirements for medical diathermy apparatus except that the maximum radiated field permitted shall be increased as the square root of the ratio of the generated power to 500 watts: *Provided*, That the radiated field shall in no case exceed the fields permitted industrial heating apparatus: *And provided further*, That equipment used in predominantly residential areas and operating on frequencies below 1,000 MHz shall not be permitted the increase in field with power as indicated in this paragraph, but shall be subject to the restrictions contained in this paragraph for diathermy equipment.

(c) Miscellaneous equipment, as defined in § 18.3(d), may be type approved under procedures similar to that for diathermy equipment with such changes in the above procedure as may be required because of the nature of the particular equipment involved.

(d) For the purpose of field strength measurements, the location of the miscellaneous equipment may be considered to be the actual physical location of such equipment or, where several such units are grouped within a circle of 200 feet radius or less, the several units may, at the election of the certifying engineer, be considered as a single unit, the location of which will be the center of the smallest enclosing circle: *Provided, however*, That if the certification includes more than one unit, the distance of 1,000 feet at which the maximum permissible radiation is determined shall be decreased by an amount equivalent to the radius of the circle encompassing the several units.

(e) It shall be the responsibility of the operator to have the equipment recertified when changes have been made that might increase the radiation beyond the specified limits.

§ 18.262 Existing epilation equipment.

The provisions of this part shall not be applicable until June 30, 1954 to epilation equipment, which uses radio frequency energy, manufactured before December 31, 1950, and shall not be applicable until December 31, 1955 for such equipment manufactured between

December 31, 1950 and June 30, 1953: *Provided*, That the foregoing provisions of this section shall be applicable only if such steps as may be necessary are promptly taken to eliminate interference to authorized radio services resulting from the operation of equipment manufactured prior to the respective dates set forth in this section.