A STATUS CHANGE ACTIVATED MULTIPLE-CHANNEL EVENT RECORDER

by

EDWARD EMIL KEMNITZ

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1967

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1969

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Thesis Approved:

Jay G Porterfield

Thesis Adviser

James E. Garton

D. D. Durham

Dean of the Graduate College

PREFACE

The study reported in this thesis was conducted primarily to improve the efficiency of event recording by operating only upon a change in status and by simplifying the analysis of data.

The writer is grateful to Professor Jay G. Porterfield, the thesis adviser, for his counsel and encouragement throughout this study. Appreciation is also expressed to technician Jesse A. Hoisington for his assistance in carrying out this research.

Appreciation is also expressed to Professor E. W. Schroeder and the Agricultural Engineering Department for providing an assistantship.

The assistance of the Agricultural Engineering Department draftsmen in the preparation of illustrative materials is also acknowledged.

I am particularly grateful to Anita, my wife, for her understanding and help during this study.

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CHAPTER I

INTRODUCTION

Farm and industrial equipment manufacturers make several hundred different machines. Each of these performs an operation which differs from the operations of the others. Test work cannot necessarily be accomplished on one of these machines and then applied to another which performs a dissimilar operation. Therefore, each machine must be tested individually both for soundness of design and for efficiency of operation (1).

Today there is less time available for the testing of a new machine, and the need for more and better instrumentation is at hand. The use of recorders in testing of farm and industrial equipment is unlimited.

The purpose for event recording is to show when an event happened, how long it lasted, and how frequently it occurred (14).

According to Nelson (18), there are twelve basic types of recorders available. The type that is of concern here is the Operations Recorder. Operations recorders are "on-off" event recorders, signifying only that a variable was in one of two possible states at a given time. They are used primarily for monitoring purposes, and have the advantage that several channels can be monitored simultaneously for long periods of time.

At present, most event recorders make use of one of two types of charts: either a circular chart or a strip chart. These charts are marked off in time divisions, and they run continually.

Circular charts vary from several inches to twelve inches in diameter. Since data does not print to the center of the chart, and since the outer rim is generally printed with the time period covered, less than one-half of the diameter is available for the printed record (21).

Strip charts vary from a few inches to at least twelve inches in width. A twelve inch strip chart presents eleven inches of printing surface with the remaining inch used for driving the chart. Paper requirements, such as resistance to temperature and humidity, are the same for both circular charts and strip charts (21).

There are many operations which are not being monitored but which should be and would be if a suitable recorder were available. Most event recorders today operate on 115 volt alternating current or by a vibration motion. Therefore, they are not suited for monitoring many operations on farm and industrial equipment that otherwise could be recorded.

Testing could be much improved and many more types of operations monitored if a suitable recorder were available. This would require a recorder that could monitor an operation(s) for extended periods of time without requiring frequent attention being given to servicing the recorder.

Since there are many operations which have extended periods of time between a change in status, the recorder needs to be operated only when there is a change in status, thus reducing the amount of paper necessary for recording. After the initial investment, the major cost of recording is the paper cost; therefore, comparisons of recorders are made on this basis (19).

This study was made to improve on the efficiency of recording through the designing of an event recorder that would monitor operations for an extended period of time, and at the same time, decrease the cost of the paper by operating only upon a change in status. The efficiency of recording would also be improved by putting the data output in a coded numeric form which would be compatible for computer analysis, thus assisting data processing mechanization. This type of data output would have the desirable feature that it would do away with the manual operation of interpolating and converting the data from the present strip and circular charts when getting the data in a form that can be handled by mechanized data processing. First by means of letters, a complete search was made of the recorder industry for existing types of event recorders. It was discovered that there did not exist a suitable recorder of this type on the market. Components were bought and a recorder was built and tested. First, tests were conducted in the lab with the test recorder being checked against two commercially available recorders. The test recorder was then mounted on a tractor for field evaluation.

CHAPTER II

OBJECTIVES

Objectives:

A. Design and build an instrument that would print on a tape the starting and ending times of an event or operation.

B. Improve the efficiency of recorders so they can operate for extended periods of time without the need that frequent attention be given to service the recorder.

C. Present the data in a coded numeric form that could be handled by mechanized data processing.

D. Evaluate the design by appropriate field and laboratory tests.

CHAPTER III

REVIEW OF LITERATURE

This review of literature has been divided into two general topics. The first topic concerns previous work done in the general area of event recorders, while the second topic discusses some of the previous use of recorders in agriculture.

Previous Work Done in Event Recorders

The first event recorders were referred to as time-recorders. In 1881, a Frenchman by the name of Pouget (20) filed a patent for registering the travel and periods of rest of locomotives, as well as other vehicles. This recorder was the forerunner of the continuous strip-chart recorders.

Green and Eaton (10), in 1906, filed their patent for an improved electric time recorder which would monitor the starting time and the duration of the run of a machine. This recorder was one of the first to make use of a circular chart for recording.

In 1908, Sohm (22) filed a patent for an electrical signal recording system which would record the time of arrival and departure of employees, check the movement of watchmen, and transmitt and record fire and burglar alarms or other signals where the time of the event was of importance and needed to be recorded. A signal would be sent either by an employee or an automatic alarm system which would cause a print of a number for that signal and the time of actuating. This was one of the first recorders in which a print was made only upon command. The printer coils would not return until the switch from the signal was released.

In 1916, Bauer (5) invented a recorder which would keep a record of events or operations which required periodical attention, such as recording the time when one or more watchmen called at different parts of a plant or building, or recording the time when different workmen arrive at a definite place for work and leave from the same place, or for keeping track of the operations of machines in which the time element occurs. The recorder would punch a hole in a certain location on the paper reserved for that signal and would print the time the signal arrived. The paper would advance one step after each signal.

In 1934, Harrison (11) applied for a patent on his recorder which was suitable for recording transient phenomena of various kinds, such as the opening and closing of doors, the operation of circuit breakers, and the operation of machinery of all kinds. His patent was assigned to the International Business Machines Corporation. The recorder was for use of monitoring operations which take place at infrequent intervals of time or, at best, with a considerable lapse of time between successively occurring phenomena. The recorder would do away with the undesirability of a constant paper feed which in transient phenomena would waste large amounts of chart paper. It was stated that there would often be as much as 75% to 95% wastage of chart paper when there was a constant paper feed. Also, there was a large amount of space required for storage of the rolls of used charts which needed to be saved. Harrison's objective was to have the chart feed a predetermined length at a constant rate of speed only when the phenomena to be recorded occurred. The exact time was printed at least once on each predetermined length of chart fed in order to provide a convenient time reference point for determining the exact time of occurrence of all phenomena which would occur during the interval of time while the chart is being fed a predetermined distance. The feed was of sufficient length and of long enough duration to enable the time of all phenomena occurring during the feed of the chart to be accurately determined either by means of suitable lines ruled on the chart or by a properly graduated rule.

Then in 1937 Engst (7) filed a patent for an improved and simple mechanism for recording accurately the time of occurrence of certain events. This mechanism has a synchronous motor which drives several counter wheels which have raised type of decimal orders on the periphery. These decimal orders represent minutes and decimal fractions of a minute. The drive for the counter wheels was designed so that the wheels are held stationary momentarily whenever a new number was presented at a printing position. Hammers, normally latched in an inoperative position, were tripped electrically at the starting or stopping of any sequence of events, the time of which was to be measured. Immediately upon release, the hammers would strike a strip of paper, fed step by step for each recording operation, to drive it into contact with an inked ribbon located between the paper and the type on the counter wheels. Promptly upon their release, the hammers were reset to their initial inoperative position from which they could again be released electrically to record the next event. An auxiliary platen was located adjacent to the number wheels so that identifying symbols could be selectively recorded near the number which represents the time of occurrence of an event.

Hobby (12) in 1945, invented an improved mechanism for making time records on a paper tape or other continuous record surface. The same mechanism would differentiate between two classes of records, such as load on and load off, or start and stop. This invention was provided an auxiliary printing device bearing two different symbols together with means for moving either symbol into operative position. It was an object of the invention to provide a simple actuating means so constructed and operated that a given load condition will always and positively be associated with a given symbol and so that indication of the condition would be entirely dependent and could not get out of step.

In 1956, Gregory (9) filed a patent for his invention which would record the occurrence of events and the time at which they occur. His recording device provided a printing chronograph which was comprised of a counter, a means for driving the counter at a constant speed whereby a time base was provided, a capability of producing a printed record of the total at any time, a means responsive to an electrical impulse to operate the printing, a means to record that impulse on strip record material, and also, to print, in alignment or other co-related relation with the record, the counter reading, and a means for advancing the strip material a step after each printing operation. The recorder had six channels for printing event symbols and independent means for producing impulses to effect operation of such printing means, whereby the occurrences of different events may be isolated and recorded either separately or, if they occur simultaneously, at the same time.

Wapner (25) filed for a patent in 1957 on his invention which relates to an event recorder which monitors events such as operations of equipment. The recorder was particularly adapted to identify events as to both sequence and actual time, especially in cases where the events occur within a few milli-seconds of each other. The tape motion starts with the occurrence of the first event of a series and continues through the period of events which occur in rapid sequence and stops only after a predetermined interval following the last event of such sequence. The choice of the interval was based on the assumption that events are not related if one occurs following another only after a substantial period of time. Since the tape is stationary except for short intervals of time, a supply of tape of convenient size may need to be replaced only after several months of normal operation. The tape is imprinted with the date and clock time in order to identify the precise clock time at which an event or the first of a series of events occurs. This invention was assigned to the Fischer and Porter Company of Warminster, Pennsylvania, who today manufacture and sell an instrument of this type.

Moyano (17) in 1961 filed for a patent on his invention which was to be used on a chart that is continuously driven at a constant speed. This invention was assigned to the Thermo Electric Company. The invention was used when it was desired that a recorder operate only upon demand and at other times maintained on a stand-by condition wherein no record of the condition need be made. With such an arrangement, it is apparent that, if the chart is stopped during such stand-by conditions, and is driven only when recording, the lengthwise time graduations thereon provided no indication of the time of the recording. The invention provides a time indicating device for use on a recording instrument, which would provide a record of time on the chart independent of the chart position. An instrument of this type is available today from the Royson Engineering Company of Hatboro, Pennsylvania.

An automatic, digital time-of-events recorder, available from Airborne Instruments Laboratory, Division of Cutler-Hamner Inc., is efficient in determining occurrence times for a large number of event channels (15). This system can handle any number of simultaneous events by scanning all channels when triggered by the clock pulse, and recording channel status (on-off) during the clock period. The approach taken in this system is the inverse of the usual approach. Instead of determining the time at which an event occurred, the system determines whether or not an event occurred during a given period of time. The recording of channel status is done with binary bits on magnetic tape or paper tape.

The Weston Instruments Division of Daystrom Incorporated developed a time and event recorder for the United States Navy Bureau of Weapons. The recorder could monitor 50 event channels and the recorder would move the chart only when information to be recorded was present; otherwise, the chart was stationary. The time of each event was marked in binary-coded decimal notation, each time an event occurred. The recorder was made up of solid-state electronic components (26).

An event recorder called a digital logging device is marketed by Deakin Phillips Electronics Ltd. of London. This device has a maximum channel capacity of 127 sources and records the start and finish of an event as two identifiable signals on a punched tape. A time marker is also punched on the tape so that when the tape is read through suitable measuring equipment, the duration of the event, and the identification of the source, can both be reconstituted. The source of the event is coded in simple binary numbers and to distinguish between its start and finish, the appropriate binary code has an extra hole punched in a unique position to identify the finish event. To eliminate the possible loss of record which may arise when the start or stop of an event occurs during the interval in which the time marker is being punched, an arrangement of interlocking buffer stores is used in the system. These stores also ensure that there is no complementary loss of time record when an event start or finish is being punched. The recorder is made up of solid-state plug-in circuitry throughout (8).

Some Previous Use of Recorders in Agriculture

Farmers find that recorders serve as silent foremen and also as mechanics helpers. The charts can be used as a basis for servicing equipment and for determining the value received from equipment. Recorders also help with scheduling and keeping idle time to a minimum.

Bateman (4) reported a study done in 1940 in which tractor operations were recorded. The recorder charts made it possible to distribute accurately the total time spent in operating the tractor and helped in determining the amount of time lost as a result of necessary servicing, making minor repairs and adjustments, filling seed containers, etc. The objective of the study was to help find improved methods of using labor, power, and machinery on the farm in order to bring about savings in production cost.

Barger and Promersberger (3) reported on a dynamometer for testing machinery in which was incorporated a strip-chart recorder for recording draft. The recording unit was demountable and was also used on a tractor drawbar loading and testing car (2). These units were used by the Agricultural Engineering Department at Kansas State College.

Vasey and Simmons (24) reported on a study made in Australia in 1957 on the Field Performance of Hay-Making Machinery. The study was interested first, in finding and classifying the observable facts of field performance, and second, in observing and classifying in such a way as to relate the facts as far as possible to their causes. They observed such things as time, production, quality of production, labor requirements, and physical quantities. Most of their recording was done by a man with a clipboard doing the observing and recording by hand.

Taylor (23) reports of work done with simple instruments in cotton ginning research. He used a 20-channel event recorder in which each channel of the recorder was capable of registering a "Yes" or "No" answer when the electro-magnet for that channel was properly energized. Such occurrences as the flow of cotton through the different suction pipes of the gin were monitored to help answer questions of the following type: what percent of the time that cotton is available for ginning does cotton flow in the wagon suction line, what percent of the time does cotton flow in the overflow suction line, what percent of the time are the gin motors drawing current, and what percent of the time that the motors are drawing current is cotton being ginned. The recorder charts ran continuously and had time graduations of minutes printed upon it. The chart would last for a one week monitoring period.

Arndt and Kuehl (1) describe the vehicles, instruments, convenience items, and other equipment used by Deere and Company in their field testing of many types of farm and industrial machines. A large part of their mobile testing is devoted to structural analysis, although many measurements were made in determining functional efficiencies. The main type of recorder used by the company is the direct-writing occillograph. This type of recorder was picked because of its convenience and lower paper cost. Also it was convenient to mark on the chart an event which had been observed.

Jordan and Suggs (13) reported on a circuit they developed to provide intermittent operation of a multipoint recorder. By doing this they reduced the cost and length of the chart greatly. Their problem involved the measuring of several variables simultaneously as is the requirement many times in environmental research investigations.

LePori and Stapleton (16) reported work they did with a modified two-channel recorder used to measure five variables against time. The recorder chart ran continuously. Fuel consumption, travel distance, left and right wheel revolutions, and time intervals were recorded as on-off events with event markers. These events were recorded by markers which received a pulse from a three volt direct current closed by snap-action switches. The draft was recorded from signals produced by calibrated electric resistance strain gage draft sensors. The time was recorded by a one-second timer powered by a 60 cycle alternating current. It marked one event on the chart every second and could be manually operated to mark positions of special interest on the chart.

Brown and Vasey (6) reported on a wheat harvester survey made in Australia in 1967. This was an investigation of the performance of wheat harvesting machines conducted over a four year period. An intensive study was made of the effect, on the performance of the various mechanisms, of increasing the throughput and of varying the proportion of grain, straw, and chaff. In this survey most of the observations and recording was done by hand by a staff of field men.

CHAPTER IV

APPARATUS AND EQUIPMENT

The assembled test event recorder is shown in Figure 1. All components were designed to be removable for inspection and ease of making repairs, modifications, and servicing. Figure 2 shows a view of how the components are removable. One end of the recorder housing was furnished with a plexi-glass window to facilitate the observation of the Sodeco-print unit without the necessity of opening the recorder box.

A Sodeco-print Model PN 208 was purchased. The front view of the Sodeco-print is shown in Figure 3. This unit is an electrical printing counter which will permit visual reading of the results on an indicating register as well as print the results on a tape. The model, PN 208 is made up of two basic elements, element 7 and element 8. The unit is designed to provide for plug-in convenience between the panel mounted case and the removable chassis assembly. The instrument case is attached to the panel by two clamps and the chassis is withdrawn by releasing four knurled screws on the front plate. This arrangement allows replacement of the ink dispensing roller, the ink ribbons, and the paper roll while at the same time ensuring a good protection for the interior mechanism.

The paper roll is 3.44 inches wide and 60 yards long. It is good for about 10,000 impressions. The paper advance occurs automatically

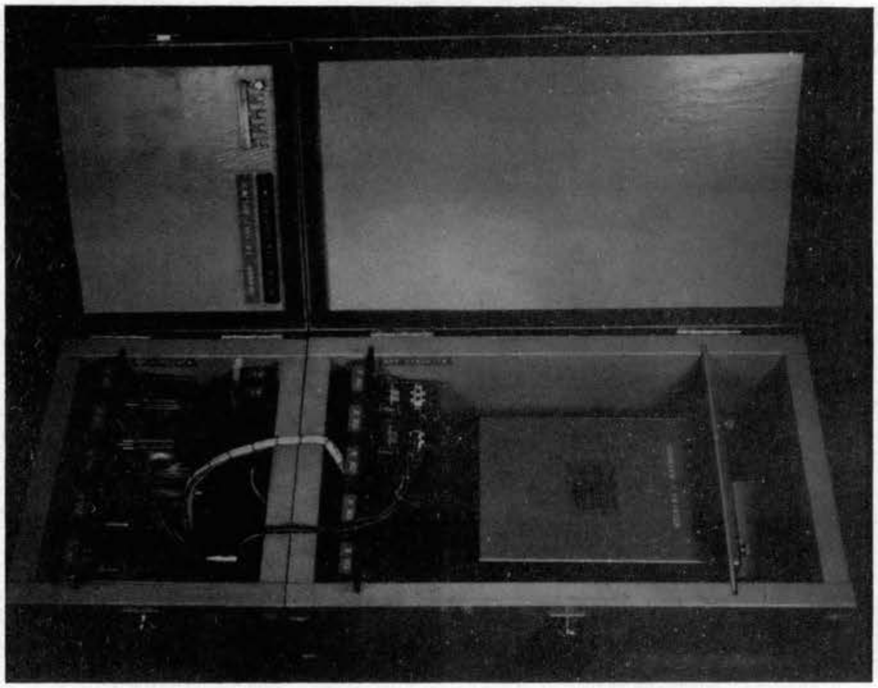


Figure 1. Assembled Test Event Recorder

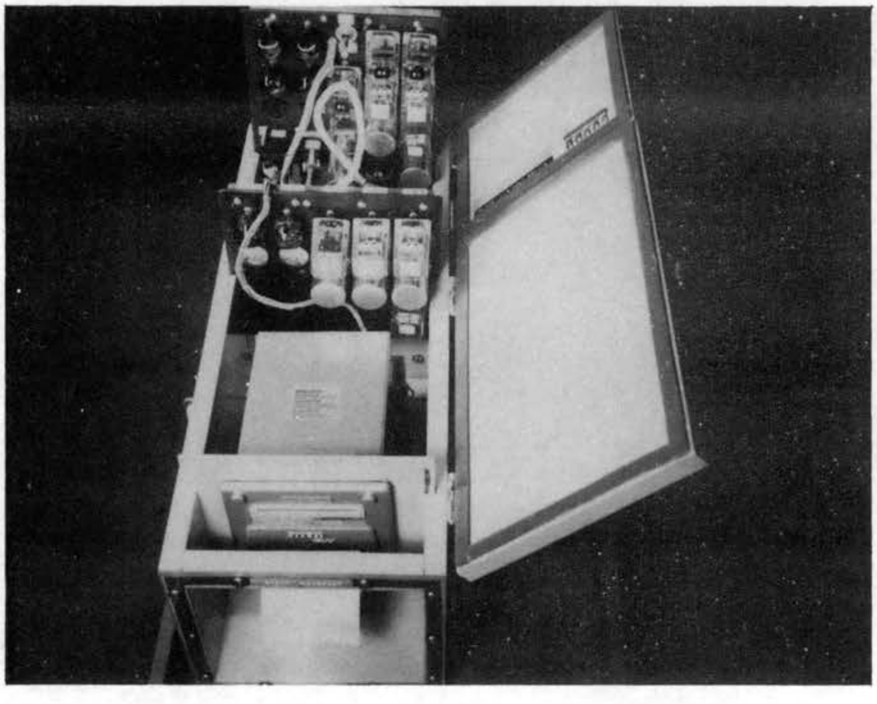


Figure 2. Showing How Components are Removable

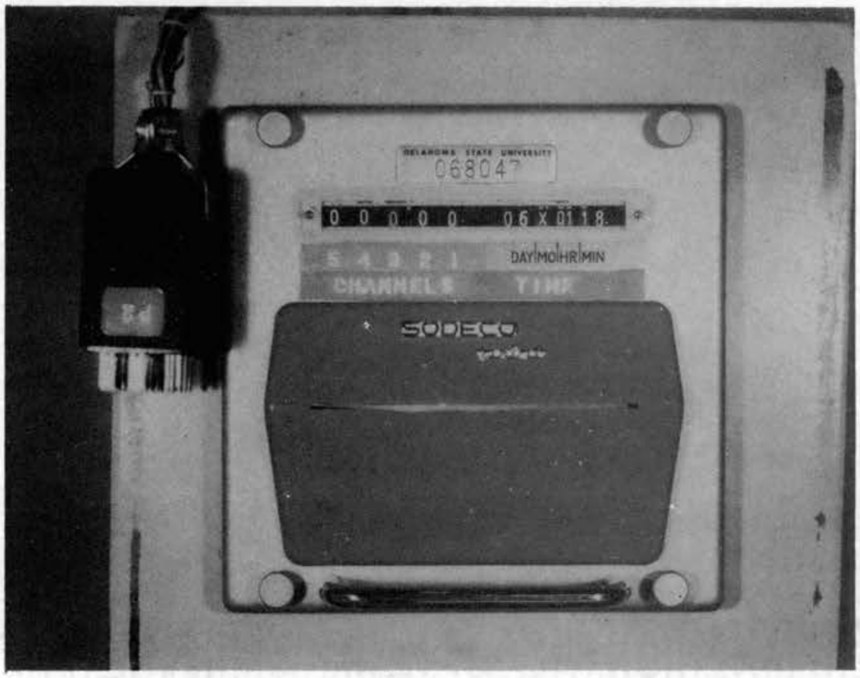


Figure 3. Front of Sodeco-print Model PN 208

after each impression and it is also possible to withdraw the tape manually.

The supply voltage for the unit is 12 volt D.C. This voltage is used throughout the entire recorder.

Print-out takes place by means of a print hammer striking the under-side of the paper tape. The print hammer is furnished with a rubber lining and is actuated by the print solenoid. The hammer, after a brief impact with the paper tape, returns to an intermediate position and remains there for the duration of the print command pulse. This provides for a speedy print-out independent of the length of the print command pulse. The advance of the paper tape and the ink ribbon occurs step-wise automatically upon release of the print hammer. The printed results become visible at the tape discharge opening after eight impressions.

It is necessary to apply short impulses of about 150 milli-seconds to the print solenoids to avoid heating of the windings. There should always be an off period of equal duration.

The basic element type 7 consists of a group of five independent monodecade count registers and a print mechanism. The count registers are designated as channels and are numbered from left to right as shown in Figure 3. The monodecate count registers are furnished with figure wheels which have readings of zero to nine on them. There should be a minimum of a 50 milli-second impulse duration to the count wheels and should be followed by an interval at least as long as the impulse. The maximum impulse frequency is ten counts per second. No particular precautionary measures for the interruption of the count pulses is necessary when print-out takes place at infrequent occasions only.

The basic element type 8 consists of six special ratio figure wheels. The element 8 registers time by the day, month, hour, and minute as shown in Figure 3. An impulse once each minute is required to operate the timing wheels. The initial time setting must be done manually.

Since an impulse once each minute was required to be supplied to the timing element 8, a single switch repeat cycle timer was bought from the A. W. Haydon Company. The timer is shown in Figure 4 mounted in the box built to hold the test recorder. The timer is equipped with a governed motor for operation on 12 volt D.C. and can give cycling time accuracy within ± 0.1% over a wide voltage variation. The timer is enclosed in a sturdy, extruded aluminum dust cover to give it protection from dust, lint, and similar foreign matter.

An impulse circuit was designed to give the desired impulse duration to the counting wheels and printing hammers. Two removable chassis boards were made, one for the "on circuits" and one for the "off circuits". The "on circuits" board, shown in Figures 5 and 6, was made up of three different functional type relays. All relays were of the plug-in type. The top row of relays are the signal relays, one for each channel. The coils of these relays should be matched with the voltage source being used to actuate the switch on the event being monitored. These relays are energized when some appropriate switch is turned on and will stay energized until the switch is turned back off.

The second row of relays are the "on count" relays which send an impulse of the desired duration to the count wheels of the Sodeco-print unit. This impulse causes the count wheels to advance one number. Since the wheels have numerals printed on them, it is necessary to

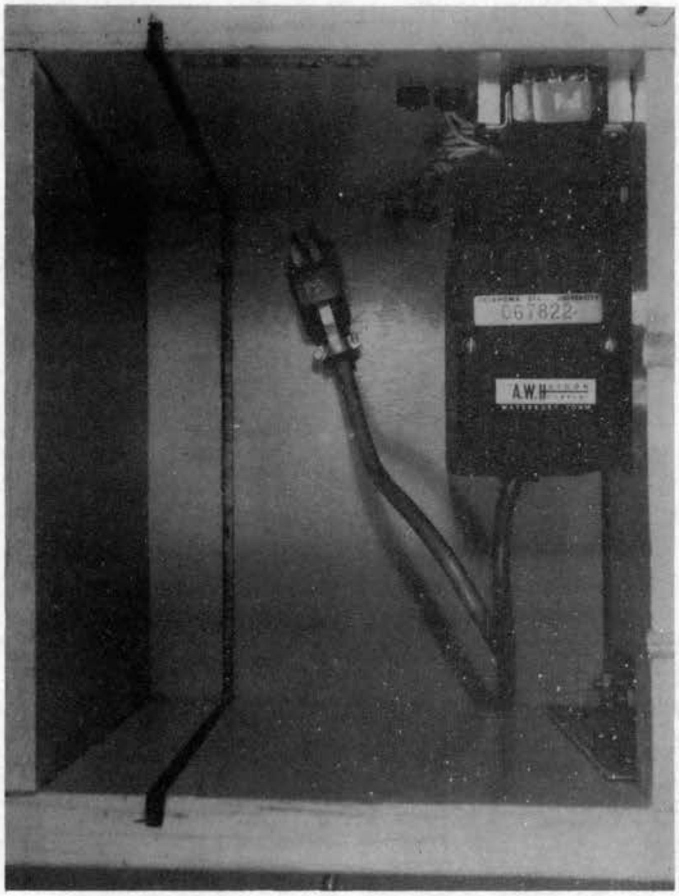


Figure 4. Single Switch Repeat Cycle Timer

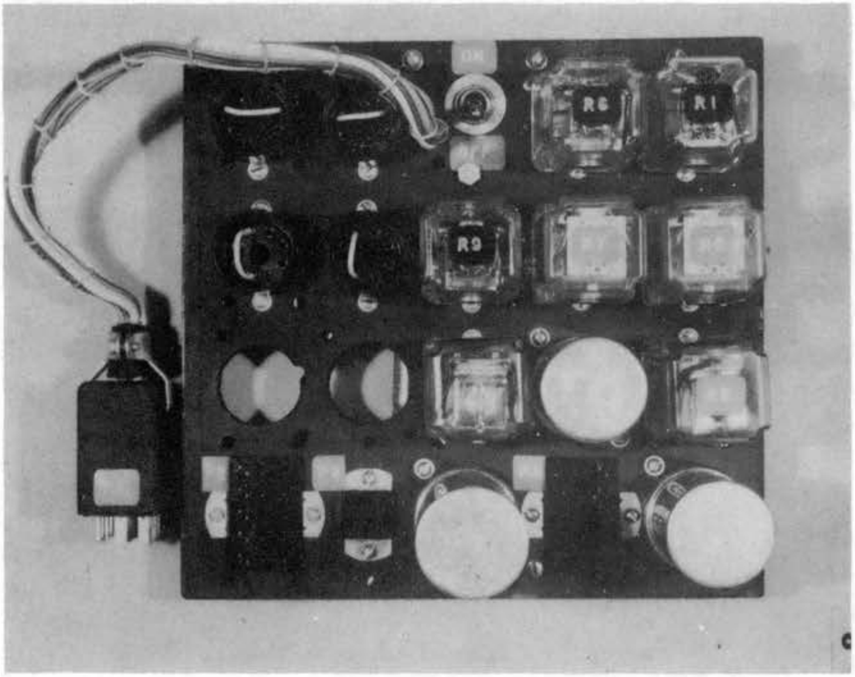


Figure 5. Front Side of "On Circuits" Chassis Board

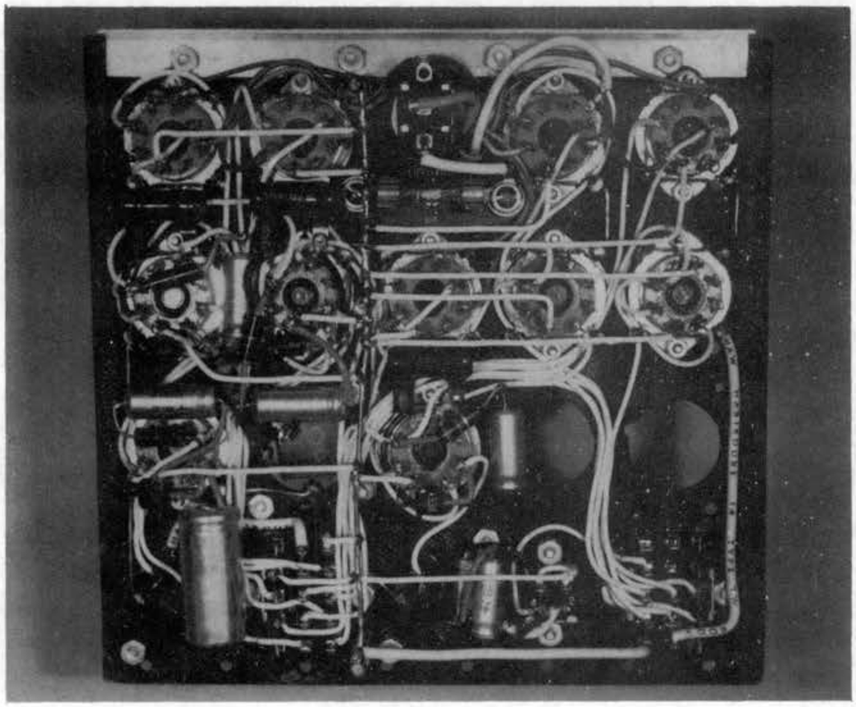


Figure 6. Back Side of "On Circuits" Chassis Board

designate the odd numbers as meaning either "on" or "off" and the even numbers as designating the opposite. There is an "on count" relay for each channel. As soon as the "on count" relay contacts re-open there is sent an impulse of desired duration to the printing hammers by the "on print" relay. One "on print" relay works for all of the channels. Since the counting and printing is being operated and controlled by direct current, it is recommended that the control switches be protected with a suitable spark suppression so as to extend the life and increase the reliability of the contacts. This spark suppression can be accomplished by the use of a RC link shunting the contact. The values for the RC link were provided by the manufacturer of the Sodeco-print unit.

The "off circuits" board, shown in Figures 7 and 8, consists mainly of two functional type of relays. These are the "off count" relays and the "off print" relay. These relays work on much the same principle as do the relays for the "on circuits" boards and are energized when the signal relay on the "on circuit" board is de-energized by the turning off of a switch.

A switch is provided on the "on circuit" board for turning the recorder on. This provides power to the timer motor, advancing buttons and all of the count and print circuits of the two chassis boards. Each of the five channels work on the same basic principle for sending the required impulses to the Sodeco-print unit.

When a switch is activated to the "on" position on the channel being monitored, the signal relay is energized causing its contacts to close thus sending current to the coil of the "on count" relay and, at the same time, fills a 3000 MFD capacitor. When the "on count" relay is energized, causing its contacts to momentarily close, an impulse is sent

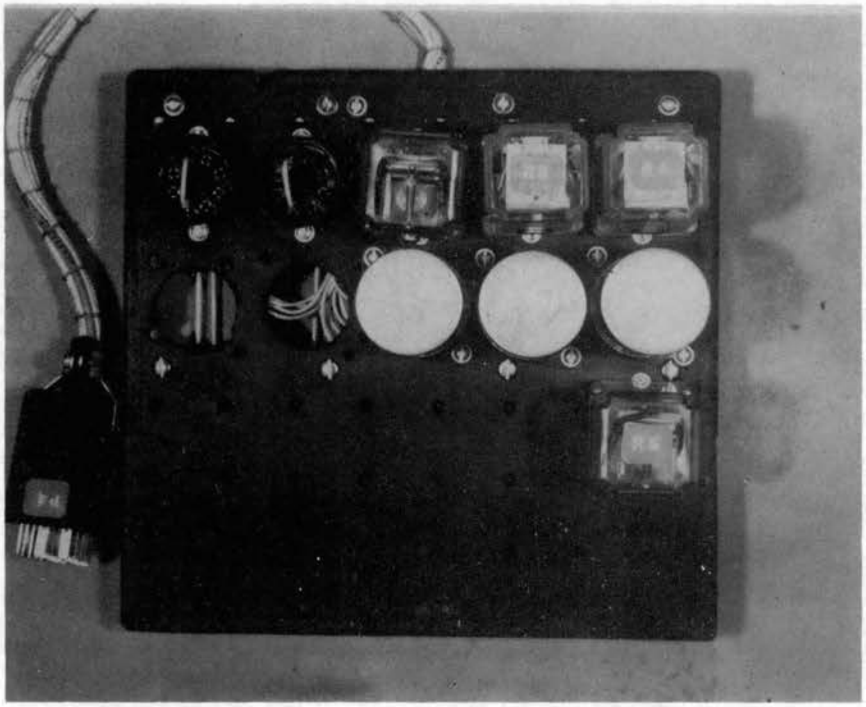


Figure 7. Front Side of "Off Circuits" Chassis Board

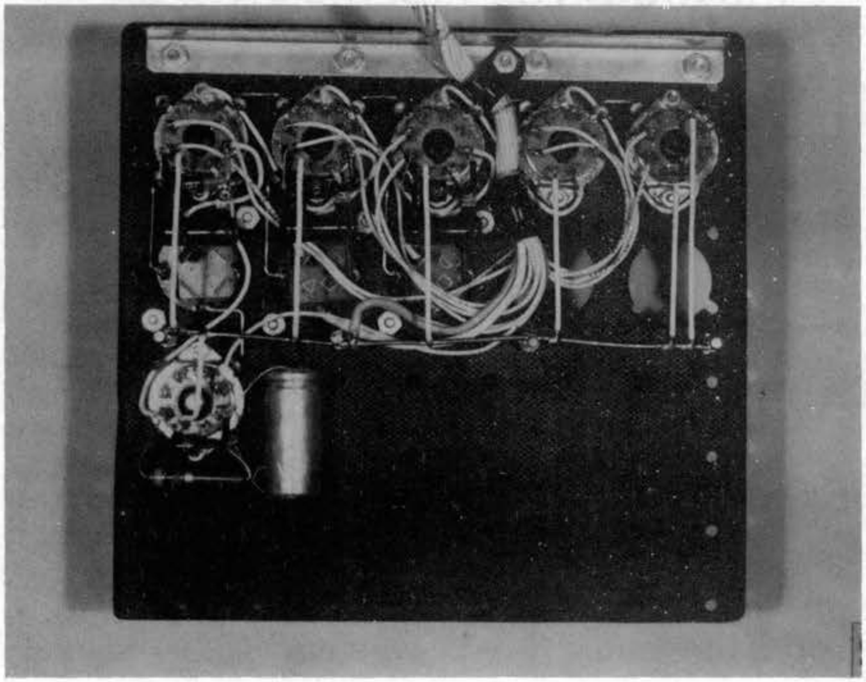


Figure 8. Back Side of "Off Circuits" Chassis Board

to the Sodeco-print unit causing it to advance one number. As these contacts on the "on count" relay are momentarily closed, another set of contacts on the same relay are momentarily opened causing the capacitor in the "on print" circuit to discharge and ready the "on print" circuit for its operation. When the contacts on the "on count" relay are back to their normal position, the "on print" is re-energized and causes an impulse to be sent to the printing mechanism of the Sodeco-print unit.

When the switch on the channel being monitored is activated to its "off" position, the contacts of the signal relay return to their normal position and a signal is sent to the coil of the "off count" relay. A series of events then take place on the "off chassis" board as has been described for the "on chassis" board.

A detailed schematic diagram of the counter/printer circuits for one channel and for all five channels is shown in Appendix A.

Provisions were made on the outside back of the box to make all necessary electrical connections, shown in Figures 9 and 10. Figure 10 is a close-up view of the terminal block on the outside of the housing. This terminal block provides for easy hook-up and maintains better sealing of the recorder housing. The power supply, as well as all leads to the signal relays, is connected at the outside terminal block. A five-term jumper was made to use when recording on a 12 volt D.C. system. With this jumper a common ground could be used for all input signals, thus making wiring hook-up easier.

A panel, shown in Figure 11, was made in which buttons were placed to advance any one of the count wheels and to advance the paper a step at a time. When the paper is advanced by this means, the time is printed

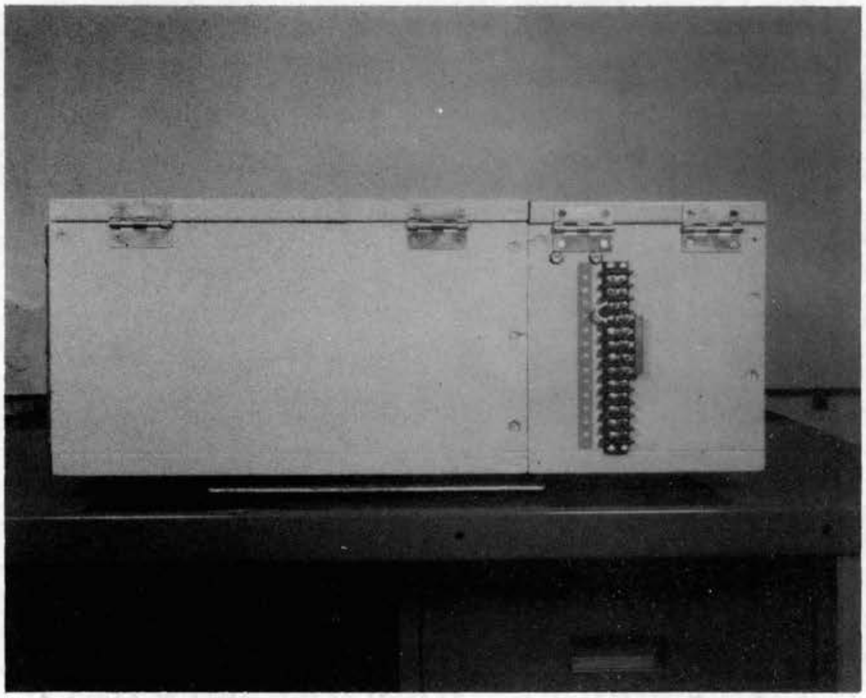


Figure 9. Back of Recorder Box

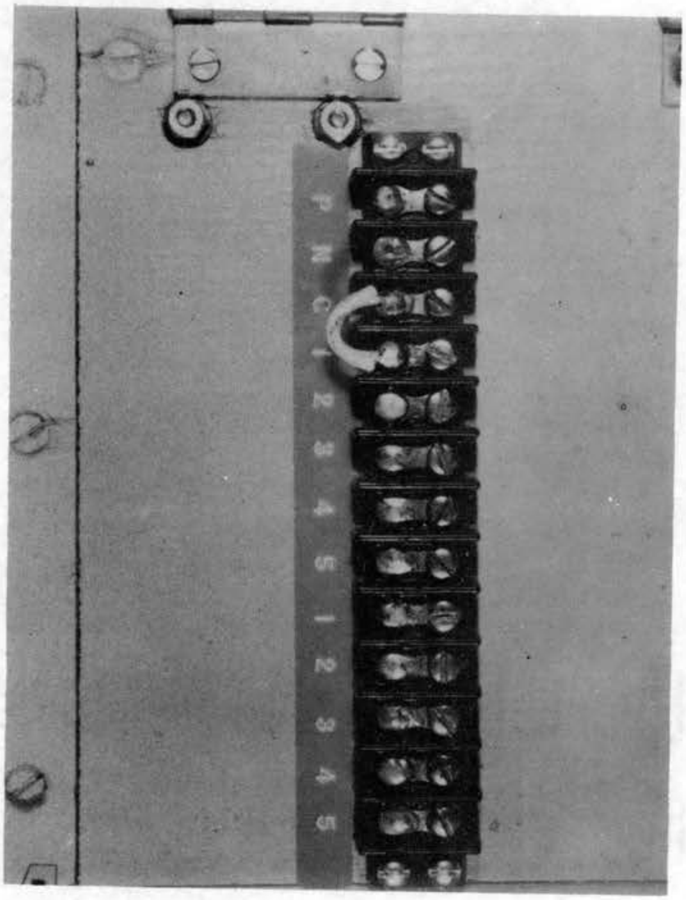


Figure 10. Close-up of Terminal Block

Figure 11. Panel of Advancing Buttons

each time the button is pushed. This can also be used as a marking device as to when a tape or data run was started and finished.

There may be times when it is desired to have an input signal to be at least a pre-selected time duration before it is recorded. This can be done by using a time-delay relay for the signal relay. Unless the signal is applied at least as long as the duration set, the signal will not be recognized and consequently not recorded. An adapter was made to allow the time-delay relay to be plugged into the signal relay socket.

All schematic wiring diagrams for the circuit boards and connectors are shown in Appendix A.

CHAPTER V

METHODS AND PROCEDURE

Laboratory Study

The laboratory study was carried out over a period of a little more than a week. In this period ten data runs were collected. The data runs were at least four hours long and some were as long as a day.

Two commercially available recorders were used along with the test recorder in collecting the data. Figure 12 shows a view of the three recorders used in the laboratory study. The recorder in the top of the view is a Servis recorder, in the middle a Standard recorder, and on bottom is the experimental or test recorder which was built.

One of the commercial units was a Servis Model M recorder equipped with an electric four-hour drive. Its circular chart would record up to a 12 hour period. The recorder has a small synchronous motor which drives a stylus that makes a short, vertical stroke on the chart. A wide line was then developed on the chart as it was being revolved constantly at clock speed. During idle periods, the stylus was stationary and a fine line was drawn on the chart. Figure 13 shows a sample chart used by the Servis recorder. Both the chart drive and the stylus drive were operated on 115 volt alternating current.

The other commercial unit used was a Standard Series RT recorder which has two channels. This recorder utilized a pre-printed chronologically marked chart-roll which moved at a constant rate and which directly

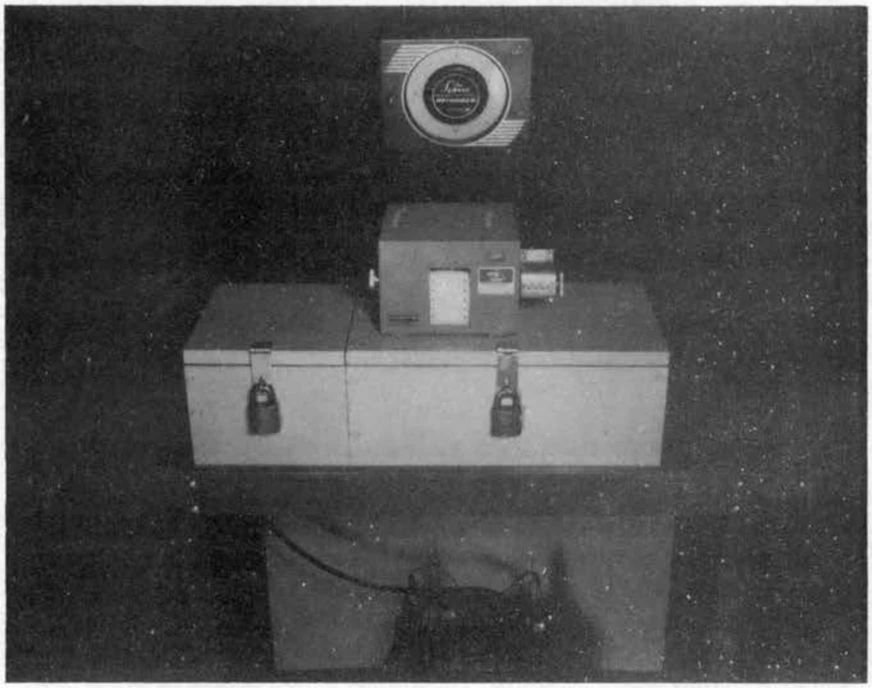


Figure 12. Three Recorders Used In The Laboratory Study

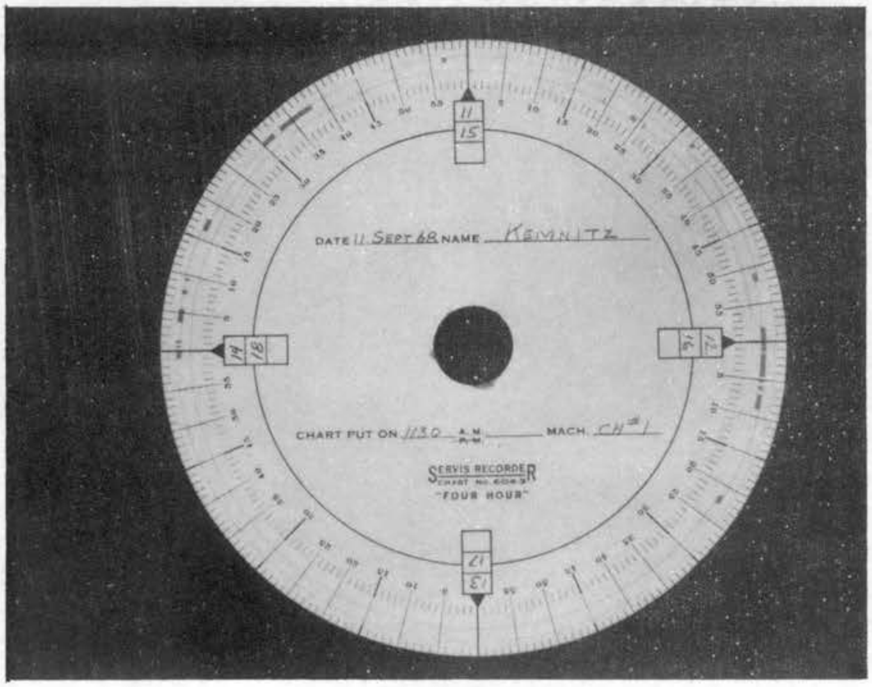


Figure 13. Sample Chart Used By The Servis Recorder

indicated the time of day. The stylus produced a continuous plot on the strip chart, marking the on-off pattern of the operation being monitored. The styli are solenoid actuated, their positions being governed by the on-off operation of the source to which they are wired. The chart drive as well as the stylus solenoid are operated on 115 volt A.C. The speed of the chart in the Standard recorder was one inch per minute. A sample section of the chart used in the recorder is shown in Figure 14.

The test recorder was wired for operating only three of its channels. Three channels should be sufficient to adequately test the recorder. The recorder was equipped with 115 volt A.C. coil signal relays for the laboratory study. A sample chart for the test recorder is shown in Figure 15.

The operations of three machine tools were monitored in the laboratory study. The three tools were the following: a drill press, a belt sander, and a band saw. The test recorder was connected so as to monitor all three machines through-out the entire test. The Servis recorder was connected to the band saw for the first five data runs and was connected to the drill press for the remaining five data runs. The Standard recorder was connected to the belt sander and band saw for the first five data runs and was connected to the drill press and band saw for the remaining five data runs. Thus, for the first five data runs each machine had two recorders monitoring it and during the last five data runs one machine had all three recorders monitoring it.

Field Study

A bracket was made to mount the test recorder on a tractor for field evaluation. Figure 16 shows the bracket which was made to mount

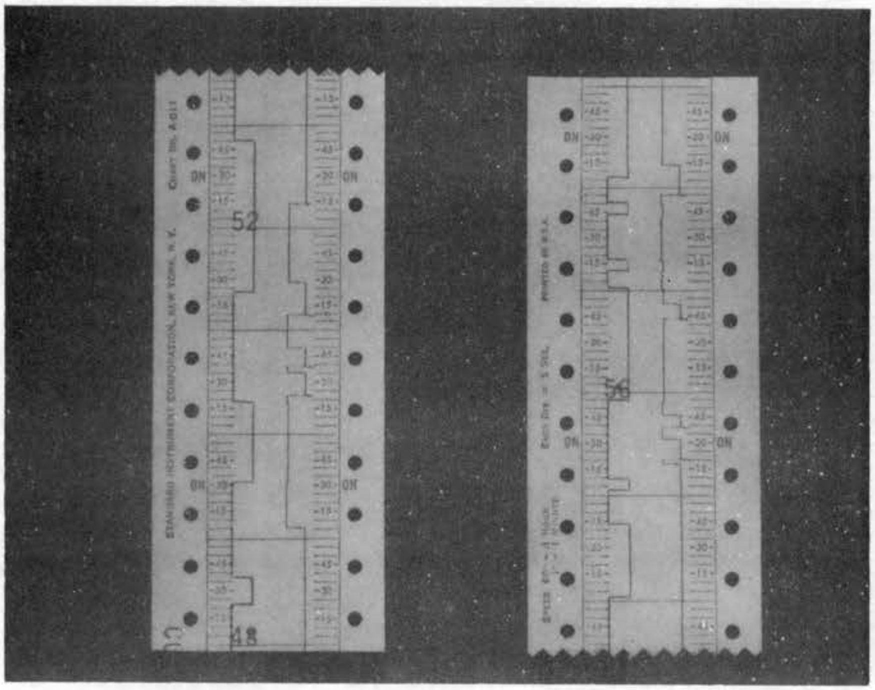
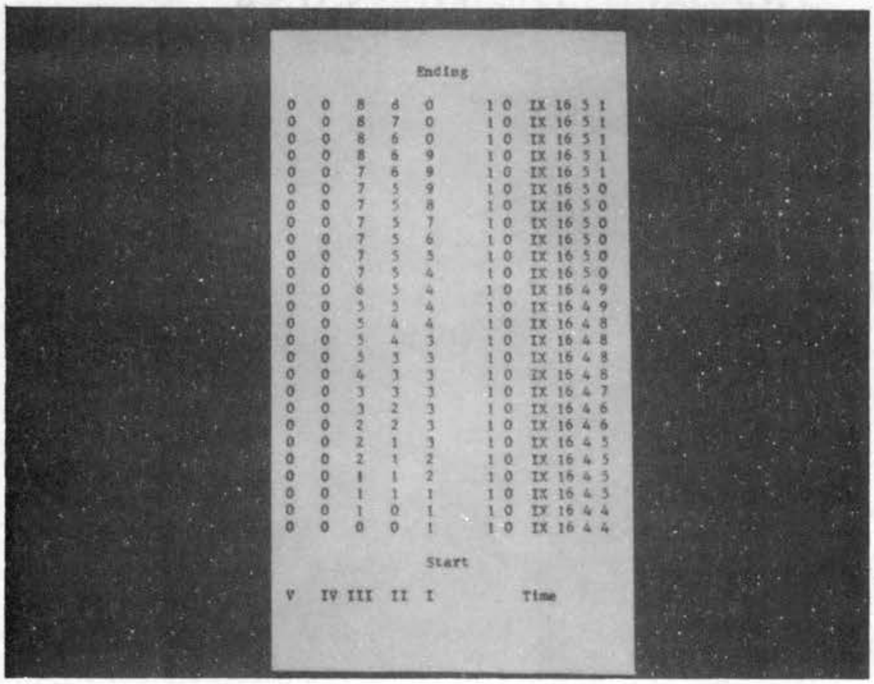


Figure 14. Sample Section of Chart Used By The Standard Recorder



```
                  Ending

0    0    8    8    0        1 0  IX 16 5 1
0    0    8    7    0        1 0  IX 16 5 1
0    0    8    6    0        1 0  IX 16 5 1
0    0    8    6    9        1 0  IX 16 5 1
0    0    7    6    9        1 0  IX 16 5 1
0    0    7    5    9        1 0  IX 16 5 0
0    0    7    5    8        1 0  IX 16 5 0
0    0    7    5    7        1 0  IX 16 5 0
0    0    7    5    6        1 0  IX 16 5 0
0    0    7    5    5        1 0  IX 16 5 0
0    0    7    5    4        1 0  IX 16 5 0
0    0    6    5    4        1 0  IX 16 4 9
0    0    5    5    4        1 0  IX 16 4 9
0    0    5    4    4        1 0  IX 16 4 8
0    0    5    4    3        1 0  IX 16 4 8
0    0    5    3    3        1 0  IX 16 4 8
0    0    4    3    3        1 0  IX 16 4 8
0    0    3    3    3        1 0  IX 16 4 7
0    0    3    2    3        1 0  IX 16 4 6
0    0    2    2    3        1 0  IX 16 4 6
0    0    2    1    3        1 0  IX 16 4 5
0    0    2    1    2        1 0  IX 16 4 5
0    0    1    1    2        1 0  IX 16 4 5
0    0    1    1    1        1 0  IX 16 4 3
0    0    1    0    1        1 0  IX 16 4 4
0    0    0    0    1        1 0  IX 16 4 4

                   Start

V    IV  III  II   I             Time
```

Figure 15. Sample Chart Used By The Test Recorder

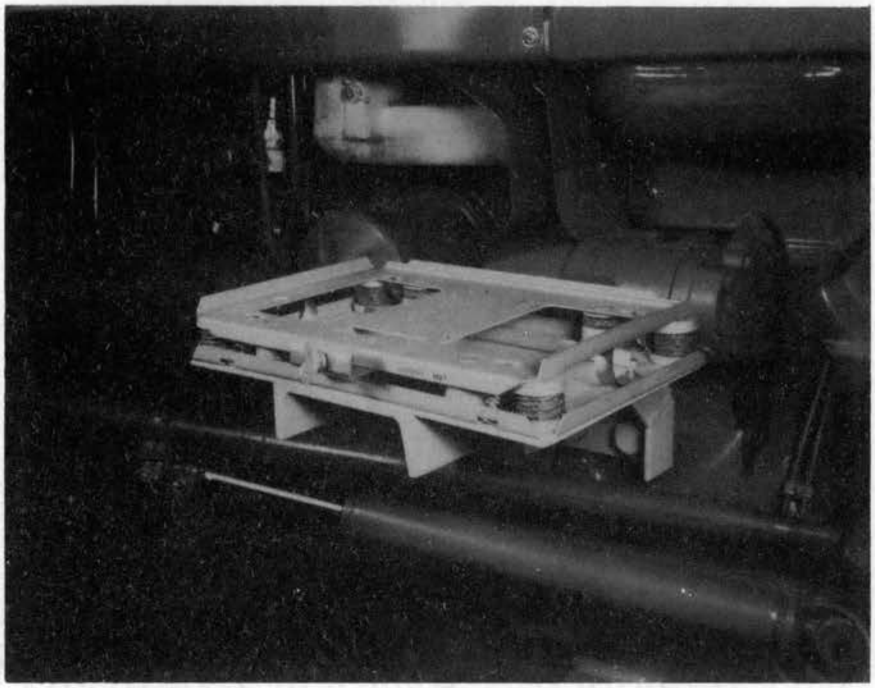


Figure 16. Bracket To Mount Recorder On Tractor

on the tractor. This bracket included a vibration dampening chassis. Figure 17 shows the recorder in its mounted position on the tractor.

Initially one channel was connected to the test recorder, this being to the ignition switch of the tractor. It was found that there existed a "dead" spot in the ignition switch between the on and start position and thus could cause a miss count in the monitoring channel. This was corrected by using a time-delay relay for the signal relay of that channel. By doing this, a signal would not be recorded until after the switch returned back to the on position after being started. The first test conducted was a vibration test to find out what effect, if any, vibration and road shock would have on the test recorder. This test consisted of driving the tractor over rough terrain for a period of several hours.

For the next series of tests the other two channels were connected to the test recorder. One channel was connected to a micro-switch positioned at the transmission selector to determine when the transmission was out of the "park" range. The other channel was connected by a micro-switch which was positioned on the brake pedal of the tractor to determine when the tractor brake was applied. Twelve volt D.C. coil relays were used for all of the signal relays used in the field study. Several tests were run by the author to observe the operations of the three channels of the recorder. The tractor was run over a variety of terrains and conditions to simulate actual field operations. Next a test pattern was set up, shown in Figure 18, over which ten different individuals drove. A comparison was made of the data obtained from each of the drivers.

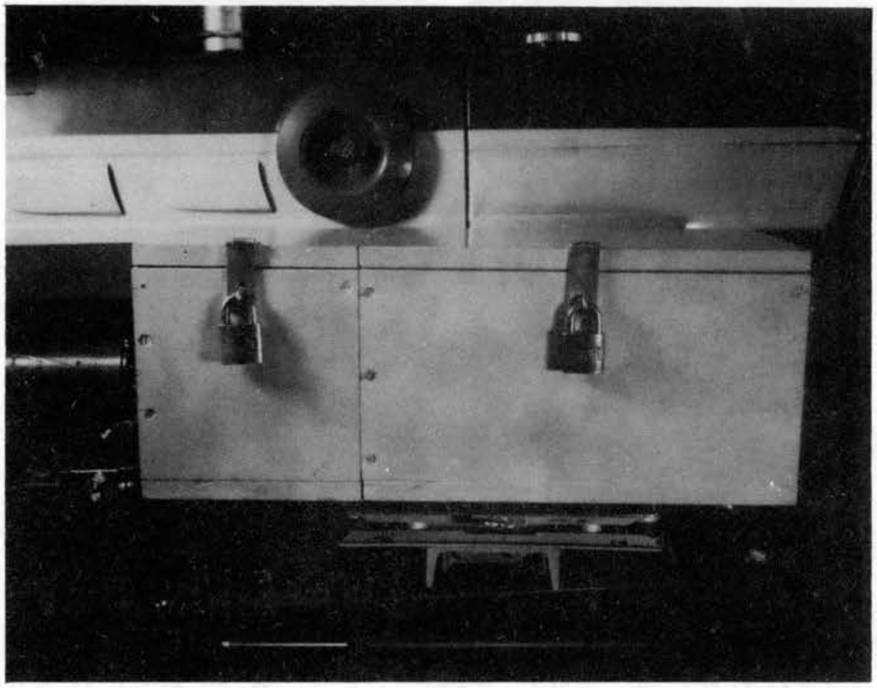


Figure 17. Recorder Mounted on Tractor

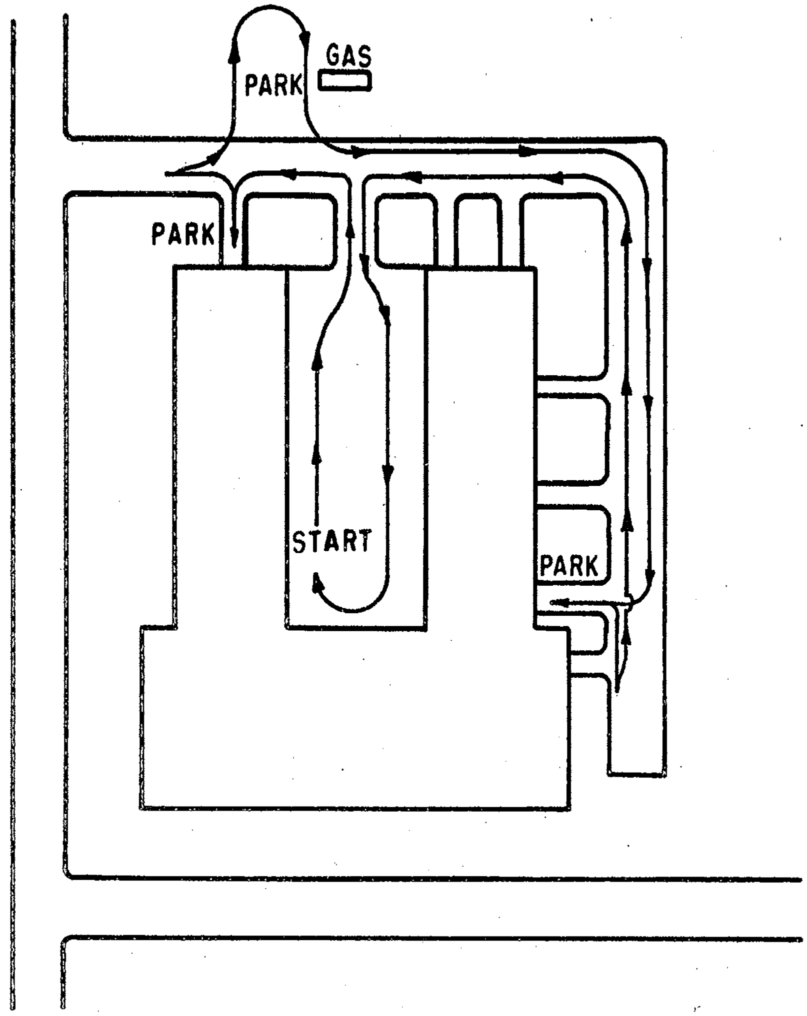


Figure 18. Test Pattern Set Up For Field Study

After this a study was conducted, in which the sensing switches to the channels were operated manually, to find out if some of the results found in the field study could be purposely duplicated. These results or discrepancies, are presented and analyzed in Chapter VI.

CHAPTER VI

PRESENTATION AND ANALYSIS OF DATA

Laboratory Study

In the laboratory study, data were collected from the three recorders and compared. The test recorder was connected to all three of the machine tools throughout the laboratory study. The Servis recorder was connected to the belt sander for the first five data runs and to the drill press for the remaining five data runs. The Standard recorder was connected to the drill press and the belt sander for the first five data runs and to the drill press and band saw for the remaining five data runs. Thus, for the first five data runs all three machines had two recorders monitoring their operations and during the remaining five data runs the drill press was monitored by all three recorders and the band saw by two of the recorders while the belt sander was monitored only by the test recorder.

A comparison of the charts from the recorders was made after each data run to see if the times recorded would match. The data sheets showing the comparisons are in Appendix B. For data run 1, there was no data collected by the Standard recorder as the paper tape got hung-up and did not feed out of the recorder case. On data day 2 someone un-plugged the Servis recorder for a period of 16 minutes, but it was still possible to make the comparison of the data for that data run. Again on data day 7, no data was collected on the Standard recorder for a part of the day because of the paper hanging-up inside of the recorder case.

The only discrepancy found in the data of the laboratory study was during data run 2 and data run 5. The discrepancy was found by noticing a miss count in one of the channels on the chart from the test recorder. This was caused by a change in status occuring too fast for the test recorder to monitor. The test recorder requires approximately two seconds of time between a status change because of the time needed for the large capacitor (3000 MFD) on the count circuit to discharge and ready itself for a signal. A change in status, of the event being monitored, could happen too quickly in either of two ways. The first way would be by a switch being moved from "on" to "off" too fast for the test recorder to monitor it, and the second way, by someone making a non-positive action of the switch. Table 1 shows a sample of a chart which contains a miss count.

The rectangular enclosures have been added to the chart to facilitate the analysis of the data. The starting end of the chart is at the bottom of the page. Each rectangular enclosure shows a complete operation of the starting and ending of an event on that particular channel. The odd numbers designate an "on" status of that particular channel, whereas the even numbers designate an "off" status of that particular channel.

Field Study

For the first test conducted in the field study, one channel of the test recorder was connected to the ignition switch of the tractor. As stated in Chapter V, a time-delay relay was used for the signal relay

TABLE I

CHART CONTAINING A MISS COUNT

	0	0	$\boxed{1}$	6	6	0	5	IX	12	1	3
	0	0	$\boxed{0}$	6	6	0	5	IX	12	1	3
	0	0	$\boxed{9}$	6	6	0	5	IX	11	5	7
	0	0	$\boxed{8}$	6	6	0	5	IX	11	5	7
	0	0	$\boxed{7}$	6	6	0	5	IX	11	0	6
Miss Count	0	0	$\boxed{6}$	6	6	0	5	IX	11	0	6
	0	0	$\boxed{5}$	6	6	0	5	IX	11	0	6
	0	0	$\boxed{3}$	6	6	0	5	IX	11	0	5
	0	0	$\boxed{2}$	6	6	0	5	IX	11	0	1
	0	0	$\boxed{1}$	6	6	0	5	IX	11	0	1
	0	0	$\boxed{0}$	6	6	0	5	IX	10	5	9
	0	0	$\boxed{9}$	6	6	0	5	IX	10	5	8
	0	0	$\boxed{8}$	6	6	0	5	IX	10	5	2
	0	0	$\boxed{7}$	6	6	0	5	IX	10	5	2
	0	0	$\boxed{6}$	6	6	0	5	IX	10	4	7
	0	0	$\boxed{5}$	6	6	0	5	IX	10	4	6
	0	0	$\boxed{4}$	6	6	0	5	IX	10	4	5
	0	0	$\boxed{3}$	6	6	0	5	IX	10	4	4
	0	0	2	6	$\boxed{6}$	0	5	IX	10	3	2
	0	0	2	6	$\boxed{5}$	0	5	IX	10	3	2
	0	0	$\boxed{2}$	6	4	0	5	IX	09	4	2
	0	0	$\boxed{1}$	6	4	0	5	IX	09	4	2
	0	0	$\boxed{0}$	6	4	0	5	IX	09	3	5
	0	0	$\boxed{9}$	6	4	0	5	IX	09	3	3
	0	0	8	$\boxed{6}$	4	0	5	IX	08	5	2
	0	0	8	$\boxed{5}$	4	0	5	IX	08	5	1
	0	0	$\boxed{8}$	4	4	0	5	IX	08	4	6
	0	0	$\boxed{7}$	4	4	0	5	IX	08	4	6
	0	0	$\boxed{6}$	4	4	0	5	IX	08	4	1
	0	0	$\boxed{5}$	4	4	0	5	IX	08	4	1
	0	0	$\boxed{4}$	4	4	0	5	IX	08	4	1
	0	0	$\boxed{3}$	4	4	0	5	IX	08	4	0
	0	0	2	$\boxed{4}$	4	0	5	IX	08	2	6
	0	0	2	$\boxed{3}$	4	0	5	IX	08	2	6
	0	0	2	2	$\boxed{4}$	0	5	IX	08	2	6
	0	0	2	2	$\boxed{3}$	0	5	IX	08	2	5
	0	0	$\boxed{2}$	2	2	0	5	IX	08	2	4
	0	0	$\boxed{1}$	2	2	0	5	IX	08	2	4
	0	0	0	$\boxed{2}$	2	0	5	IX	08	2	3
	0	0	0	$\boxed{1}$	2	0	5	IX	08	2	3
	0	0	0	0	$\boxed{2}$	0	5	IX	08	2	2
	0	0	0	0	$\boxed{1}$	0	5	IX	08	2	2

to overcome a "dead" spot between the on and start positions of the ignition switch on the tractor. The first test consisted of driving the tractor over a variety of terrains and conditions to simulate field conditions of vibration and shock. This test was conducted to determine what effect, if any, vibration and road shock would have on the test recorder. Table II shows a sample of the chart made during the vibration test. As can be seen by looking at the chart, the only result from the test was an advance in the chart paper, which was caused by a severe road shock. There was no sign of a miss count or a miss print occurring because of vibration or shock to the test recorder unit. It was believed that the only time an advance of the tape occurred was at a time when the shock was severe enough that the dampening chassis, under the test recorder, had reached its maximum position of movement and therefore lost its effect. The chart did not necessarily advance a full stop when being affected by a vibration or shock.

After the vibration test was conducted, the other two channels of the test recorder were connected. One of the channels was connected to the transmission selector to determine when the transmission was out of the "park" position. The other channel was connected to the brake pedal to determine when the brake was applied. The two channels received their signals from micro-switches which were mounted on the tractor.

With the three channels connected, the author made a series of tests with the tractor by driving over a varied range of conditions at different speeds to observe the operation of the test recorder. Again it was observed that the only effect from severe road shock was

TABLE II

VIBRATION TEST

0	0	0	0	8	1	7	IX	11	0	6
0	0	0	0	7	1	7	IX	11	0	1
0	0	0	0	6	1	7	IX	11	0	0
0	0	0	0	5	1	7	IX	10	5	3
0	0	0	0	4	1	7	IX	10	5	3
0	0	0	0	3	1	7	IX	10	4	8
0	0	0	0	2	1	7	IX	10	4	8
0	0	0	0	1	1	7	IX	10	4	8
0	0	0	0	0	1	7	IX	10	4	8
0	0	0	0	9	1	7	IX	10	4	8
0	0	0	0	8	1	7	IX	10	4	8
0	0	0	0	7	1	7	IX	10	4	8
0	0	0	0	6	1	7	IX	10	4	8
0	0	0	0	5	1	7	IX	10	4	8

Above Space Caused by a
Severe Road Shock

an advancement of the paper chart. The only other condition observed during this test was that there was a miss count in the channel which was monitoring the brake action. This miss count occurred when there was a "choppy action" of the brake pedal. Table III shows a section of the chart during this period of the study. This condition occurred when the brake was applied while traveling at road gear speed and applying the brake while passing over rough terrain. This caused the brake pedal to change status faster than the recorder could sense the change. A later test, in which two channels were connected to the brake, revealed that this type of choppy action could be overcome by using a time-delay relay for the signal relay. One channel was monitoring with a standard relay while the second channel monitored with the time-delay relay; then, a comparison was made between the two channels. Table IV shows a chart in which two channels were connected to the brake pedal. By using the time-delay relay, a change in status of the brake was not recorded until a complete and positive brake action took place.

For the next series of tests, a test pattern was set up. This test pattern was shown in Figure 18. A total of ten different individuals drove the tractor over the test pattern. The pattern consisted of driving a prescribed course in which three complete stops were made. These stops are designated as "Park" in Figure 18. Comparisons of the charts were made to determine if one could follow the sequence of events made by each driver while driving the prescribed course. Table V shows a typical chart made by one of the drives. Appendix C contains the data obtained from the test pattern by the ten drivers.

TABLE III

CHART SHOWING MISS COUNT IN BRAKE CHANNEL

Miss Count

0	0	4	4	0	1	8	IX	11	4	4
0	0	4	4	9	1	8	IX	11	4	4
0	0	3	4	9	1	8	IX	11	4	4
0	0	3	3	9	1	8	IX	11	4	4
0	0	3	3	8	1	8	IX	11	4	0
0	0	3	3	7	1	8	IX	11	4	0
0	0	3	3	6	1	8	IX	11	4	0
0	0	3	2	6	1	8	IX	11	4	0
0	0	2	2	6	1	8	IX	11	3	9
0	0	1	2	6	1	8	IX	11	3	9
0	0	1	2	5	1	8	IX	11	3	9
0	0	1	1	5	1	8	IX	11	3	9
0	0	1	1	4	1	8	IX	11	3	7
0	0	1	1	1	1	8	IX	11	3	7
0	0	1	1	0	1	8	IX	11	3	5
0	0	1	1	9	1	8	IX	11	3	5
0	0	1	1	8	1	8	IX	11	3	5
0	0	1	1	7	1	8	IX	11	3	4
0	0	1	1	6	1	8	IX	11	3	4
0	0	1	1	5	1	8	IX	11	3	4
0	0	1	1	4	1	8	IX	11	3	3
0	0	1	1	3	1	8	IX	11	3	3
0	0	1	1	2	1	8	IX	11	3	2
0	0	1	1	1	1	8	IX	11	3	2
0	0	1	1	0	1	8	IX	11	3	2
0	0	1	0	0	1	8	IX	11	3	2
		Ignition	Transmission	Brake						

TABLE IV

TEST WITH BRAKE ON TWO CHANNELS

0	0	$\boxed{1}$	2	$\boxed{7}$	2	5	IX	11	0	6
0	0	$\boxed{0}$	2	$\boxed{6}$	2	5	IX	11	0	6
0	0	9	2	$\boxed{6}$	2	5	IX	11	0	6
0	0	9	2	5	2	5	IX	11	0	5
0	0	9	2	5	2	5	IX	11	0	5
0	0	9	2	4	2	5	IX	11	0	5
0	0	9	2	2	2	5	IX	11	0	5
0	0	9	2	0	2	5	IX	11	0	5
0	0	9	2	9	2	5	IX	11	0	5
0	0	9	2	8	2	5	IX	11	0	5
0	0	9	2	6	2	5	IX	11	0	5
0	0	9	2	5	2	5	IX	11	0	5
0	0	9	2	5	2	5	IX	11	0	5
0	0	9	2	4	2	5	IX	11	0	5
0	0	9	2	3	2	5	IX	11	0	5
0	0	9	2	$\boxed{2}$	2	5	IX	11	0	5
0	0	9	2	$\boxed{1}$	2	5	IX	11	0	5
0	0	$\boxed{9}$	2	$\boxed{0}$	2	5	IX	11	0	5
0	0	$\boxed{8}$	2	$\boxed{9}$	2	5	IX	11	0	5
0	0	7	2	$\boxed{9}$	2	5	IX	11	0	5
0	0	$\boxed{7}$	2	$\boxed{8}$	2	5	IX	11	0	4
0	0	$\boxed{6}$	2	$\boxed{7}$	2	5	IX	11	0	4
0	0	5	2	$\boxed{7}$	2	5	IX	11	0	4
0	0	$\boxed{5}$	2	$\boxed{6}$	2	5	IX	11	0	4
0	0	$\boxed{4}$	2	$\boxed{5}$	2	5	IX	11	0	4
0	0	3	2	$\boxed{5}$	2	5	IX	11	0	4
0	0	3	2	4	2	5	IX	11	0	4
0	0	3	2	3	2	5	IX	11	0	4
0	0	3	2	2	2	5	IX	11	0	4
0	0	3	2	1	2	5	IX	11	0	4
0	0	3	2	0	2	5	IX	11	0	3
0	0	3	2	0	2	5	IX	11	0	3
0	0	3	2	9	2	5	IX	11	0	3
0	0	3	2	8	2	5	IX	11	0	3
		Time-Delay		Standard						

TABLE V

TYPICAL CHART FROM TEST PATTERN

0	0	8	8	6	1	9	IX	11	5	2
0	0	8	8	5	1	9	IX	11	5	2
0	0	7	8	5	1	9	IX	11	5	2
0	0	7	7	5	1	9	IX	11	5	2
0	0	7	7	4	1	9	IX	11	5	1
0	0	7	7	3	1	9	IX	11	5	1
0	0	6	6	3	1	9	IX	11	5	1
0	0	6	6	2	1	9	IX	11	5	0
0	0	5	5	1	1	9	IX	11	5	0
0	0	5	5	0	1	9	IX	11	5	0
0	0	5	5	9	1	9	IX	11	5	0
0	0	5	4	9	1	9	IX	11	5	0
0	0	4	4	9	1	9	IX	11	5	0
0	0	4	4	8	1	9	IX	11	4	9
0	0	3	3	7	1	9	IX	11	4	9
0	0	3	3	6	1	9	IX	11	4	9
0	0	3	3	5	1	9	IX	11	4	9
0	0	3	2	5	1	9	IX	11	4	9
0	0	3	2	4	1	9	IX	11	4	9
0	0	2	2	4	1	9	IX	11	4	8
0	0	2	2	3	1	9	IX	11	4	8
0	0	1	1	3	1	9	IX	11	4	8
0	0	1	1	2	1	9	IX	11	4	8
0	0	1	1	1	1	9	IX	11	4	8
0	0	1	1	0	1	9	IX	11	4	8
0	0	1	0	0	1	9	IX	11	4	8
		Ignition	Transmission	Brake						

Using Table V as an example, the chart is divided into four separate sections. In each of these sections a complete series of operations have occurred. Taking the first section (bottom of chart) as an example, the bottom line of data shows at what time the ignition switch was turned on. The second line shows the time at which the transmission selector was taken out of the "park" position; it also shows that the ignition switch is still turned on. The third line shows the time the brake pedal was first applied; here too, it shows there has been no change in status of the other two channels. The fourth line from the bottom of the chart shows the time the brake pedal was released; again, no change in status has occurred in the other two channels being monitored. The fifth line shows the time at which the brake pedal was applied for a second time in this section of the chart; once again, there is no change in status in the other two channels. The sixth line from the bottom of the chart shows that there has been a change in status in two of the channels at the same time. The ignition switch has been turned off and the transmission selector has been put back into "park". The chart also shows that the brake pedal is still being applied. The seventh and last line of this section shows that the brake pedal was released. There has been no change in status of the other two channels at this time. Each of the other sections in Table V and in all other Tables of data are read and analyzed in the same manner.

Several discrepancies were found to exist in the charts made during the test pattern study. Such things as miss counts were detected in both the channels monitoring the transmission and the brake. These miss counts were caused either by a non-positive action of the switch, by the interval between a change in status being too short, or by the operator accidently moving the micro-switch and thus sending a false signal. It was believed that the micro-switches used for the transmission and brake channels were too sensitive and were not of the type which should be used to monitor this type of operation. Also, it may be that the micro-switches were located in undesirable places, as they were in easy reach of the operator.

Two other new types of discrepancies were found in this portion of the field study. One was that there was a faint print encountered on the chart. The cause for this faint print was determined in a later test which showed that this discrepancy happened when a severe vibration or shock was applied to the end of the test recorder box while at the same time there was occurring a printing operation. This condition apparently occurred during the test pattern when a printing operation was occurring at the same time the tractor was changing direction of travel. Table VI shows a chart in which a faint print was observed.

The other discrepancy found during this test pattern was that there occurred an identical print of the previous print, in other words, a print showed no change of status occurring. Later tests which were conducted showed that this discrepancy occurred at a time when the change in status signals for any one channel were being sent to the test recorder too frequently to be monitored correctly. The extra print is believed to have been caused by transient currents generated because of the opening and closing of the control switches too quickly. This did not occur when monitoring under normal operating conditions. Table VII shows a chart which contains a miss print or a duplicate print.

TABLE VI

CHART SHOWING FAINT PRINT

```
0  0  8  9  8    2  5  IX  11  5  1
0  0  8  9  8    2  5  IX  11  5  1
0  0  8  8  7    2  5  IX  11  5  1
0  0  8  7  6    2  5  IX  11  5  1
0  0  8  6  5    2  5  IX  11  5  1
0  0  8  5  5    2  5  IX  11  5  1
0  0  8  4  4    2  5  IX  11  5  1
0  0  8  3  4    2  5  IX  11  5  1
0  0  8  2  3    2  5  IX  11  5  1
0  0  8  0  3,   2  5  IX  11  5  1
0  0  8  0  3    2  5  IX  11  5  1

[illegible]  [illegible]  8  9  3    2  5  IX  11  5  1
0  0  8  9  2    2  5  IX  11  5  1
0  0  8  8  1    2  5  IX  11  5  1
0  0  8  7  1    2  5  IX  11  5  1
0  0  8  6  0    2  5  IX  11  5  1
0  0  8  5  0    2  5  IX  11  5  1
0  0  8  4  9    2  5  IX  11  5  1
0  0  8  4  8    2  5  IX  11  5  1
0  0  8  3  7    2  5  IX  11  5  1
0  0  8  1  6    2  5  IX  11  5  1
0  0  8  0  5    2  5  IX  11  5  1
0  0  8  9  5    2  5  IX  11  5  1
0  0  8  9  3    2  5  IX  11  5  1
0  0  7  9  3    2  5  IX  11  5  1
0  0  7  9  1    2  5  IX  11  5  1
0  0  7  8  1    2  5  IX  11  5  1

0  0  7  7  0    2  5  IX  11  5  0
```

Faint Print Above Caused by a
Severe Shock During Printing

TABLE VII

CHART SHOWING MISS PRINT

0	0	6	6	2	2	0	IX	09	2	8
0	0	5	6	2	2	0	IX	09	2	8
0	0	5	5	2	2	0	IX	09	2	7
0	0	5	5	1	2	0	IX	09	2	7
0	0	5	5	0	2	0	IX	09	2	7
0	0	5	5	9	2	0	IX	09	2	7
0	0	5	5	8	2	0	IX	09	2	6
0	0	5	5	8	2	0	IX	09	2	6
0	0	5	5	7	2	0	IX	09	2	5
0	0	5	5	6	2	0	IX	09	2	5
0	0	5	5	5	2	0	IX	09	2	4
0	0	5	5	4	2	0	IX	09	2	4
0	0	5	5	3	2	0	IX	09	0	3
0	0	5	4	3	2	0	IX	09	0	3
0	0	5	3	2	2	0	IX	09	0	3
0	0	5	3	1	2	0	IX	08	4	1
0	0	5	3	0	2	0	IX	08	4	1
0	0	5	3	9	2	0	IX	08	4	1
0	0	5	3	8	2	0	IX	08	3	7
0	0	5	3	7	2	0	IX	08	3	7
0	0	5	3	6	2	0	IX	08	3	6
0	0	5	3	5	2	0	IX	08	3	6
0	0	5	3	4	2	0	IX	08	3	5
0	0	5	3	3	2	0	IX	08	3	5
0	0	5	3	2	2	0	IX	08	3	4
0	0	5	3	1	2	0	IX	08	3	4
0	0	5	3	0	2	0	IX	08	3	4
0	0	5	2	0	2	0	IX	08	3	4
0	0	4	2	0	2	0	IX	08	3	3
0	0	3	2	0	2	0	IX	08	3	3
0	0	2	2	0	2	0	IX	08	3	0
0	0	1	2	0	2	0	IX	08	3	0
0	0	0	2	0	1	9	IX	18	1	9
0	0	0	1	0	1	9	IX	18	1	9

Miss Print Above Appears
As an Extra Print

CHAPTER VII

DISCUSSION OF RESULTS

The comparison of the charts from the three different recorders used in the laboratory study showed that the test recorder would work quite satisfactorily as long as there was a positive change in status of the event being recorded, and too, that the change did not occur more frequently than every 1 1/2 to 2 seconds.

Although all comparisons of the charts from the laboratory study were made by human observation, this type of data analysis for a large quantity of data would not be practical. In such a case, the data could be punched verbatim onto computer cards and run through a computer to obtain the desired information summarized in print-out form.

In the laboratory study, it was quite obvious as to the improved efficiency obtained with the test recorder. The amount of paper tape used was a considerable saving over the two commercially available recorders used. It was necessary to collect the data and/or change the chart on the two commercial units daily whereas the test recorder could monitor for an extended period of time without being serviced.

As has been indicated in Chapter VI, the major discrepancy found in the analysis of the data was the occurrence of a miss count resulting from one of two things. This was either a non-positive action of the switch sending the signal to the recorder, or the changing of a status occurred too frequently for the recorder to monitor it. This phenomenon of a miss count occurred much more often during the field study than it did during the laboratory study. This can be explained, at least in part, by the fact that a better type of switch was used in the laboratory study for sending the signals to the recorder. The type of micro-switches used in the field study were much too sensitive to be used on a field machine. The choice of operations for the field study did point out a limitation of the test recorder. It would be recommended not to use the test recorder on an operation such as the brake where there is chance of a change of status occurring too quickly for the recorder to monitor.

In the case of the transmission selector, there would have been less chance of a miss count if the micro-switch had been mounted out of sight and reach of the tractor operator. In the case of the brake pedal, the discrepancy of a miss count could be eliminated by the use of a time-delay relay for the signal relay of that channel. This was shown to be possible in one of the tests performed where two channels were monitoring the brake pedal, one with a standard relay and the other a time-delay relay.

One main advantage of the test recorder is that it is possible to monitor a signal produced by any voltage. All that needs to be done is to plug-in a signal relay whose coil will match the voltage of the monitoring switch.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

An investigation was conducted to determine the feasibility of designing and constructing an event recorder which would improve the efficiency of recording by operating only upon a change in status and by simplifying the analysis of data. A thorough study was made to determine the kinds and types of event recorders available on the market. It was found that a suitable recorder was not available to be used for extended periods of time on an agricultural machine.

An electric counter/printer unit was bought and an electrical impulse circuit was designed and built to transmit a change in status signal to the counter/printer unit. The circuit for the test recorder was twelve volt D.C., but an input signal of any desired voltage could be monitored.

The test recorder was first tested in the laboratory against two commercial recorders. One of these commercial recorders used a strip chart while the other used a circular chart. All three recorders were used to monitor 115 volt A.C. signals from three different machines that were in the laboratory. For the first part of the study there were two recorders connected to each machine and for the remaining part of the study one machine was monitored by all three recorders.

For the field study, the test recorder was mounted on a tractor and connected to operations being monitored through twelve volt D.C. circuits. Studies were made to determine the effect of vibration and shock on the test recorder unit as well as to observe the operation of the test recorder.

The test recorder satisfied the objectives both in the lab studies and the field studies provided there was a positive and complete change in status of the event being monitored. When a change in status occurred more often than approximately two seconds apart, there was a chance of a miss count or a miss print or some combination of both.

Conclusions

1. The test recorder satisfied the objectives when it was used for the purpose for which it was intended.
2. The test recorder would monitor events for extended periods of time without the need for frequent attention being given to service the recorder.
3. There was a considerable amount of paper saved for the amount of data collected, therefore resulting in a cost saving.
4. The test recorder proved to have the unique advantage of being able to monitor events from a variety of voltages.
5. The removability of the different components proved to be a good design.
6. The choice of operations monitored in the field test and/or the switches used in the field study pointed out some limitations of the test recorder.

7. Having the data in a coded numeric form is a very desirable feature in that it puts the data in a direct form that can be handled by mechanized data processing.

Suggestions For Future Study

1. The test recorder should be used on a field machine for making a thorough study of specific operations for a considerable period of time.
2. Investigate the possibility of building a test recorder of this type with solid state electronics. This would decrease the time required between a change in status as well as put the recorder in a package of a more desireable size.
3. Develop a computer program to analyze the data received from the test recorder, thus simplifying the analysis where large quantities of data are involved.
4. Search for a counter/printer unit which would be more durable and not affected as much by severe shock. Also a similar unit built within the United States should be more economical to purchase.
5. Investigate the possibility of improving the shock proof dampening chassis.

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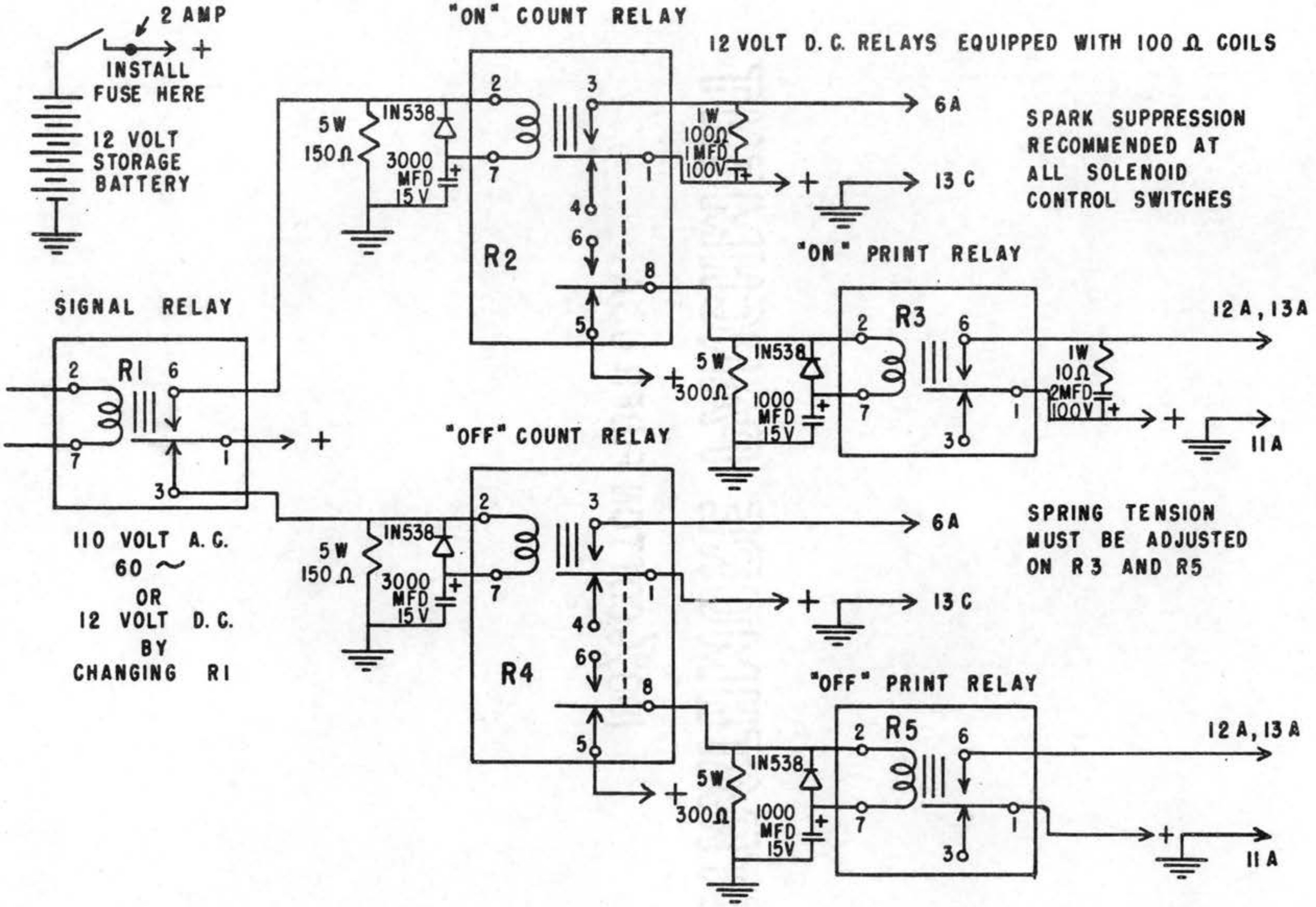
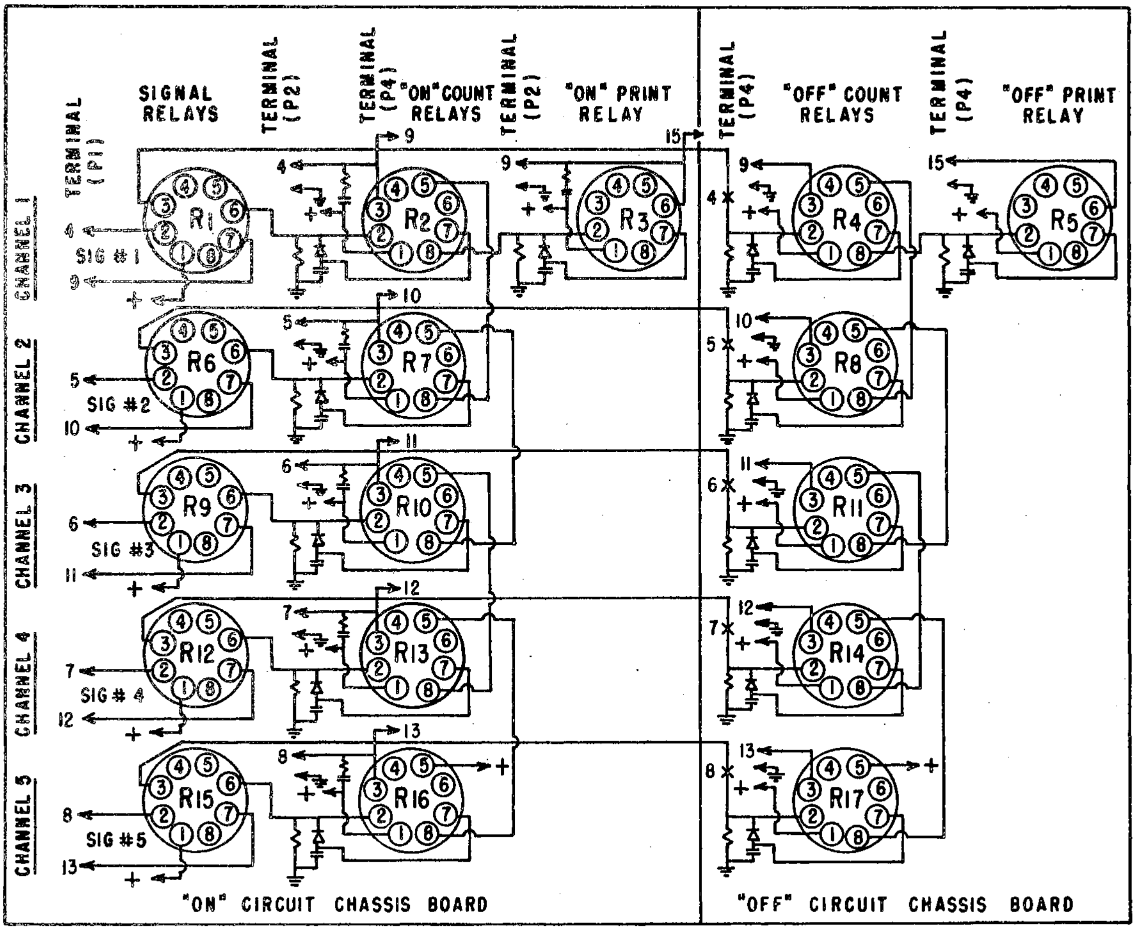
APPENDIX A

SCHEMATIC WIRING DIAGRAMS



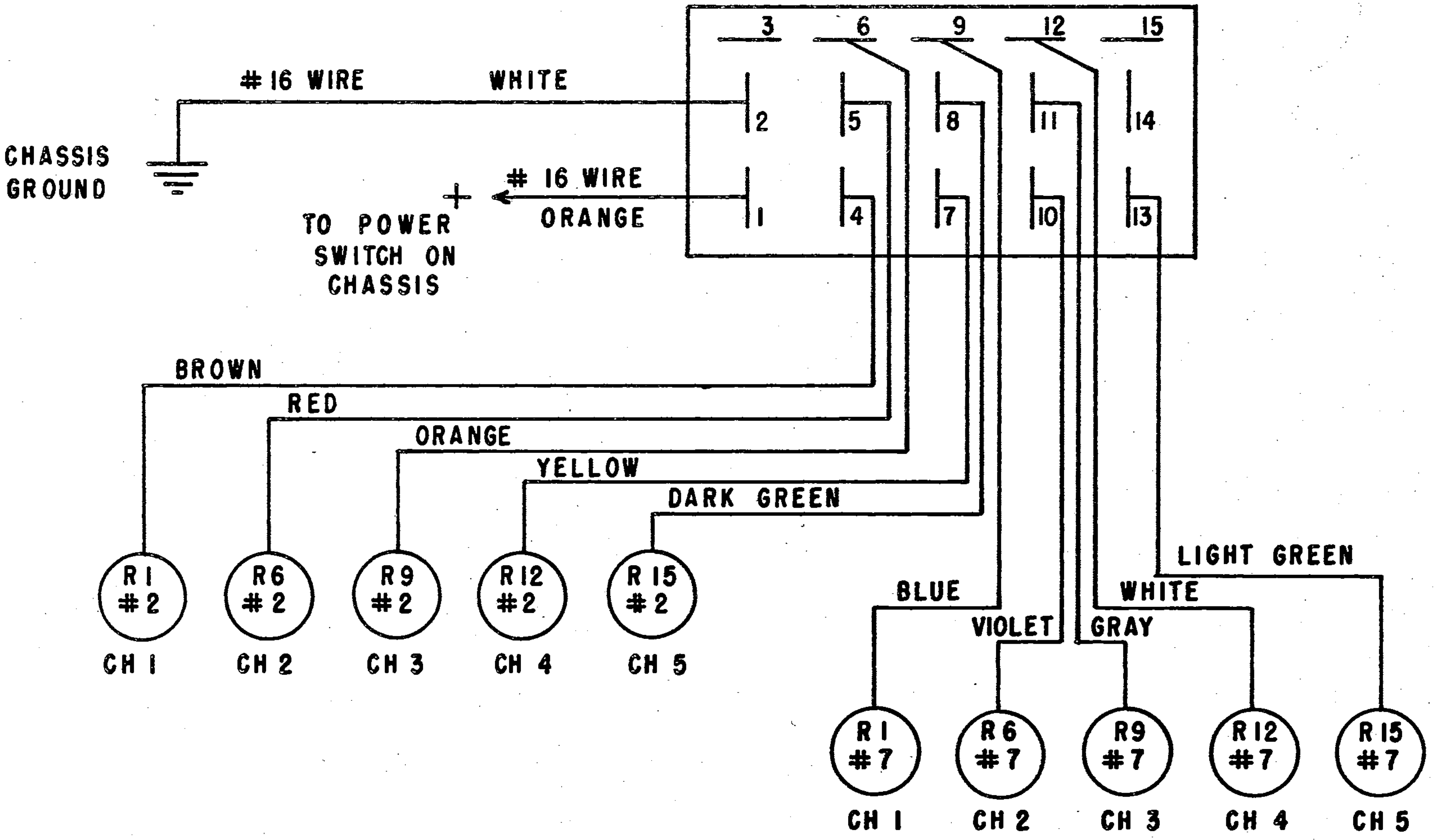
COUNTER/PRINTER CIRCUIT FOR INPUT INTO SODECO MODEL PN 208

FIVE CHANNEL COUNTER/PRINTER CIRCUIT FOR INPUT INTO SODECO MODEL PN 208

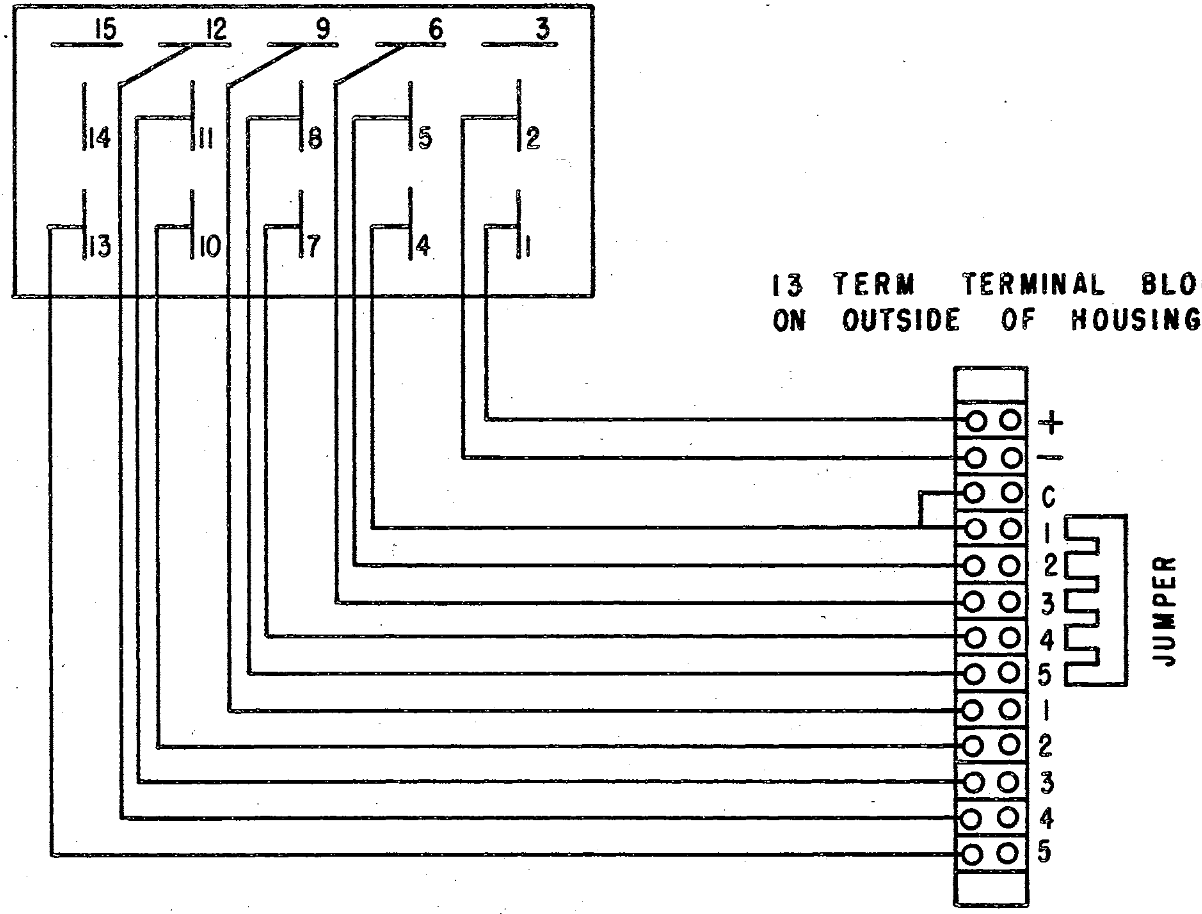


PLUG P1 FROM CHASSIS TO HOUSING

(VIEWED FROM BACK OF CHASSIS)



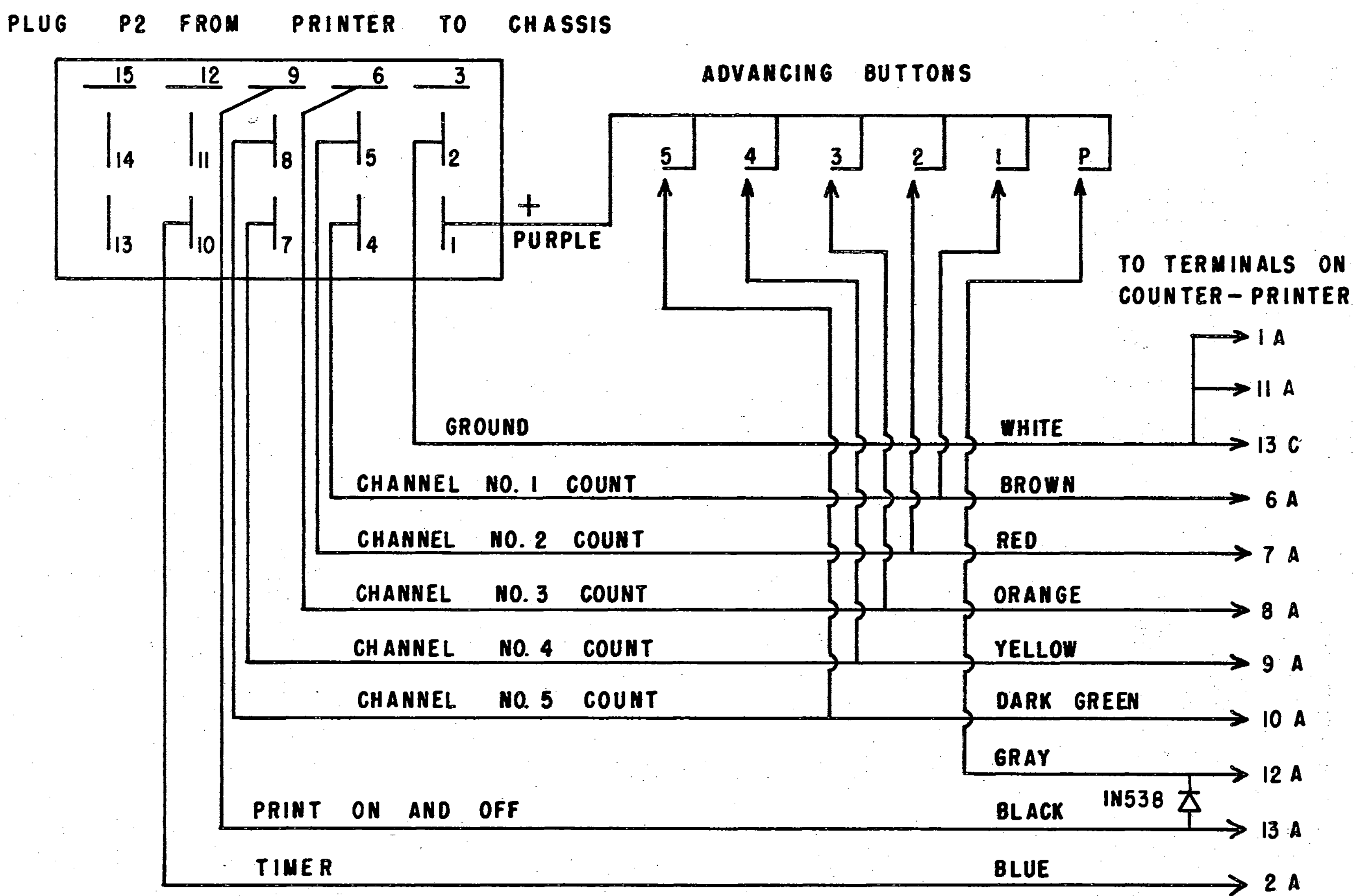
SOCKET P1 ON HOUSING

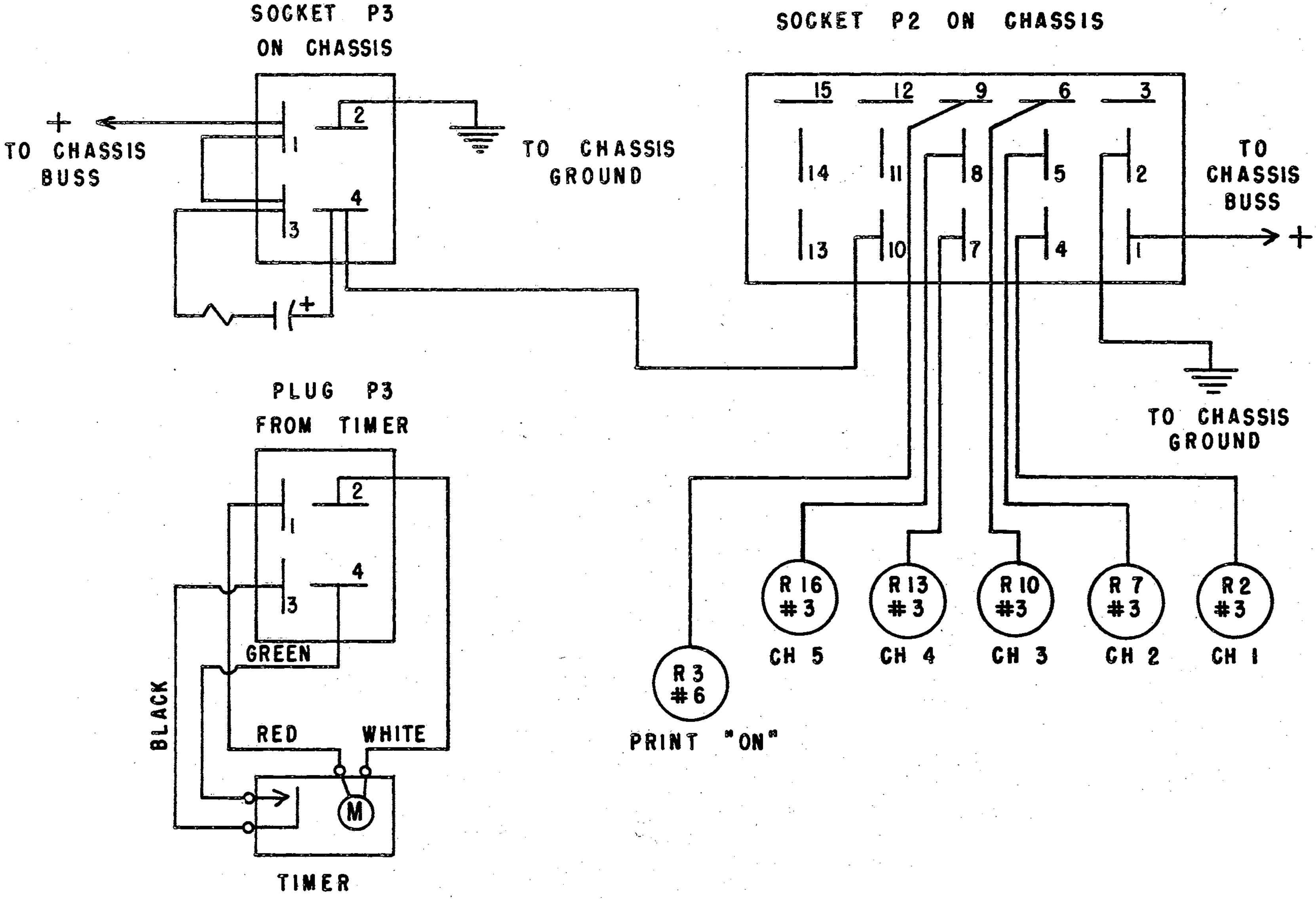


13 TERM TERMINAL BLOCK
ON OUTSIDE OF HOUSING

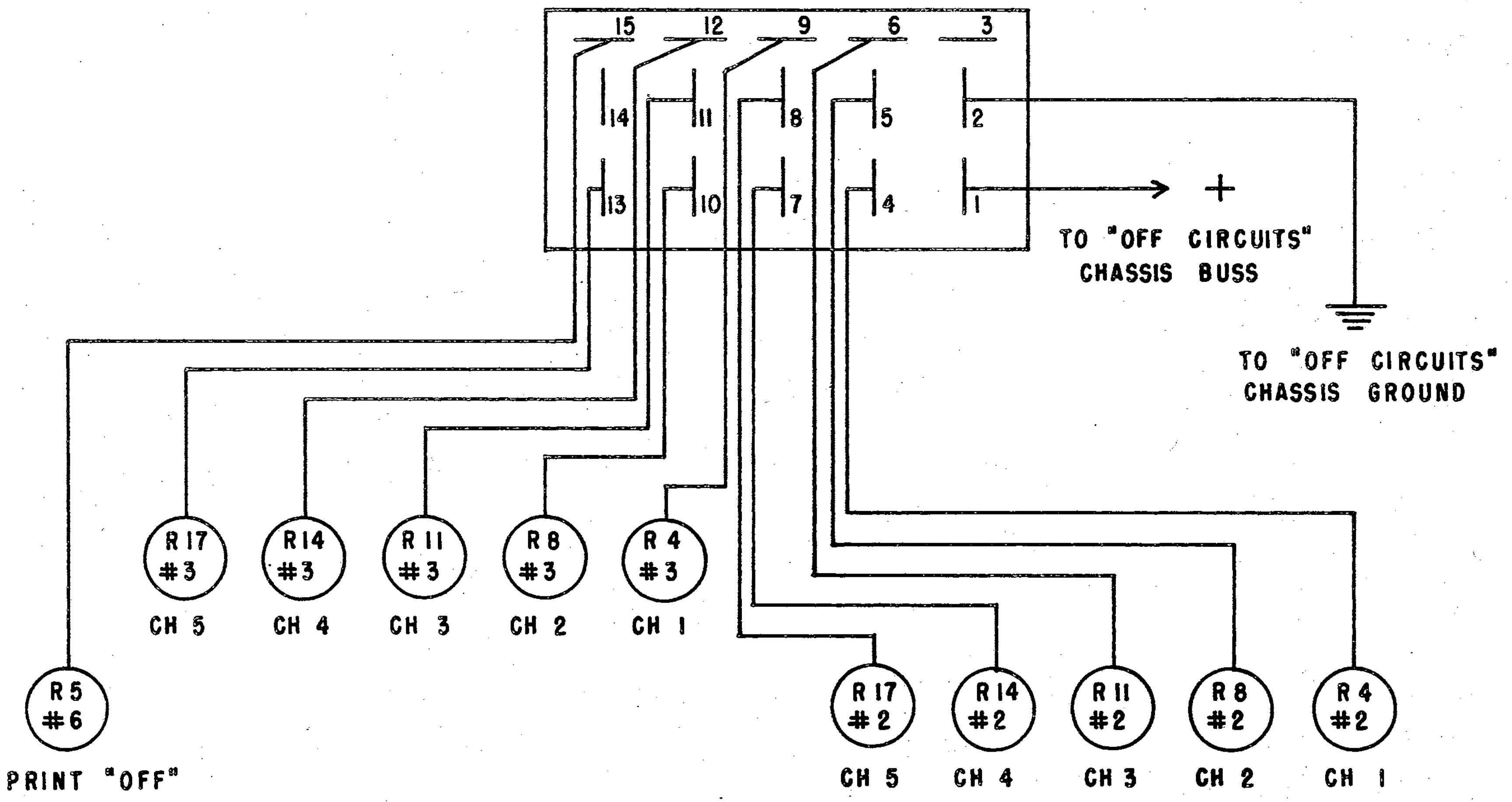
USE JUMPER FOR
12 VOLT SIGNALS

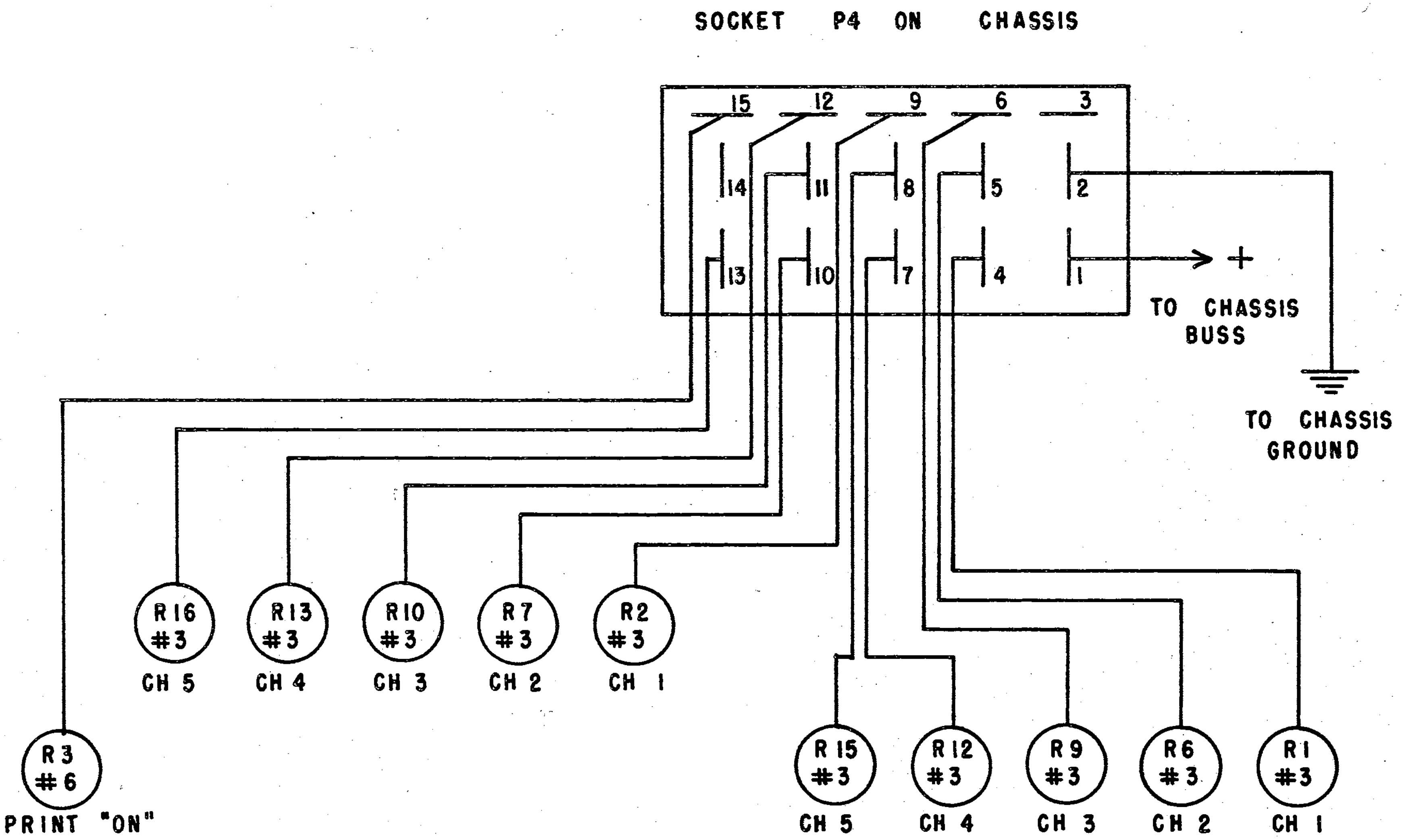
REMOVE JUMPER
FOR 110 VOLT SIGNALS

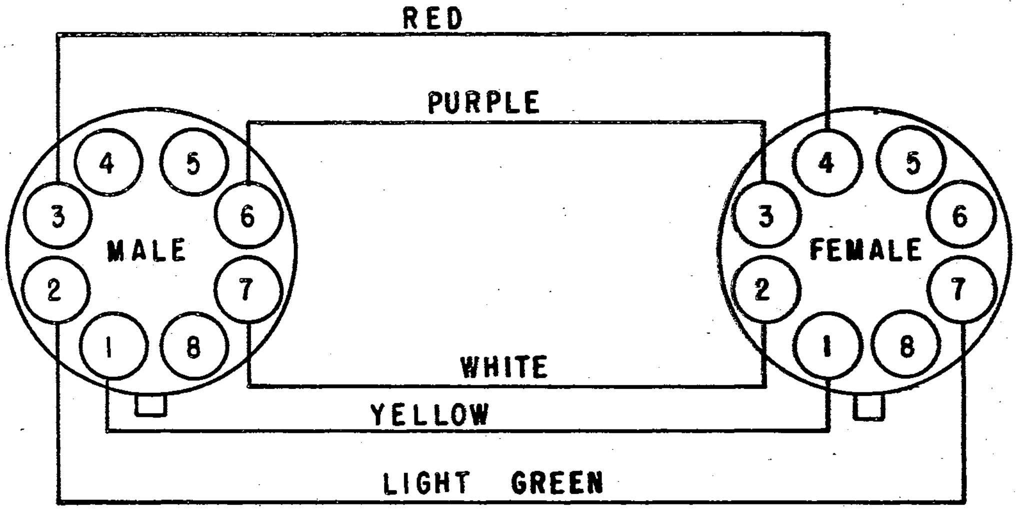

PLUG P2 FROM PRINTER TO CHASSIS
15
12
9
6
3
14
11
8
5
2
13
10
7
4
1
+
PURPLE
ADVANCING BUTTONS
5
4
3
2
1
P
TO TERMINALS ON COUNTER-PRINTER
1 A
11 A
GROUND
WHITE
13 C
CHANNEL NO. 1 COUNT
BROWN
6 A
CHANNEL NO. 2 COUNT
RED
7 A
CHANNEL NO. 3 COUNT
ORANGE
8 A
CHANNEL NO. 4 COUNT
YELLOW
9 A
CHANNEL NO. 5 COUNT
DARK GREEN
10 A
GRAY
12 A
IN538
PRINT ON AND OFF
BLACK
13 A
TIMER
BLUE
2 A


SOCKET P3
ON CHASSIS
+
TO CHASSIS
BUSS
1
2
3
4
+
TO CHASSIS
GROUND
SOCKET P2 ON CHASSIS
15
12
9
6
3
14
11
8
5
2
13
10
7
4
1
TO
CHASSIS
BUSS
+
TO CHASSIS
GROUND
PLUG P3
FROM TIMER
1
2
3
4
GREEN
BLACK
RED
WHITE
M
TIMER
R 3
#6
PRINT "ON"
R 16
#3
CH 5
R 13
#3
CH 4
R 10
#3
CH 3
R 7
#3
CH 2
R 2
#3
CH 1

PLUG P4 FROM "OFF CIRCUITS" CHASSIS




SOCKET P4 ON CHASSIS
15
12
9
6
3
14
11
8
5
2
13
10
7
4
1
+
TO CHASSIS BUSS
TO CHASSIS GROUND
R16 #3
CH 5
R13 #3
CH 4
R10 #3
CH 3
R7 #3
CH 2
R2 #3
CH 1
R3 #6
PRINT "ON"
R15 #3
CH 5
R12 #3
CH 4
R9 #3
CH 3
R6 #3
CH 2
R1 #3
CH 1



NOTE: USED WHEN TIME DELAY
RELAY IS USED FOR SIGNAL RELAY

CONNECTOR WIRING DIAGRAM

APPENDIX B

LABORATORY DATA

Interpretation of Data Sheets in Appendix B

The data sheets contained in Appendix B show the comparison made of the charts from the three recorders used in the laboratory study. These comparisons were made to determine if the times recorded would match.

APPENDIX B-I

DATA RUN #1

4 Sept. 68 All Day Run Time - 6 Hours

CH #1	CH #2	CH #3	
		Servis	Test
		0839-0839	0839-0839
		0844-0844	0844-0844
		0849-0849	0849-0849
		0936-0936	0936-0936
		0950-0951	0950-0951
		0954-0954	0954-0954
		1052-1053	1052-1053
		1054-1057	1054-1057
		1117-1119	1117-1119
		1125-1125	1125-1125
		1134-1134	1134-1134
		1135-1135	1135-1135
		1357-1357	1357-1357
		1404-1404	1404-1404

CH #1 and CH #2 - NO DATA

NOTE:
No Data Collected on Standard Event Recorder Because of Paper Hanging Up Inside of Recorder

Off at 1413

Check OK

APPENDIX B-II

DATA RUN #2

5 Sept. 68 Morning Run Time - 4 Hours

CH #1		CH #2		CH #3	
Standard	Test	Standard	Test	Servis	Test
0822:33-0822:40	0822-0822	0823:18-0823:33	0823-0823	0824-0824	0824-0824
0825:35-0826:08	0825-0826	0826:21-0826:30	0826-0826	0840-0841	0840-0841
1032:00-1032:30	1032-1032	0851;40-0851;57	0851-0852	0841-0841	0841-0841
				0846-0846	0846-0846
Check OK		Check OK		0933-0935	0933-0935
				0942-0942	0942-0942
				Check OK	
				1028-1029	1044-1045
				1030-1031	1046-1047
				1036-1036	1052-1052
				1042-1043	1058-1059
				1045-1045	1101-1101
				1049-1049	1105-1106
				1050-1050	1106-1106
				1141-1141	1157-1157
				1157-1157	1213-1213

Someone unplugged the Servis recorder for 16 min.

Check OK except for some error in switching and causing test recorder to miss one number.

APPENDIX B-III

DATA RUN #3

5 Sept. 68 | Afternoon | Run Time - 4 Hours

CH #1		CH #2		CH #3	
Standard	Test	Standard	Test	Servis	Test
1406:10-1406:40	1406-1407	1542:50-1543:30	1543-1543	1303-1303	1303-1303
1408:05-1410:17	1408-1410	1646:20-1646:21	1646-1646	1335-1335	1335-1335
1545:02-1545:30	1545-1545			1338-1338	1338-1338
1546:09-1547:52	1546-1548	Check OK		1426-1426	1426-1426
1548:12-1549:10	1548-1549			1428-1428	1428-1428
1632:40-1632:53	1632-1633			1431-1431	1431-1431
1642:34-1643:23	1642-1643			1502-1502	1501-1502
1643:45-1644:08	1643-1644			1521-1523	1521-1523
				1538-1538	1538-1538
Check OK				1541-1541	1541-1541
				1608-1609	1608-1609
				1609-1609	1609-1609
				1611-1611	1611-1611
				1638-1638	1638-1638
				1641-1641	1641-1641
				Check OK	

APPENDIX B-IV

DATA RUN #4

6 Sept. 68 Morning Run Time - 4 Hours

CH #1		CH #2		CH #3	
Standard	Test	Standard	Test	Servis	Test
0808:30-0808:45	0808-0808	0834:50-0835:40	0834-0835	0829-0830	0829-0830
0810:17-0810:48	0810-0810	0842:23-0842:37	0842-0842	0833-0834	0833-0834
0812:16-0813:12	0812-0813	0849:15-0849:25	0849-0849	0840-0842	0840-0842
0814:45-0815:10	0814-0815	0911:48-0911:57	0911-0912	0848-0849	0848-0849
0815:50-0816:07	0815-0816	1119:59-1120:17	1119-1120	0859-0859	0859-0859
0820:43-0821:30	0820-0821			0902-0902	0902-0902
1029:45-1030:35	1029-1030	Check OK		0910-0911	0910-0911
1045:20-1045:53	1045-1045			0934-0934	0934-0934
1057:45-1058:23	1057-1058			0938-0938	0938-0938
1130:28-1131:14	1130-1131			1013-1014	1013-1014
				1017-1017	1017-1017
Check OK				1121-1121	1120-1121
				1124-1124	1124-1124
				1149-1149	1149-1149
				1152-1152	1152-1152
				Check OK	

APPENDIX B-V

DATA RUN #5

6 Sept. 68 — Afternoon — Run Time - 4 Hours

CH #1		CH #2		CH #3	
Standard	Test	Standard	Test	Servis	Test
1529:10-1529:38	1529-1529	1527:35-1528:00	1527-1528	1335-1335	1335-1335
1531:28-1531:42	1531-1531	1539:40-1540:00	1539-1539	1338-1338	1338-1338
1532:05-1532:27	1532-1532	1541:40-1541:50	1541-1541	1417-1417	1417-1417
1540:30-1540:47	1540-1540	1555:45-1556:08	1555-1556	1421-1421	1420-1420
1542:17-1542:25	1542-1542	1558:33-1558:42	1558-1558	1508-1508	1507-1507
1556:36-1556:57	1556-1556			1510-1510	1509-1510
1557:06-1557:08	1557-1557	Check OK		1541-1542	1541-1541
1557:09-1557:11	-1557(No On)			1617-1617	1616-1617
1557:57-1558:22	1557-1558			1617-1618	1617-1618
1607:53-1607:55	1607-1607			1620-1620	1620-1620
1608:20-1613:15	1608-1613			1624-1625	1623-1625
1618:31-1621:59	1618-1621				
1635:10-1638:45	1635-1638			Check OK except for some error in switching and causing test recorder to miss one number.	
Check OK except for missing one ON count					

APPENDIX B-VI

DATA RUN #6

9 Sept. 68 Morning Run Time - 4 Hours

CH #1			CH #2	CH #3	
Standard	Servis	Test	Test	Standard	Test
0911:16-0912:20	0911-0912	0911-0912	0935-0936	0859:02-0859:43	0859-0859
0912:35-0915:40	0912-0915	0912-0915	0936-0936	1147:43-1149:27	1147-1149
			0937-0937		
Check OK			1003-1004	Check OK	
			1045-1045		
			1046-1046		
			1125-1125		
			1128-1129		
			1134-1135		
			No Check Made		

APPENDIX B-VII

DATA RUN #7

9 Sept. 68 Afternoon Run Time - 5 Hours

CH #1			CH #2	CH #3	
Standard	Servis	Test	Test	Standard	Test
	1255-1255	1255-1255	1305-1306		1250-1251
	1255-1256	1255-1256	1310-1310		1252-1253
	1257-1257	1257-1257	1536-1537		1536-1536
	1313-1314	1313-1314	1612-1617		1544-1547
	1447-1449	1447-1449		-1610:42	1602-1610
1621:28-1621:59	1621-1622	1621-1622	No Check	1700:46-1701:12	1700-1701
1622:25-1623:00	1622-1623	1622-1623	Made		

Note:

No Data Collected On Standard Event Recorder Before 1605 Because Of Paper Hanging Up Inside Of Recorder.

APPENDIX B-VIII

DATA RUN #8

10 Sept. 68 Morning Run Time - 5 Hours

CH #1			CH #2	CH #3	
Standard	Servis	Test	Test	Standard	Test
0814:31-0816:10	0814-0816	0814-0816	0809-0810	0926:07-0926:19	0926-0926
0824:28-0826:00	0824-0826	0825-0826	0933-0934	0928:08-0928:55	0928-0928
0850:15-0850:19	0850-0850	0850-0850	1134-1134	0930:20-0931:04	0930-0931
0850:55-0852:03	0850-0852	0850-0852		0933:03-0933:38	0933-0933
0928:02-0929:51	0928-0929	0928-0929	No check	0935:38-0935:50	0935-0935
0942:03-0942:22	0942-0942	0942-0942	Made	1058:40-1059:20	1058-1059
				1111:35-1111:47	1111-1111
Check OK				1114:14-1114:27	1114-1114
				1248:53-1251:13	1248-1251
				1251:33-1251:58	1251-1251
				Check OK	

APPENDIX B-IX

DATA RUN #9

10 Sept. 68 | Afternoon | Run Time - 4 Hours

CH #1			CH #2	CH #3	
Standard	Servis	Test	Test	Standard	Test
1322:55-1323:52	1322-1323	1322-1323	1339-1340	1359:45-1400:56	1359-1400
1324:13-1325:18	1324-1325	1324-1325	1520-1521	1448:36-1449:20	1448-1449
1325:35-1326:37	1325-1326	1325-1326		1534:35-1534:43	1534-1534
1351:39-1351:43	1351-1351	1351-1351	No Check Made		
1352:21-1353:51	1352-1353	1352-1353		Check OK	
1354:27-1354:33	1354-1354	1354-1354			
1355:03-1355:44	1354-1355	1354-1355			
1446:10-1451:20	1445-1451	1445-1451			
1534:05-1534:35	1534-1534	1533-1534			
1535:33-1535:45	1535-1535	1535-1535			
Check OK					

APPENDIX B-X

DATA RUN #10

11 Sept. 68 — All Day — Run Time - 9 Hours

CH #1			CH #2	CH #3	
Standard	Servis	Test	Test	Standard	Test
0846:33-0846:43	0846-0846	0846-0846	0847-0847	0845:51-0846:05	0845-0846
1314:08-1317:35	1313-1317	1314-1317	1243-1243	1130:53-1130:58	1130-1130
1320:42-1321:08	1320-1320	1320-1320	1544-1548	1143:08-1143:18	1143-1143
1323:05-1325:53	1322-1325	1322-1325			
1328:04-1329:12	1327-1329	1327-1329	No Check Made	Check OK	
1331:37-1332:02	1331-1331	1331-1331			
1333:44-1334:18	1333-1334	1333-1334			
1336:13-1341:25	1335-1341	1336-1341			
1401:00-1402:18	1400-1402	1400-1402			
1424:15-1425:56	1424-1425	1424-1425			
Check OK					

APPENDIX C

FIELD DATA

Interpretation of the Field Data in Appendix C

Taking the chart Appendix C-1 (Driver #1) as example, it can be seen that the chart is divided into four separate sections. In each of these sections a complete series of operations have occurred. Taking the first section (bottom of chart) as an example, the bottom line of data shows at what time the ignition switch was turned on. The second line shows the time at which the transmission selector was taken out of the "park" position; it also shows that the ignition switch is still turned on. Third line shows the time the brake pedal was first applied; here too, it shows there has been no change in status of the other two channels. The fourth line from the bottom of the chart shows the time the brake pedal was released; again, no change in status has occurred in the other two channels being monitored. The fifth line shows the time at which the brake pedal was applied for a second time in this section of the chart; once again, there is no change in status in the other two channels. The sixth line from the bottom of the chart shows that there has been a change in status in two of the channels at the same time. The ignition switch has been turned off and the transmission selector has been put back into "park". The chart also shows that the brake pedal is still being applied. The seventh and last line of this section shows that the brake pedal was released. There has been no change in status of the other two channels at this time. Each of the other sections in Appendix C-1, and in other charts of Appendix C, are read and analyzed in the same manner.

APPENDIX C-I

DRIVER #1

0	0	8	8	6	1	9	IX	11	5	2
0	0	8	8	5	1	9	IX	11	5	2
0	0	7	8	5	1	9	IX	11	5	2
0	0	7	7	5	1	9	IX	11	5	2
0	0	7	7	4	1	9	IX	11	5	1
0	0	7	7	3	1	9	IX	11	5	1
0	0	6	6	3	1	9	IX	11	5	1
0	0	6	6	2	1	9	IX	11	5	0
0	0	5	5	1	1	9	IX	11	5	0
0	0	5	5	0	1	9	IX	11	5	0
0	0	5	5	9	1	9	IX	11	5	0
0	0	5	4	9	1	9	IX	11	5	0
0	0	4	4	9	1	9	IX	11	5	0
0	0	4	4	8	1	9	IX	11	4	9
0	0	3	3	7	1	9	IX	11	4	9
0	0	3	3	6	1	9	IX	11	4	9
0	0	3	3	5	1	9	IX	11	4	9
0	0	3	2	5	1	9	IX	11	4	9
0	0	3	2	4	1	9	IX	11	4	9
0	0	2	2	4	1	9	IX	11	4	8
0	0	2	2	3	1	9	IX	11	4	8
0	0	1	1	3	1	9	IX	11	4	8
0	0	1	1	2	1	9	IX	11	4	8
0	0	1	1	1	1	9	IX	11	4	8
0	0	1	1	0	1	9	IX	11	4	8
0	0	1	0	0	1	9	IX	11	4	8

APPENDIX C-II

DRIVER # 2

0	0	6	9	8	1	9	IX	12	0	3
0	0	6	9	7	1	9	IX	12	0	3
0	0	5	9	7	1	9	IX	12	0	3
0	0	5	8	7	1	9	IX	12	0	3
0	0	5	8	6	1	9	IX	12	0	2
0	0	5	8	5	1	9	IX	12	0	2
0	0	5	7	5	1	9	IX	12	0	2
0	0	5	7	4	1	9	IX	12	0	2
0	0	5	7	3	1	9	IX	12	0	2
0	0	5	6	3	1	9	IX	12	0	2
0	0	4	6	3	1	9	IX	12	0	2
0	0	4	6	2	1	9	IX	12	0	2
0	0	4	6	1	1	9	IX	12	0	2
0	0	3	5	1	1	9	IX	12	0	2
0	0	3	5	0	1	9	IX	12	0	1
0	0	3	5	9	1	9	IX	12	0	1
0	0	3	5	8	1	9	IX	12	0	1
0	0	3	5	7	1	9	IX	12	0	1
0	0	3	5	6	1	9	IX	12	0	0
0	0	3	5	5	1	9	IX	12	0	0
0	0	3	3	4	1	9	IX	12	0	0
0	0	2	3	4	1	9	IX	12	0	0
0	0	2	3	3	1	9	IX	12	0	0
0	0	1	3	3	1	9	IX	12	0	0
0	0	1	2	3	1	9	IX	12	0	0
0	0	1	2	2	1	9	IX	11	5	9
0	0	1	2	1	1	9	IX	11	5	9
0	0	1	2	0	1	9	IX	11	5	8
0	0	1	2	9	1	9	IX	11	5	8
0	0	1	1	9	1	9	IX	11	5	8
0	0	1	1	8	1	9	IX	11	5	8
0	0	0	1	8	1	9	IX	11	5	8
0	0	0	1	7	1	9	IX	11	5	8
0	0	9	1	7	1	9	IX	11	5	8
0	0	9	0	7	1	9	IX	11	5	8
0	0	9	0	6	1	9	IX	11	5	7
0	0	9	8	6	1	9	IX	11	5	7

APPENDIX C-III

DRIVER #3

0	0	4	7	5	1	9	IX	12	1	2
0	0	3	7	4	1	9	IX	12	1	2
0	0	3	6	4	1	9	IX	12	1	1
0	0	3	6	3	1	9	IX	12	1	1
0	0	3	6	2	1	9	IX	12	1	1
0	0	3	6	1	1	9	IX	12	1	0
0	0	3	6	0	1	9	IX	12	1	0
0	0	3	5	0	1	9	IX	12	1	0
0	0	3	5	9	1	9	IX	12	1	0
0	0	2	5	9	1	9	IX	12	1	0
0	0	1	5	9	1	9	IX	12	1	0
0	0	1	5	8	1	9	IX	12	1	0
0	0	1	4	8	1	9	IX	12	1	0
0	0	1	4	7	1	9	IX	12	1	0
0	0	1	3	7	1	9	IX	12	1	0
0	0	0	3	7	1	9	IX	12	1	0
0	0	9	3	6	1	9	IX	12	0	9
0	0	9	2	6	1	9	IX	12	0	9
0	0	9	2	5	1	9	IX	12	0	9
0	0	9	2	4	1	9	IX	12	0	9
0	0	9	2	3	1	9	IX	12	0	9
0	0	9	2	2	1	9	IX	12	0	9
0	0	9	2	1	1	9	IX	12	0	9
0	0	9	1	1	1	9	IX	12	0	9
0	0	8	1	0	1	9	IX	12	0	9
0	0	8	1	9	1	9	IX	12	0	9
0	0	7	1	9	1	9	IX	12	0	9
0	0	7	0	9	1	9	IX	12	0	8
0	0	7	0	8	1	9	IX	12	0	8
0	0	7	9	8	1	9	IX	12	0	8

APPENDIX C-IV

DRIVER #4

0	0	4	0	5	1	9	IX	12	5	6
0	0	4	9	4	1	9	IX	12	5	5
0	0	3	9	4	1	9	IX	12	5	5
0	0	3	9	3	1	9	IX	12	5	5
0	0	3	9	2	1	9	IX	12	5	5
0	0	3	9	1	1	9	IX	12	5	5
0	0	3	9	0	1	9	IX	12	5	5
0	0	3	9	9	1	9	IX	12	5	5
0	0	2	8	7	1	9	IX	12	5	5
0	0	2	7	6	1	9	IX	12	5	5
0	0	1	7	6	1	9	IX	12	5	4
0	0	1	7	5	1	9	IX	12	5	4
0	0	1	7	4	1	9	IX	12	5	4
0	0	1	6	4	1	9	IX	12	5	4
0	0	0	6	3	1	9	IX	12	5	4
0	0	0	6	2	1	9	IX	12	5	4
0	0	0	5	2	1	9	IX	12	5	4
0	0	9	5	2	1	9	IX	12	5	4
0	0	9	5	1	1	9	IX	12	5	3
0	0	9	5	0	1	9	IX	12	5	3
0	0	9	5	9	1	9	IX	12	5	3
0	0	9	4	9	1	9	IX	12	5	3
0	0	9	2	9	1	9	IX	12	5	3
0	0	9	1	9	1	9	IX	12	5	3
0	0	8	0	9	1	9	IX	12	5	3
0	0	8	9	9	1	9	IX	12	5	3
0	0	7	9	9	1	9	IX	12	5	3
0	0	7	8	9	1	9	IX	12	5	3
0	0	6	8	9	1	9	IX	12	5	3
0	0	6	8	8	1	9	IX	12	5	3
0	0	5	8	8	1	9	IX	12	5	2
0	0	5	8	7	1	9	IX	12	5	2
0	0	5	8	6	1	9	IX	12	5	2
0	0	5	8	5	1	9	IX	12	5	2
0	0	5	7	5	1	9	IX	12	5	2

APPENDIX C-V

DRIVER #5

0	0	8	5	7	1	9	IX	13	2	7
0	0	7	5	7	1	9	IX	13	2	7
0	0	7	4	7	1	9	IX	13	2	6
0	0	7	4	6	1	9	IX	13	2	6
0	0	7	3	6	1	9	IX	13	2	6
0	0	6	3	6	1	9	IX	13	2	6
0	0	6	3	5	1	9	IX	13	2	6
0	0	6	3	4	1	9	IX	13	2	6
0	0	5	2	4	1	9	IX	13	2	6
0	0	5	1	3	1	9	IX	13	2	5
0	0	5	1	2	1	9	IX	13	2	5
0	0	5	0	2	1	9	IX	13	2	5
0	0	4	0	2	1	9	IX	13	2	5
0	0	3	0	2	1	9	IX	13	2	5
0	0	2	0	2	1	9	IX	13	2	5
0	0	1	0	2	1	9	IX	13	2	5
0	0	1	9	2	1	9	IX	13	2	5
0	0	0	8	2	1	9	IX	13	2	5
0	0	9	8	2	1	9	IX	13	2	5
0	0	9	7	2	1	9	IX	13	2	4
0	0	9	7	1	1	9	IX	13	2	4
0	0	9	7	0	1	9	IX	13	2	4
0	0	9	7	9	1	9	IX	13	2	4
0	0	9	6	9	1	9	IX	13	2	4
0	0	9	5	9	1	9	IX	13	2	4
0	0	8	4	9	1	9	IX	13	2	4
0	0	7	4	9	1	9	IX	13	2	4
0	0	6	4	9	1	9	IX	13	2	4
0	0	6	4	8	1	9	IX	13	2	4
0	0	5	4	8	1	9	IX	13	2	4
0	0	5	3	8	1	9	IX	13	2	3
0	0	5	3	7	1	9	IX	13	2	3
0	0	5	3	6	1	9	IX	13	2	3
0	0	5	3	5	1	9	IX	13	2	3
0	0	5	2	5	1	9	IX	13	2	3
0	0	4	2	5	1	9	IX	13	2	3
0	0	4	1	5	1	9	IX	13	2	2

APPENDIX C-VI

DRIVER #6

0	0	6	8	9	1	9	IX	13	3	7
0	0	5	8	9	1	9	IX	13	3	7
0	0	5	8	8	1	9	IX	13	3	7
0	0	5	7	8	1	9	IX	13	3	7
0	0	5	7	7	1	9	IX	13	3	6
0	0	5	7	6	1	9	IX	13	3	5
0	0	5	7	5	1	9	IX	13	3	5
0	0	5	6	5	1	9	IX	13	3	5
0	0	4	6	5	1	9	IX	13	3	5
0	0	4	6	4	1	9	IX	13	3	5
0	0	3	6	4	1	9	IX	13	3	5
0	0	3	5	4	1	9	IX	13	3	5
0	0	3	5	3	1	9	IX	13	3	4
0	0	3	4	3	1	9	IX	13	3	4
0	0	2	4	3	1	9	IX	13	3	4
0	0	2	4	2	1	9	IX	13	3	4
0	0	1	4	2	1	9	IX	13	3	4
0	0	1	3	2	1	9	IX	13	3	4
0	0	1	3	1	1	9	IX	13	3	3
0	0	1	2	0	1	9	IX	13	3	3
0	0	1	2	9	1	9	IX	13	3	3
0	0	1	1	9	1	9	IX	13	3	3
0	0	0	1	9	1	9	IX	13	3	3
0	0	0	1	8	1	9	IX	13	3	3
0	0	9	1	8	1	9	IX	13	3	3
0	0	9	0	8	1	9	IX	13	3	3
0	0	9	0	7	1	9	IX	13	3	2
0	0	9	9	7	1	9	IX	13	3	2
0	0	8	9	7	1	9	IX	13	3	0
0	0	8	8	7	1	9	IX	13	3	0
0	0	8	7	7	1	9	IX	13	3	0
0	0	8	6	7	1	9	IX	13	3	0

APPENDIX C-VII

DRIVER #7

0	0	6	6	9	1	9	IX	13	5	0
0	0	5	6	8	1	9	IX	13	4	9
0	0	5	5	8	1	9	IX	13	4	9
0	0	5	5	7	1	9	IX	13	4	8
0	0	5	5	6	1	9	IX	13	4	8
0	0	5	5	5	1	9	IX	13	4	8
0	0	5	4	5	1	9	IX	13	4	8
0	0	4	4	5	1	9	IX	13	4	8
0	0	3	4	5	1	9	IX	13	4	8
0	0	3	3	4	1	9	IX	13	4	7
0	0	3	3	3	1	9	IX	13	4	6
0	0	3	2	3	1	9	IX	13	4	6
0	0	2	2	3	1	9	IX	13	4	6
0	0	1	2	3	1	9	IX	13	4	6
0	0	0	2	3	1	9	IX	13	4	6
0	0	9	2	3	1	9	IX	13	4	6
0	0	9	2	2	1	9	IX	13	4	6
0	0	9	1	2	1	9	IX	13	4	6
0	0	9	1	1	1	9	IX	13	4	5
0	0	9	1	0	1	9	IX	13	4	5
0	0	9	0	0	1	9	IX	13	4	4
0	0	8	0	0	1	9	IX	13	4	4
0	0	7	0	0	1	9	IX	13	4	4
0	0	7	9	0	1	9	IX	13	4	4
0	0	7	9	9	1	9	IX	13	4	3
0	0	7	8	9	1	9	IX	13	4	2

APPENDIX C-VIII

DRIVER #8

0	0	8	8	8	1	9	IX	13	5	8
0	0	7	8	8	1	9	IX	13	5	8
0	0	7	7	7	1	9	IX	13	5	8
0	0	7	7	6	1	9	IX	13	5	8
0	0	7	7	5	1	9	IX	13	5	7
0	0	7	7	4	1	9	IX	13	5	7
0	0	7	7	3	1	9	IX	13	5	7
0	0	6	6	3	1	9	IX	13	5	7
0	0	5	6	3	1	9	IX	13	5	7
0	0	4	6	3	1	9	IX	13	5	7
0	0	3	6	3	1	9	IX	13	5	7
0	0	3	5	3	1	9	Ix	13	5	7
0	0	3	5	2	1	9	IX	13	5	6
0	0	3	5	1	1	9	IX	13	5	6
0	0	2	4	1	1	9	IX	13	5	6
0	0	1	4	1	1	9	IX	13	5	6
0	0	0	4	1	1	9	IX	13	5	6
0	0	0	3	1	1	9	IX	13	5	6
0	0	9	3	1	1	9	IX	13	5	6
0	0	9	3	0	1	9	IX	13	5	6
0	0	9	3	9	1	9	IX	13	5	6
0	0	9	3	8	1	9	IX	13	5	6
0	0	9	3	7	1	9	IX	13	5	6
0	0	9	3	6	1	9	IX	13	5	6
0	0	9	3	5	1	9	IX	13	5	6
0	0	9	3	4	1	9	IX	13	5	6
0	0	9	3	3	1	9	IX	13	5	6
0	0	8	2	3	1	9	IX	13	5	6
0	0	8	0	3	1	9	IX	13	5	6
0	0	7	9	2	1	9	IX	13	5	5
0	0	7	9	1	1	9	IX	13	5	5
0	0	7	9	0	1	9	IX	13	5	5
0	0	7	9	9	1	9	IX	13	5	5
0	0	7	8	9	1	9	IX	13	5	4
0	0	7	7	9	1	9	IX	13	5	4
0	0	6	7	9	1	9	IX	13	5	4

APPENDIX C-IX

DRIVER #9

0	0	8	3	3	1	9	IX	14	1	5
0	0	8	2	3	1	9	IX	14	1	5
0	0	8	1	3	1	9	IX	14	1	5
0	0	8	0	3	1	9	IX	14	1	4
0	0	8	9	3	1	9	IX	14	1	4
0	0	8	8	3	1	9	IX	14	1	4
0	0	8	7	3	1	9	IX	14	1	2
0	0	8	7	2	1	9	IX	14	1	2
0	0	7	5	2	1	9	IX	14	1	1
0	0	7	5	1	1	9	IX	14	1	1
0	0	7	5	0	1	9	IX	14	1	1
0	0	7	5	9	1	9	IX	14	1	1
0	0	7	5	8	1	9	IX	14	1	1
0	0	7	4	7	1	9	IX	14	1	0
0	0	6	4	7	1	9	IX	14	1	0
0	0	6	4	6	1	9	IX	14	1	0
0	0	5	4	6	1	9	IX	14	1	0
0	0	5	3	6	1	9	IX	14	1	0
0	0	5	3	5	1	9	IX	14	1	0
0	0	5	3	4	1	9	IX	14	1	0
0	0	5	3	3	1	9	IX	14	1	0
0	0	5	3	3	1	9	IX	14	1	0
0	0	5	3	2	1	9	IX	14	0	9
0	0	5	2	2	1	9	IX	14	0	9
0	0	4	2	2	1	9	IX	14	0	9
0	0	3	2	2	1	9	IX	14	0	9
0	0	2	2	2	1	9	IX	14	0	9
0	0	2	2	1	1	9	IX	14	0	9
0	0	1	2	1	1	9	IX	14	0	9
0	0	1	1	1	1	9	IX	14	0	9
0	0	1	1	0	1	9	IX	14	0	8
0	0	1	0	0	1	9	IX	14	0	8
0	0	0	0	0	1	9	IX	14	0	8
0	0	0	0	9	1	9	IX	14	0	8
0	0	9	9	9	1	9	IX	14	0	8
0	0	9	9	8	1	9	IX	14	0	7
0	0	9	8	8	1	9	IX	14	0	7

APPENDIX C-X

DRIVER #10

0	0	6	5	3	1	9	IX	14	3	2
0	0	5	4	2	1	9	IX	14	3	2
0	0	5	4	1	1	9	IX	14	3	1
0	0	5	4	0	1	9	IX	14	3	1
0	0	5	4	9	1	9	IX	14	3	1
0	0	5	3	9	1	9	IX	14	3	1
0	0	4	3	9	1	9	IX	14	3	1
0	0	3	3	9	1	9	IX	14	3	1
0	0	3	2	8	1	9	IX	14	3	1
0	0	3	2	7	1	9	IX	14	2	9
0	0	3	1	7	1	9	IX	14	2	9
0	0	2	0	7	1	9	IX	14	2	9
0	0	1	0	7	1	9	IX	14	2	9
0	0	1	9	7	1	9	IX	14	2	9
0	0	1	9	6	1	9	IX	14	2	9
0	0	1	9	5	1	9	IX	14	2	8
0	0	1	8	5	1	9	IX	14	2	8
0	0	1	7	5	1	9	IX	14	2	8
0	0	0	7	5	1	9	IX	14	2	8
0	0	9	7	5	1	9	IX	14	2	8
0	0	[illegible]	7	4	1	9	IX	14	2	8
0	0	9	5	4	1	9	IX	14	2	8
0	0	9	5	3	1	9	IX	14	2	7
0	0	9	4	3	1	9	IX	14	2	7
0	0	9	3	3	1	9	IX	14	2	7

VITA

EDWARD EMIL KEMNITZ

Candidate for the Degree of

Master of Science

Thesis: A STATUS CHANGE ACTIVATED MULTIPLE-CHANNEL EVENT RECORDER

Major Field: Agricultural Engineering

Biographical:

Personal Data: Born at Hayden, Colorado, April 30, 1941, the son of John A. and Kathrine V. Kemnitz.

Education: Graduated from Perry High School, Perry, Oklahoma in 1959. Received the Bachelor of Science degree in Agricultural Engineering in January, 1967, from Oklahoma State University; completed the requirements for the Master of Science degree in May, 1969.

Professional Experience: Graduate Research Assistant for one year and Graduate Teaching assistant for one semester for the Agricultural Engineering Department, Oklahoma State University.