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DEVELOPMENT AND UTILIZATION OF THE MODEL LSC201 LIGHTNING COUNTER

by

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INTRODUCTION AND REVIEW

The Forest Fire Research Institute (Kourtz, 1974) has developed a system to enable prediction of lightning-caused forest fires. An integral part of this system is a thunderstorm tracking technique. This technique involves the use of a dense network of limited range, electronic lightning counters.

From 1970-1973 the Institute was involved with the research and design of various electronic lightning counters in an effort to meet the requirements of the thunderstorm tracking network concept. During the above period, six different lightning counters were developed and tested. Two of the counters looked at the infrared field associated with a lightning discharge, two looked at the radio frequency field, one looked at the magnetic field and the sixth looked at the electrostatic field. The electrostatic field sensor (original design by Pierce and Cianos) was chosen as the counter that would be utilized for the thunderstorm tracking network. Briefly, the reasons for this choice were: a well defined range, minimum amount of maintenance, a design that lent itself to mass production, electronic stability and reliability and reasonable unit cost. This electronic field sensor is commonly known as the Pierce Lightning Counter or Model LSC101 as produced by Quality Technology, Ottawa, Ontario. (For more detail on sensors, see Kourtz, 1973).

A network of 20 counters (Model LSC101) was installed in the northwestern fire region of Ontario for the 1973 thunderstorm season. The network was spread over a 50,000 square mile area and the individual counters were located at manned weather stations. Every morning the counts from each sensor were relayed into the Dryden Fire Centre of the Ontario Ministry of Natural Resources. As the thunderstorm season progressed, it became clear that the sensor network was identifying thunderstorm occurrences throughout the region. A detailed approach for the correlation of thunderstorm and lightning fire occurrence is outlined by Kourtz (1974).

As originally suspected, the major drawback of the Pierce counter proved to be the large and cumbersome antenna that it required. During the summers of 1973 and 1974, research and testing was carried out by the Institute in cooperation with Quality Technology Limited, in an effort to design a lightning counter which could operate with a much smaller and more portable antenna. The work carried out over the last two summers led to a new design for a lightning counter, that is now being produced as the Model LSC201.

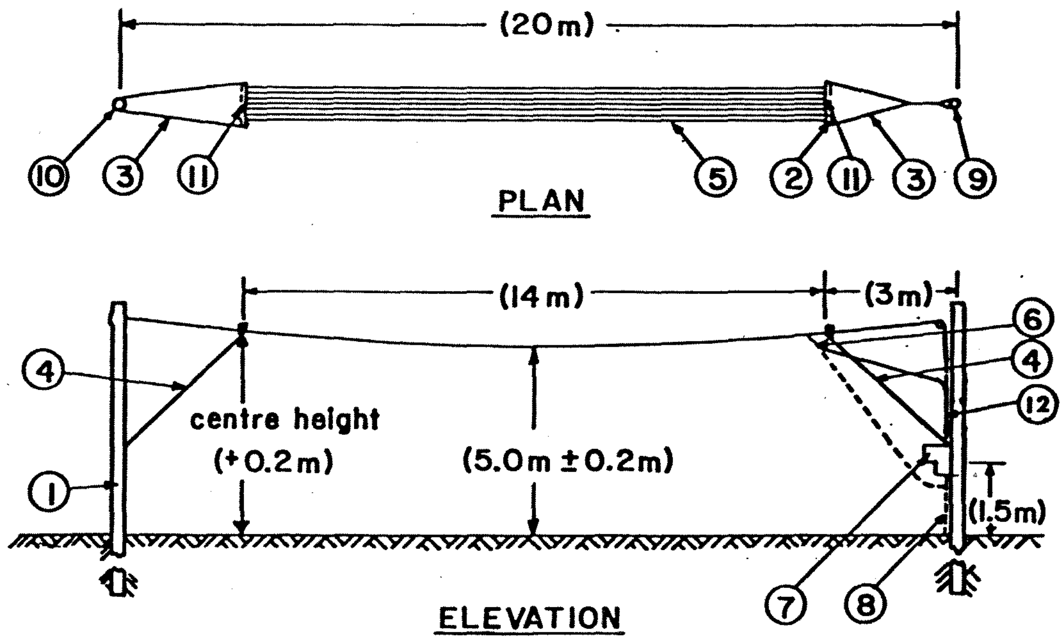
The purpose of this report is to outline the basis and goals for, tests on and experience with, the new Model LSC201 Lightning Stroke Counter. Also, a set of guidelines pertaining to counter installation will be presented.

BASIS FOR DEVELOPMENT OF THE MODEL LSC201

The majority of problems encountered with the Lightning Stroke Counter Model LSC101 were related to the large antenna that the counter required. The antenna consisted of 6 fifty-foot strands of copper wire (spaced 6-inches apart). The ends of the wires were attached to two wooden spacers and elevated to a height of 15-feet above ground. Thus, it was necessary to install 2 twenty-foot poles of about 8-inch diameter to serve as support for the antenna. Because of this large configuration, difficulties arose with regard to installation and storage of the antenna, (see Figure 1), yet a proper installation is essential for satisfactory performance.

It was found that forest canopy affects counter performance. With a complete canopy over the antenna, the effective range of the sensor becomes negligible. Thus, a clearing of approximately 2,000 square feet was required for proper antenna installation. Because a clearing of the above size may not exist in particular areas, it may be necessary to accept inferior counter performance or forego installation of a counter at a weather station site. It was also found that at certain locations, because of ground condition, it was very difficult, if not impossible, to excavate holes for installation of the support poles, further hindering proper site selection.

All counters tested by the Institute, can be triggered by external noise. External noise in this paper refers to any phenomena external to the sensor, aside from a lightning discharge, that will initiate a response from a lightning counter. In particular, the LSC101 counter was easily triggered by a high voltage source, for example, a faulty vehicle ignition system or "leaky" power lines within a distance of one to two hundred feet of the sensor. Thus, a particular site may be chosen for any one of several



1. Wooden mast approx. 6.5 m overall.
2. Hardwood spreader 50 mm x 25 mm with 8 clearance holes at 150 mm centres.
3. Terylene rope, 20 mm circumference.
4. Terylene rope anti-twist guys, as 3.
5. Stranded wire not exceeding 3 mm diameter.
6. Stranded wire as 5., insulated.
7. Ventilated (lockable) housing for counter,(outdoor location).
8. Earth connection, as 5. Resistance to earth less than 100 ohms.
9. Pulley.
10. Saddle.
11. Wires bonded.
12. Stand-off insulators to give 5 cm clearance between downlead and mast.
    OR: Free drop with entry through underside of enclosure as shown dotted.

Note: The insulation resistance of the aerial and downlead system must exceed 20 megohms.

FIGURE 1 Antenna required for the Pierce (Model LSC101) Lightning Stroke Counter.

reasons, only to find that there exists an intermittent noise source, necessitating relocation or acceptance of an inferior performance.

Further, in an effort to extend the life of the antenna, it was recommended that it be dismantled each fall and reinstalled each spring. It should be noted, that despite the above problems, within two to three weeks from initial installation, the 1973 lightning sensor network in the northwest fire region of Ontario was operating satisfactorily. This was accomplished by moving some antennae to new locations until performance was satisfactory. The same network continued to operate satisfactorily throughout the 1974 fire season. However, it was the consensus of provincial personnel and the Institute, that a new design featuring a small antenna would be more adaptable to field conditions as found in Ontario and throughout Canada. A set of desirable specifications were drawn up as goals for the design of the new Model Lightning Stroke Counter.

GOALS FOR PERFORMANCE OF A NEW COUNTER

The reasons cited for the initial choice of the Pierce counter to form the basis of a thunderstorm tracking network remain valid. Thus, the primary goal was to design a new lightning counter capable of duplicating the performance of the Pierce lightning counter but utilizing a much smaller antenna. Improved noise discrimination and a preference for cloud to ground flashes were secondary goals.

Some forestry agencies have shown interest in a directional lightning sensor. Because direction was not one of the goals of the original study, a brief explanation would be in order. Kourtz, (1974) described a directional radio frequency sensor developed and tested by McGill University (Ballantyne and Stansbury, 1973) in conjunction with the Institute. This sensor was capable of allocating lightning discharges to individual quadrants. At an estimated production cost of $1,000 and with a maximum range of 80 miles, this sensor could provide the same storm area coverage as four Pierce counters at an equivalent cost. This would allow for the installation of one counter, rather than four. If minimizing counter locations is the main concern of an organization, then a network of directional counters might suffice. However, there are major concessions to be made if installing a thunderstorm tracking network composed of long-range directional counters.

The initial concession is that an organization has to be satisfied with inferior information on storm location. The directional counter described indicates a storm occurrence within a 5,000 square mile area compared to a 1,200 square mile area represented by a short-range Pierce counter.

A long-range system is often deemed necessary due to a lack of manned weather stations. Thus, the directional counter bypasses the problem of a shortage of manned weather stations rather than provide the incentive for an organization to develop a dense network of weather stations. Kourtz, (1974) shows that an important relationship exists between sensor counts, forest fuel moisture content (as calculated by the Canadian Fire Weather Index System) and lightning fire occurrence. Thus, to enhance an organization's ability to predict the occurrence of lightning fires, a thunderstorm tracking network must work hand-in-hand with an effective weather station network.

Finally, if a directional counter did meet the needs of an organization, there would be an unknown time delay till an operational version could be produced. The directional counter was designed as a research instrument rather than a field operations instrument. It would require design modification, component specification, contracting of mass production, and further testing prior to operational field use. All these factors were considered by the Institute in the development of the new Model LSC201 Lightning Stroke Counter.

DESIGN FEATURES OF THE MODEL LSC201

The new instrument (Model LSC201 Lightning Stroke Counter) has been made more portable by replacing the former large antenna with a small parallel plate type. This plate took on several configurations throughout development but the first practical antenna consisted of a 12-inch square sheet of 1/16-inch plastic with copper cladding on both sides. The smaller antenna resulted in lower signal levels and a corresponding requirement for new electronics. In addition to a more sensitive amplifier, the usual approach of analyzing the signal for frequency characteristics in this new model has been changed to a pulse analysis.

The detector is designed to be sensitive to the rate of change of the vertical component of the static electric field. The new pulse analysis means that a detected signal must exceed both a specified rate and duration in order to be counted. The duration requirement results in the rejection of very short pulses and high frequency components, no matter how strong they are. This duration requirement theoretically eliminates the counting of in-range dart leader pulse signals and distant return stroke radiation signals. The minimum rate requirement suppresses the counting of slower field changes, characteristic of cloud to cloud discharges, which in any case, usually results in relatively small net changes in the vertical static field at the detector site, except at close range. Thus, the type of lightning discharge capable of operating the counter has been more tightly defined, such as to prefer cloud to ground strokes within its defined detector range. Figure 2, gives a general illustration of the system response to three different inputs and the rejection of two of them.

Initial development proceeded from a configuration where antenna and electronics were physically separated as in the Model LSC101. However, the reliable detection range was unduly limited by noise. A much more useful performance resulted from integrating the electronics into the antenna as a single package. This new configuration has the advantage of preventing the connecting cable from acting as part of the antenna. This advantage means that sensitivity is nearly independent of cable length or installation height (providing that normal precautions are taken against shielding of trees, etc.). The "mushroom" shaped plastic detector (see Figure 3) is the resulting configuration of the detector which contains both antenna and major electronics.

TEST SETUP

The Pierce counter was used as the benchmark for rating the performance of all prototype lightning counters. All prototype counters as well as the Pierce were linked to a multi-channel event recorder. The counters were equipped with relays to allow for an input voltage to the recorder whenever the sensors were triggered. The recorder enabled monitoring to within a few minutes, the time the sensors began counting and the time counting terminated. It also allowed for monitoring of simultaneous counting (counters triggered at identical times).

Access to McGill Weather Radar in Montreal allowed for examination of

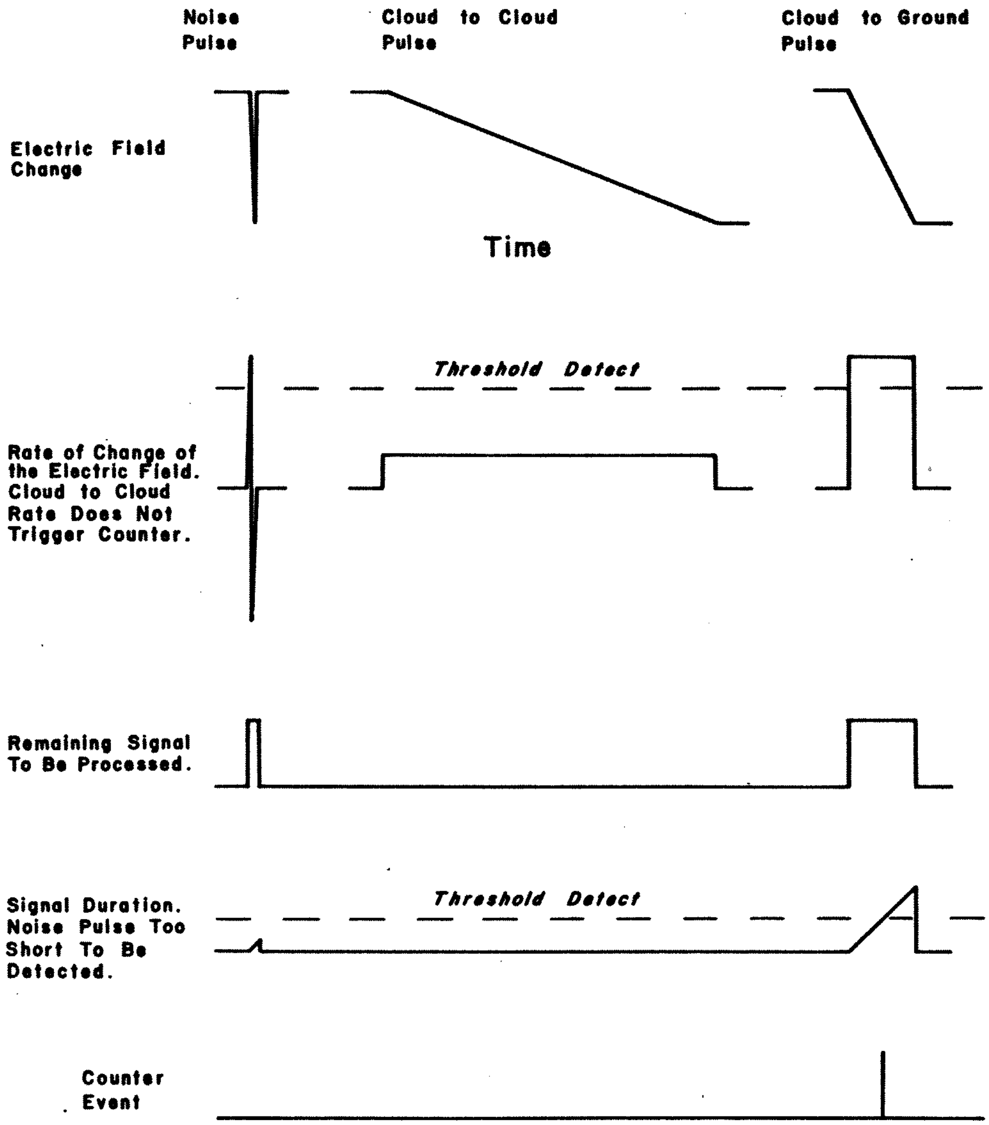


FIGURE 2 Theoritical response of the Model LSC201 Lightning Stroke Counter to three types of change in the electric field.

The noise pulse is not recognized by the counter as the field change associated with the noise pulse occurs over too short a time period. The cloud to cloud pulse is not recognized as the electric field change occurs over too long a time period. The cloud to ground pulse is recognized by the counter.

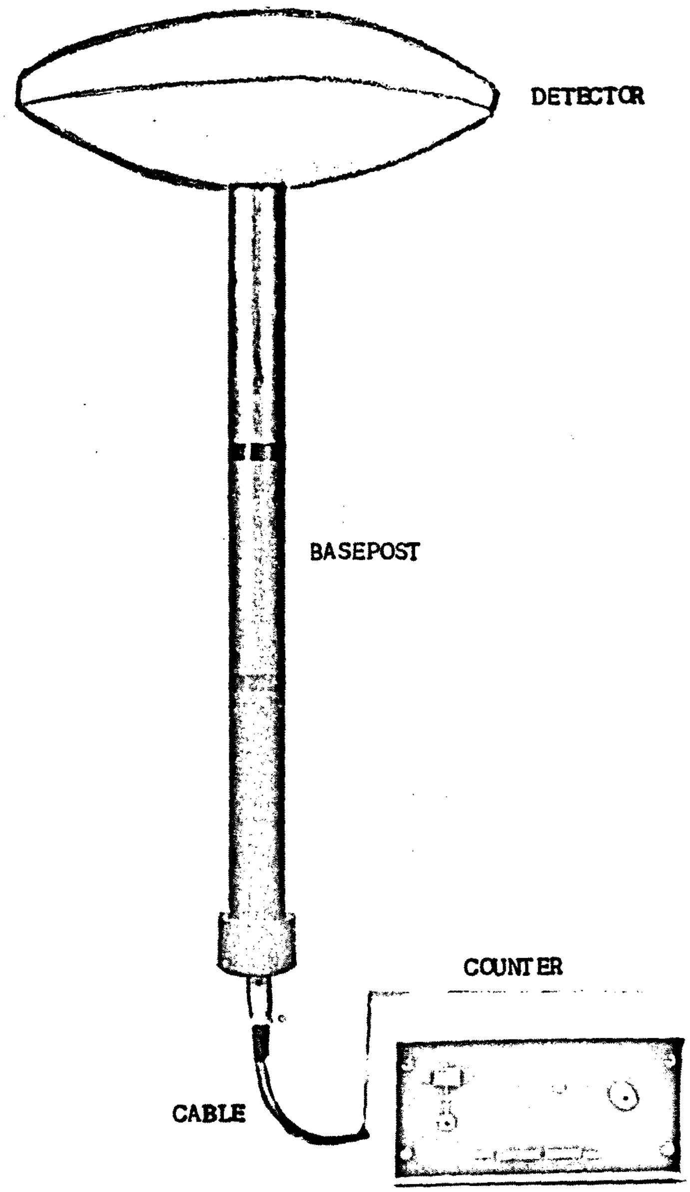


FIGURE 3 The Model LSC201 Lightning Stroke Counter

pictures of their weather radar screen (pictures taken at 5 minute intervals). Thus, with the time of counting, parallel event recordings and storm cell location, there existed the necessary information to compare prototype performance to performance of the Pierce counter.

The location for testing was the Central Research Forest southeast of Ottawa. Although the aspects of this location could not duplicate all aspects found in the field, in close proximity to the antenna were power lines, vehicles, generators, forest canopy, aircraft, small radio transmitters, and buildings. Significant features not found in the area were radar bases, large radio transmitters and mountainous terrain.

In addition to the above test, several forestry organizations throughout Canada installed networks utilizing the Model LSC201 counters. These were: La Société de Conservation de l'Outaouais, centered at Maniwaki, Québec; the north central fire region of Ontario, centered at Thunder Bay; and the northeastern fire region of Ontario, centered at Sudbury. Also, the British Columbia Forest Service installed nine counters on a test basis. The Institute monitored the Québec network on a daily basis and participated in installation of the network. The Institute did not have field contact with the British Columbia and Ontario networks but has received brief reports from both provinces on the performance of the LSC201.

RESULTS

Research Forest

1. Range of various prototypes extended from 10 to 100 miles.
2. Prototype chosen for field operation and mass produced as the Model LSC201 has a range of 15 to 25 miles.
3. The counter is not affected by hydro lines, generators or vehicles as was the Pierce.
4. Complete forest cover decreases range by a factor of 4 or 5.
5. Average battery life is 2 to 3 months.
6. Average storm counts registered by Model LSC201 was half that registered by the Pierce.
7. Elevation of antenna was unnecessary, if no tall objects in proximity.

Field

Point 2 to 6 of the Ottawa results were verified. In addition, varied field conditions indicated the following:

1. Radar induces a noise problem.
2. Large radio transmitters induce a noise problem.
3. Extreme cable length (over 50-feet) induces a noise problem.
4. High winds can induce a noise problem.
5. Lightning in vicinity of counters damages circuitry. This problem existed primarily where counters were at extreme heights.
6. Cold weather (below 4.4° C) causes sporadic counter response.
7. High altitudes causes sporadic counter response. (Pertaining to mountains - possibly related to winds or temperature).

Discussion

The Model LSC201 achieved two of the predefined goals, it is portable and shows preference for cloud to ground strokes. The former is a self-evident advantage. However, at this time the advantage (if any) of cloud-to-ground preference is undetermined. It has resulted in the "50-20"* rule (Kourtz, 1974) being temporarily revised to a "20-20" rule. Thus, an area is most likely to have lightning fires if the lightning sensor reports 20 or more counts and yesterday's Duff Moisture Code is 20 or greater.

Analysis is now being conducted to determine if there exists a correlation between varying lightning counts, DMC, FFMC and rainfall. However, this analysis is being conducted on the 1973 and 1974 data from the Pierce network of the northwestern fire region of Ontario. Data from the LSC201 networks are not being utilized in this analysis. The Outaouais region was characterized by a wet summer season with minimal lightning starts and Ontario data has only recently been obtained. Analysis on the LSC201 results will be delayed until 1975 results are accumulated. For

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* "50-20" rule - lightning fires are more likely to occur on days when counters indicate 50 or more and the DMC (Duff Moisture Code) is 20 or greater.

the present, the best prediction mechanism remains the correlation determined from the 1973 northwestern Ontario study and as modified for the Model LSC201 Lightning Stroke Counter.

The goal of improved noise discrimination was not achieved. The noise problem remains but exists in different forms than those associated with the Pierce counter. Because most of the new problems occurred in the field, there was no forewarning and thus, no recommendations for site selection with regard to these problems. As a result, several organizations were faced with a confusing situation when attempting to interpret network results and understandably doubted the validity of the data obtained from the LSC201 networks.

The network in Québec (Model LSC201) was made to work satisfactorily within two to three weeks of initial installation. This was similar to the experience with the Pierce network in northwestern Ontario in 1973. This success was achieved through daily monitoring, close contact with the manufacturer, experience from development of the LSC201 and, in certain instances, a trial and error technique for site selection.

Fire Control agencies cannot be expected to completely follow the above procedure for obtaining satisfactory results. Agencies utilizing the LSC201 must monitor the counters on a daily basis and should have contact with the manufacturer. However, lightning counters are a relatively new piece of technology and agencies cannot be expected to have a great deal of experience with their performances. Thus, the intention of the Institute is that the LSC201 be a self-sufficient and reliable piece of technology which will provide valid information when utilized under established guidelines. Testing by the Institute at the Central Research Forest confirmed the above characteristics but only as related to that particular test site and guidelines for site selection were then based on the test results. As the thunderstorm season progressed, it became apparent that certain characteristics of field locations degraded the validity of counter information and that a revised set of installation guidelines was necessary.

INSTALLATION GUIDELINES

Following are a number of guidelines, which if followed, will result in improved network performance. These guidelines are based on the Institute's experience with the Québec network, reports received from Ontario and British Columbia on the performance of the LSC201, and test results achieved at the Central Research Forest:

1. Select the most open area within a reasonable distance of the weather station for counter installation.
2. Elevate the antenna to a height of no more than 50-feet in attempts to avoid shielding effects (trees, buildings, towers).
3. Test effects of noise source on counter before installation (notably radio transmitters).
4. Progressively move counter away from noise source till the source has no effect on counter (e.g., radio transmitters at Davidson, Québec, affected the counter to a distance of 300-feet).
5. Change the battery in the middle of the fire season regardless of what the battery test indicates.
6. Refrain from mounting antenna on the highest point in the area, (e.g., on top of a 100-foot tree).
7. Try not to operate counters at consistently cold temperatures (4.4° C, 40° F).
8. Avoid installation of counters at radar bases.
9. Install a .1 microfarad capacitor across the terminals on the front panel (see Figure 4). This procedure will lessen the noise problem but also decrease counter range. It should be used as a last resort in trying to counteract a noise problem.
10. Incorporate daily reporting of counts with reporting of other daily weather measurements.
11. If the weather station is unreliable (counters cannot be read and reset each day) disregard lightning report and utilize lightning information from adjacent weather stations. A new counter location should be considered.

NOTE: The above guidelines apply to the early version of the Model LSC201 Lightning Stroke Counter (counters bearing serial numbers 2000 to 2100). The Model LSC201 Lightning Stroke Counter was modified for the 1975 field season (discussed on page 15). Guidelines 5 and 9 do not pertain to the modified version of the LSC201 (counters bearing serial numbers 2100 to 2200).

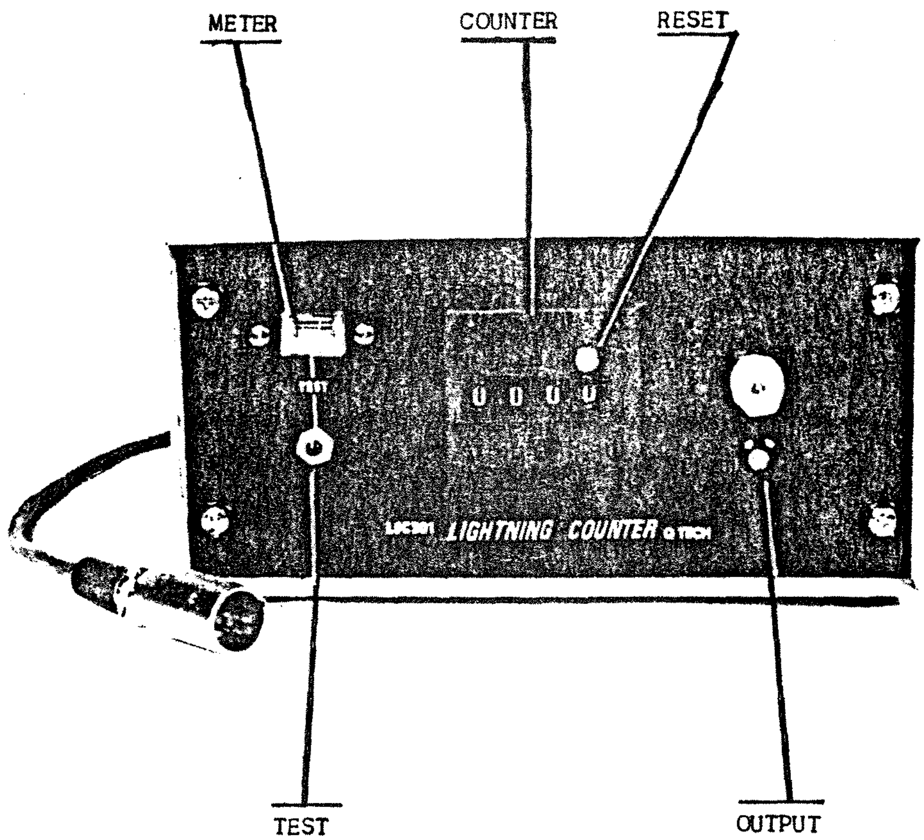

FIGURE 4 Face of counter box.

If a capacitor is necessary, it is connected across the red (white) and black terminals marked <u>output</u>.

If the above recommendations are incorporated, the majority of problems with the LSC201 should be overcome. There remain the problems created by faulty circuitry or unique noise sources. In these cases, contact should be made with the manufacturer[1/] or the Institute.

Future work in the lightning field will involve: establishment of firmer guidelines for site choice, modification of the LSC201 (if necessary) for improved noise suppression, and further analysis on relationship between lightning counts and various measures of the moisture content of forest fuels.

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MODIFICATIONS TO THE LSC201

As a result of problems encountered during the summer of 1974, two modifications were made to the LSC201 Lightning Stroke Counter. These modifications will be incorporated to all units delivered for the 1975 season. The modifications involved replacement of an amplifier and decoupling of the power supply. The amplifier change will allow the counter to operate on one battery for a complete fire season. The decoupling of the power supply eliminates the cable from acting as part of the antenna and removes the necessity of installing a capacitor across the front panel terminals.

SUMMARY

The Model LSC201 counter possesses the basic attributes required for an electronic lightning counter as part of a system to predict the occurrence of lightning-caused forest fires. In addition, the LSC201 features portability, an asset which will result in it replacing the Pierce counter as the basis of a thunderstorm tracking network. It is necessary, however, to be aware of its limitations and the guidelines which pertain to the installation of the new counter.

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