Jan. 3, 1967 D. D. MILLER ETAL 3,295,849

AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 1

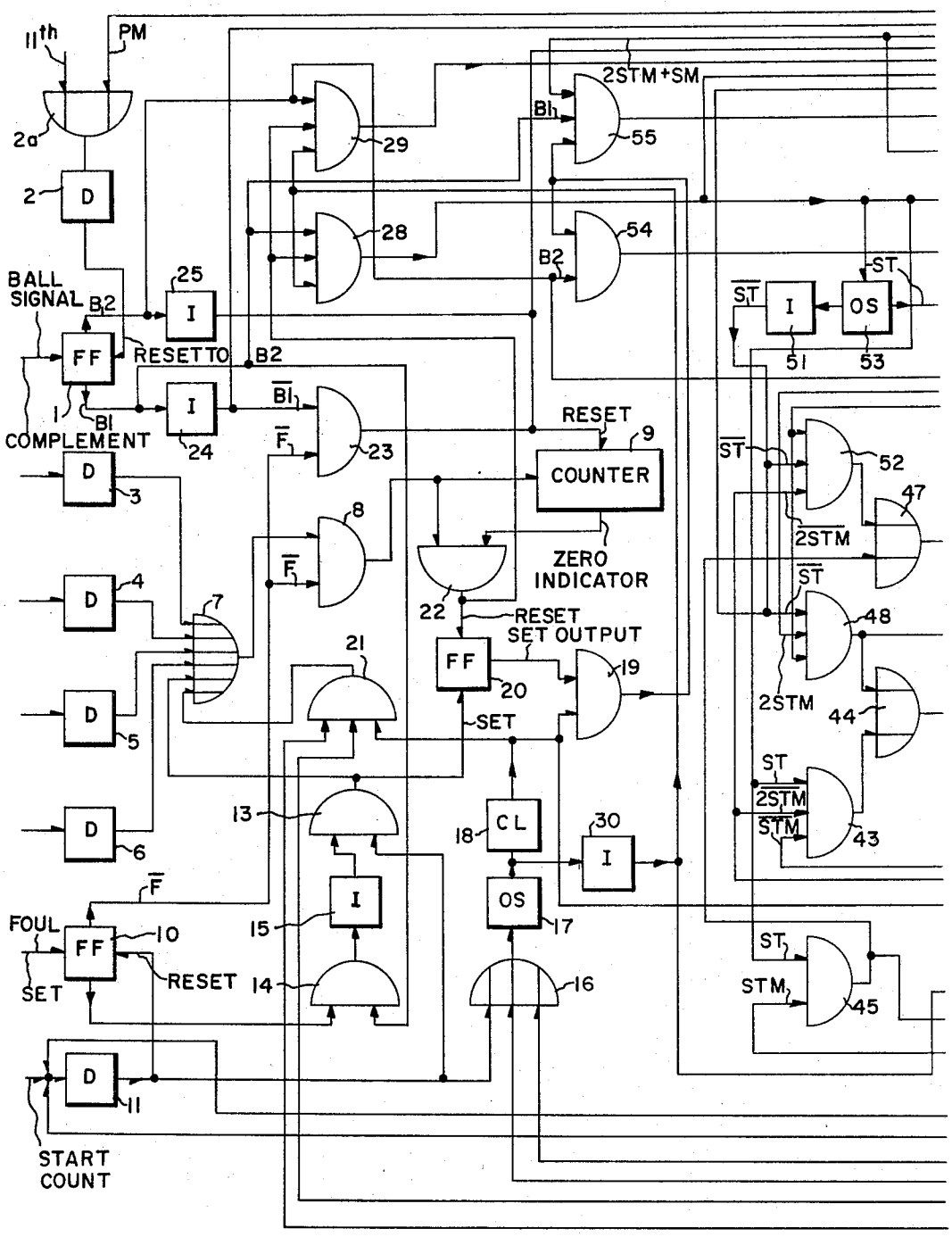


FIG.1A

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AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 2

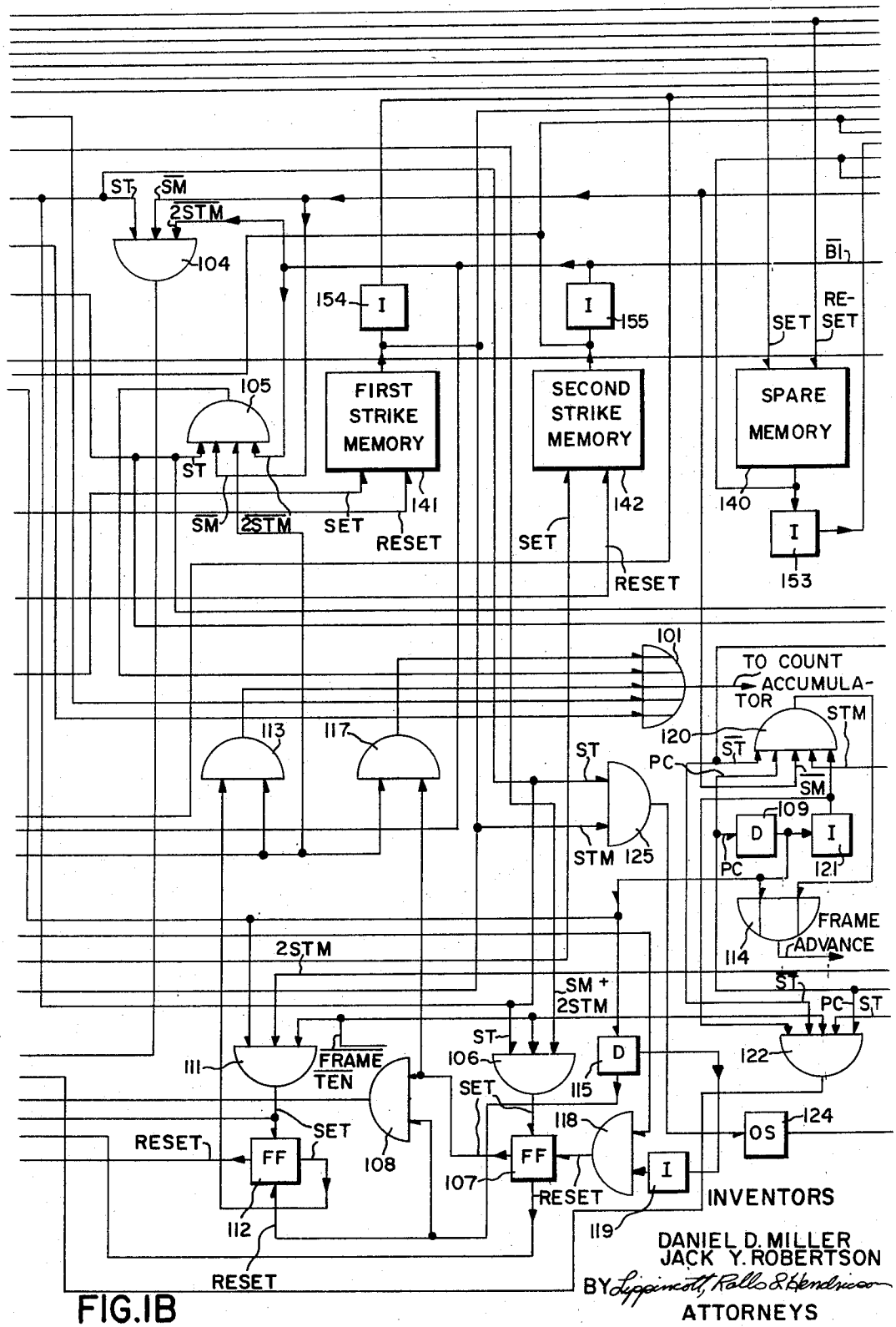


FIG.1B

AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 5

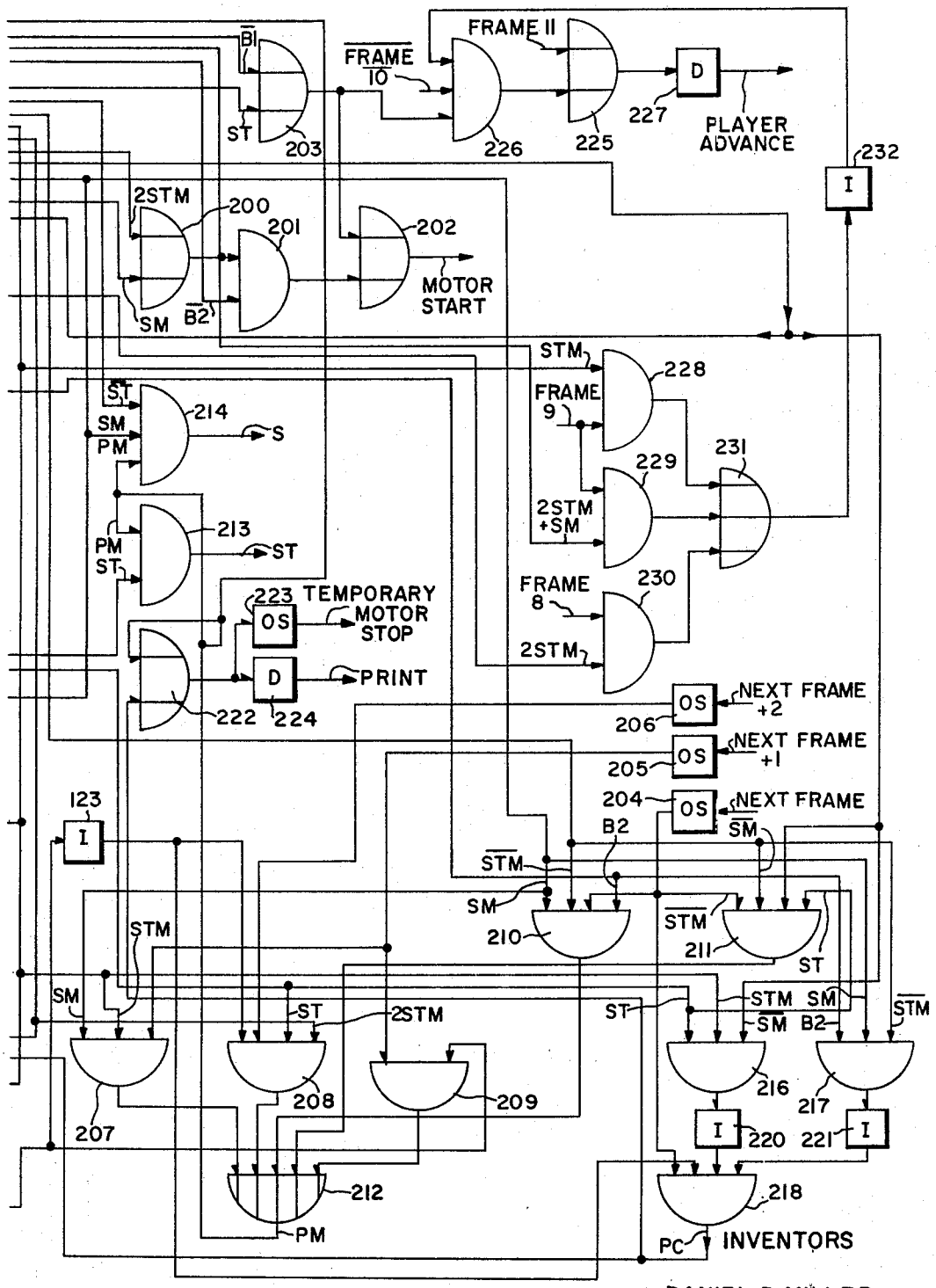
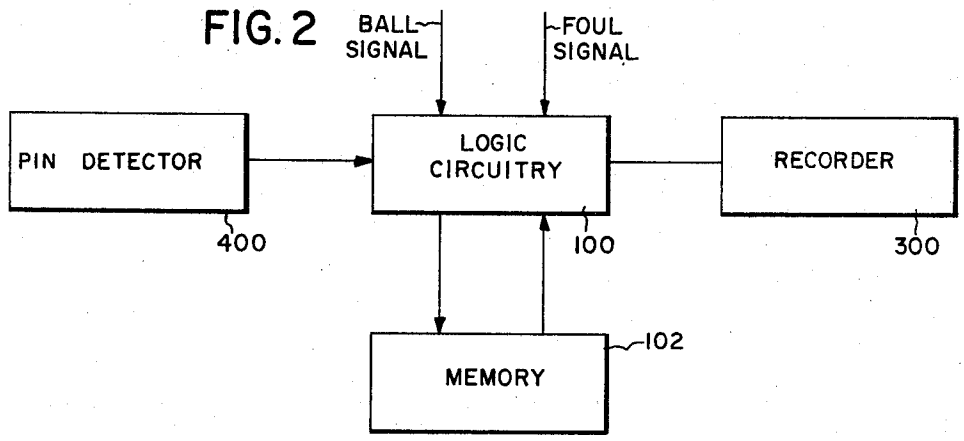


FIG.IC

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FIG. 2



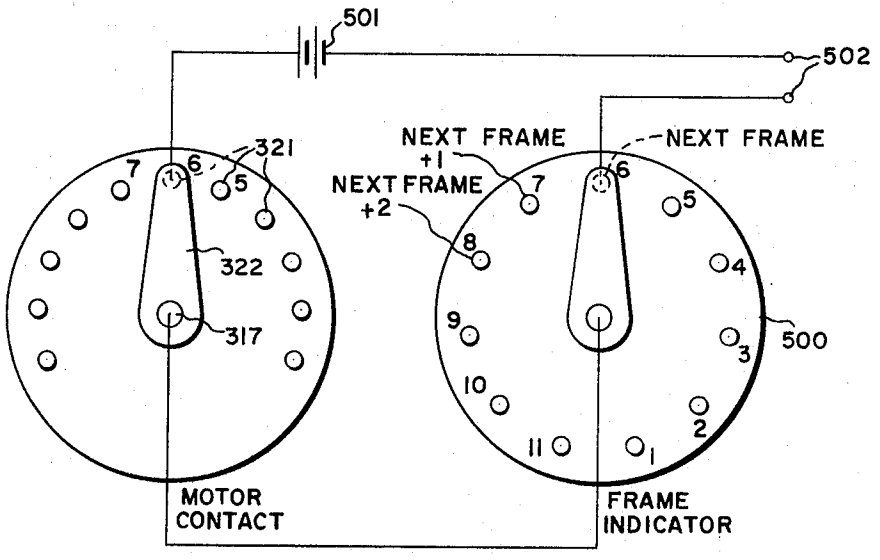


FIG. 14

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AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 5

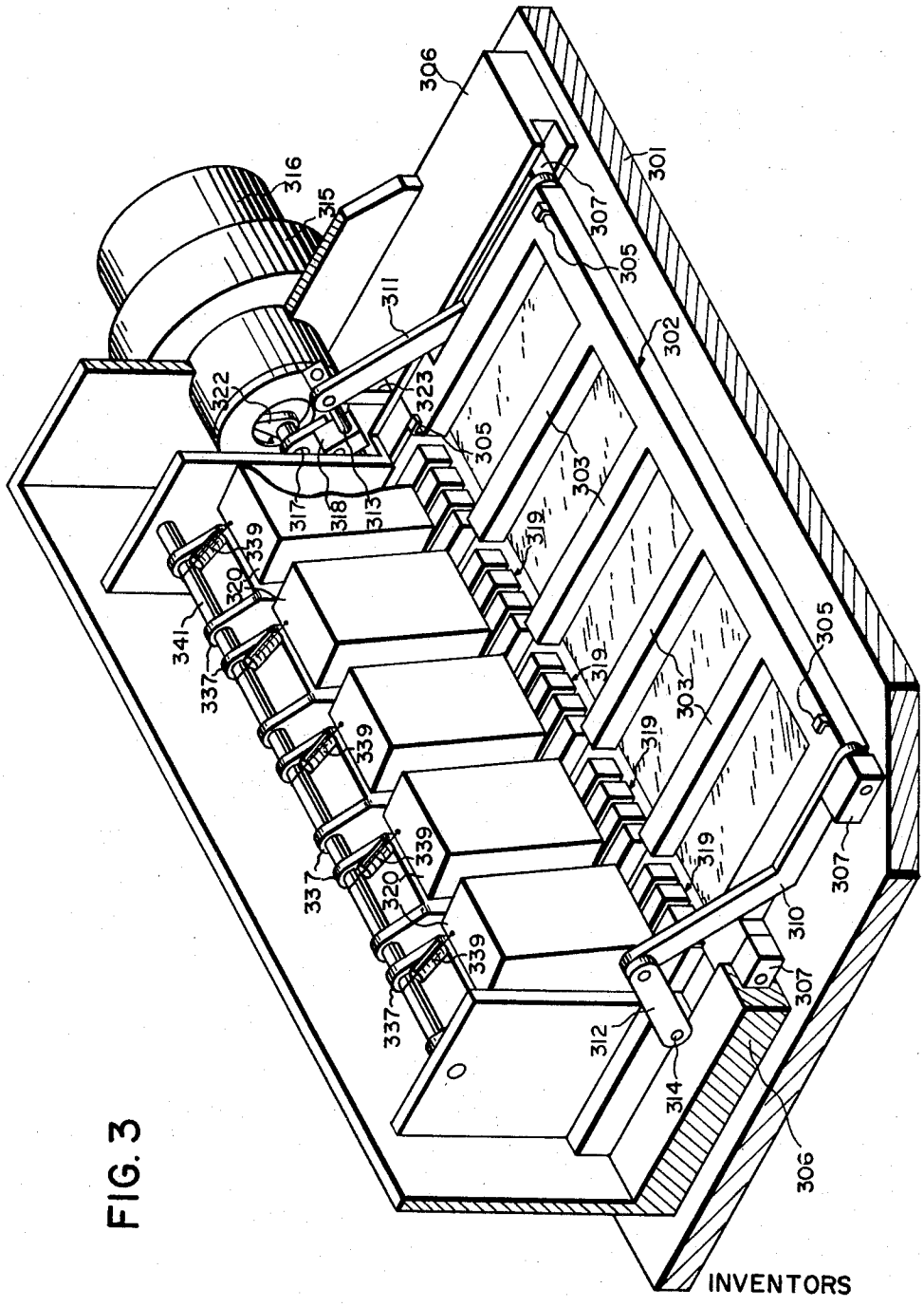


FIG. 3

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AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 6

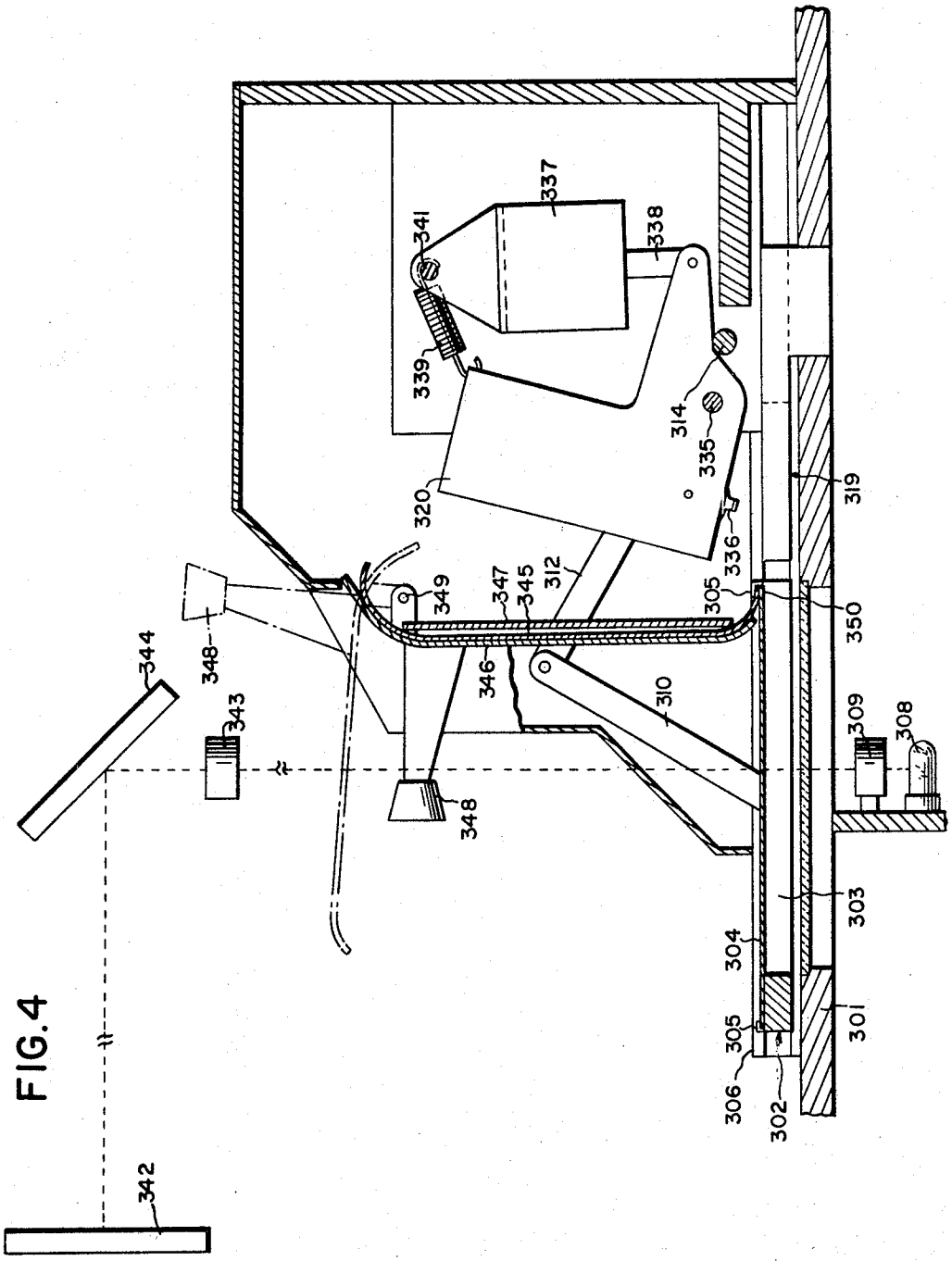


FIG. 4

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AUTOMATIC BOWLING SCOREKEEPING APPARATUS

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FIG.5

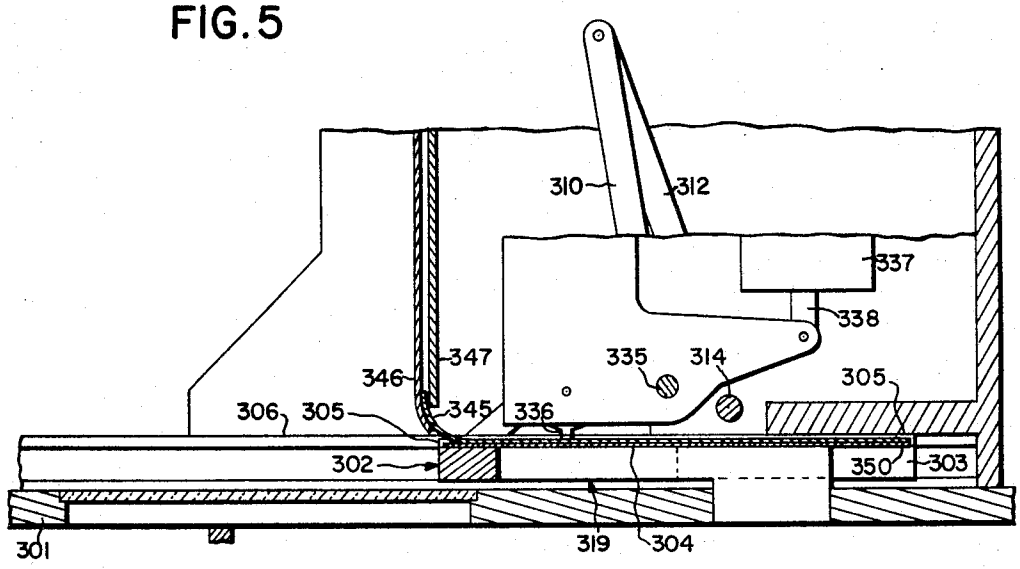
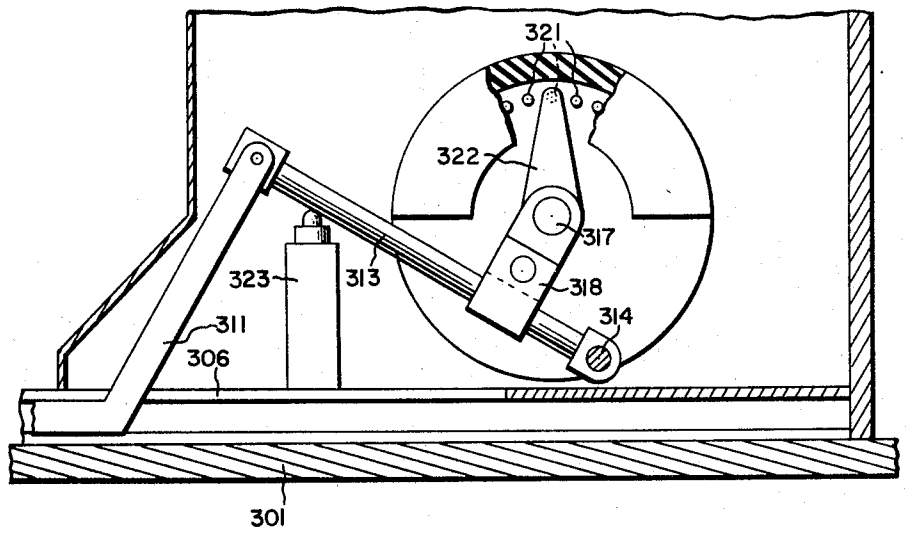


FIG.6



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AUTOMATIC BOWLING SCOREKEEPING APPARATUS

Filed Sept. 6, 1963 8 Sheets-Sheet 8

FIG.7

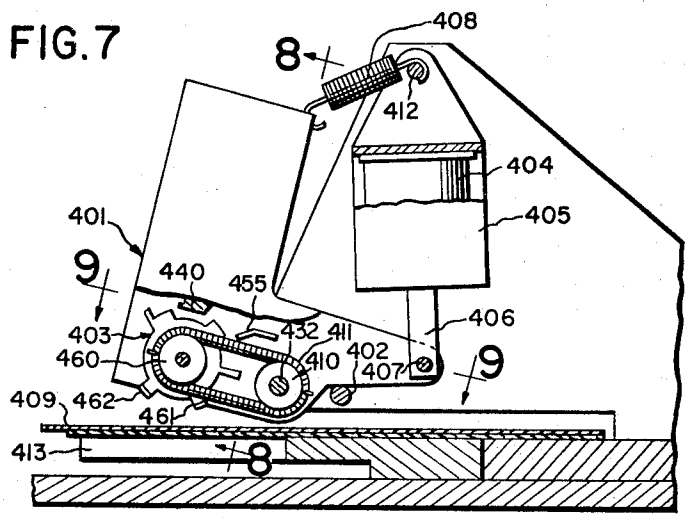


FIG.8A

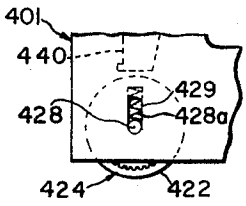


FIG.8

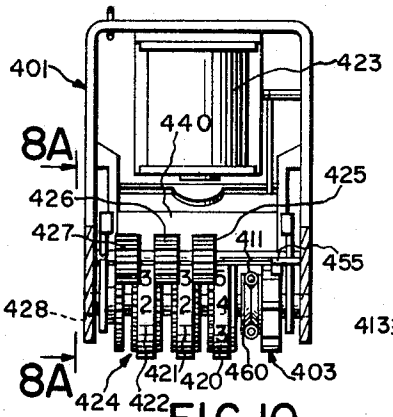


FIG.9

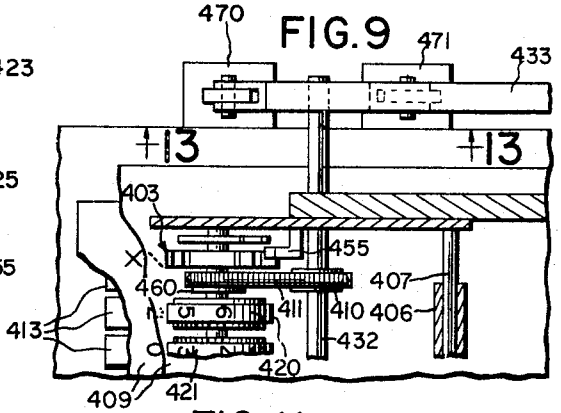


FIG.10

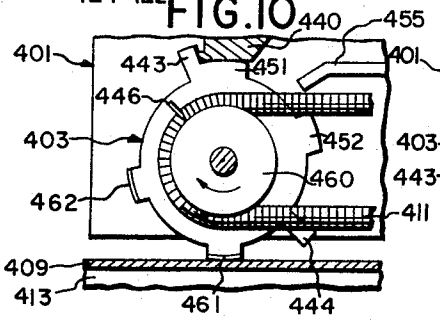


FIG. 11

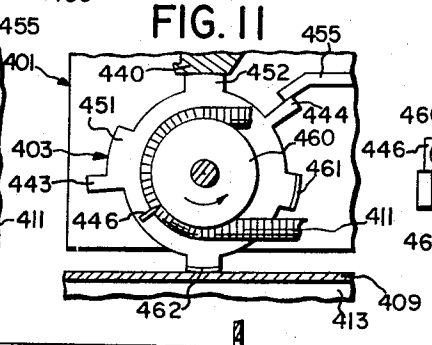


FIG.12

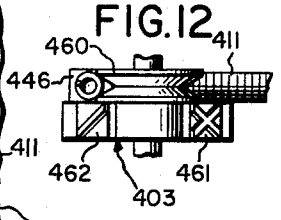
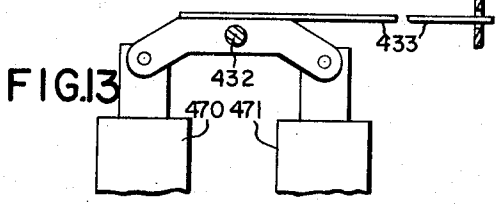


FIG.13



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United States Patent Office 3,295,849 Patented Jan. 3, 1967

3,295,849

AUTOMATIC BOWLING SCOREKEEPING APPARATUS

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Filed Sept. 6, 1963, Ser. No. 307,145
4 Claims. (Cl. 273—54)

This invention relates to apparatus for automatically scoring bowling games. In particular, the apparatus of the invention provides electronic pulses from a pin sensor which indicates the number of pins left standing after a ball has been rolled, a pulse indicating that the ball has been rolled, and an indication of the occurrence of a foul. These pulses pass to an electronic circuit which interprets them to provide output signals to a recording equipment. The recording equipment keeps the cumulative score of a player or team of players, and also indicates the occurrence of spares, strikes, and fouls, if desired. This information can be recorded in proper sequence automatically for a team of five players playing in the order prescribed for leaque play by the American Bowling Congress (ABC).

In the past, bowling scores have been tabulated manually by skilled scorekeepers. These persons record line and frame scores, perform the required arithmetic, and tabulate the result to be projected on a screen for viewing. Such a manual system has numerous disadvantages. First, human errors invariably will creep into all phases of the scorekeeper's work from time to time. He may miscount the pins, record a score for the wrong bowler, err in arithmetic, and so forth. Second, the labor cost for scorekeepers is high; labor expense is a substantial fraction of the expense of bowling alley operation—yet, to keep bowling popular, prices must be kept low. Third, manual scorekeeping is necessarily slow, delaying each game, and limiting the number of games which may be bowled during operating hours. This factor increases the rate of equipment amortization on a per-game basis.

Automatic scorekeeping equipment has been designed in the past. One type of such equipment is described in U.S. Patent 2,590,444. To date, however, this type of equipment has not proved commercially practical because of certain problems inherent in making use of it. First of all, the scorekeeping equipment must be used in conjunction with a pinsetter mechanism. Currently-installed pinsetters must be substantially modified, and the owners of the pinsetters (who are usually not the alley owners, since pinsetters are generally leased) are often unwilling to have their equipment modified. Second, the scorekeeping apparatus uses a large number of relays and rotating contacts, which tend to become contaminated with dust and dirt, with the result that play is frequently interrupted for long cleaning periods—to say nothing of the errors caused by a contact failure. Third, and most important, the equipment tends to slow down play rather than speed it up. Normally, the pinsetter goes down over the pins only after a first ball (provided it has not been a strike); at that time the standing pins are lifted, and the fallen pins removed. During this move the standing pins may be easily counted by an adaptation on the pinsetter for scorekeeping. However, there is no reason (other than the scoring problem) to lift the standing pins following the second ball; since a pin lift is a slow operation at best, the game is speeded by simply sweeping all the pins off the alley. But to take advantage of the prior-art automatic scorekeeper, the pinsetter mechanism must be altered to make this second pickup, thereby slowing down the game considerably just to obtain the standing pin count after the second ball.

This invention uses optical sensing equipment for detecting the pinfall resulting from a rolled ball. This equipment is described in copending application of John G. Bolger, Serial No. 178,873, filed March 12, 1962, now U.S. Patent 3,140,872, and assigned to the same assignee as this invention. The system of this invention in contrast to the prior art, therefore eliminates the roadblock previously encountered with a scorekeeping system tied to the pinsetter to obtain its count. No alteration of presently installed pinsetting equipment is required, and no extra pickup time is introduced to delay the game. The pulses from the optical pinspotter are transmitted to the logic circuitry.

The logic circuitry of this invention is entirely electronic. No relays or rotating contacts are used in that portion of the apparatus which converts the STAND input signal to the SCORE output signal.

Moreover, the apparatus hereof employs a chain of STAND pulses to indicate standing pins, rather than the ten separate pulses used in the prior-art apparatus. Thus only a single transmission line is needed to transmit the STAND input signal from the sensor to the logic circuitry. The prior-art, on the other hand, has required a separate transmission line for each pin because all the pin signals were received simultaneously instead of sequentially, and were transmitted in parallel to relays.

Briefly the logic circuitry responds to input signals which report any or all of the following information:

(1) that a ball has been rolled; or

(2) that a player has stepped over the foul line (a foul); or

(3) the STAND count (the number of pins still standing after a ball has been rolled).

In response to these input signals, the following output signals are provided which are fed to the score-recording apparatus of the invention:

(1) frame-advance;

(2) record a cumulative score;

(3) record a STRIKE (all pins felled on the first ball);

(4) record a SPARE (all pins felled on the second ball); and

(5) change players.

The logic circuitry interprets the input signals to provide the proper output signals at the proper times and in the proper sequence. This interpretation is accomplished within the space of a fraction of a second—many orders of magnitude less than that required by the prior-art systems. In addition, the scoring is vastly more accurate than accomplished in the prior art, in view of the numerous potentially dirty relay contacts and rotating switches which are eliminated.

The output signals from the logic circuitry are passed to the recording equipment. In a preferred embodiment of the invention, these signals include a signal indicating when the next player is to roll according to the playing sequence prescribed by the ABC. Then one score accumulator (or counter) is used for each player, and the output signals from the logic circuitry automatically switched from one player to the next in the prescribed sequence. The recording equipment, such as a desk unit and plurality of printer-counters—one for each player—prints or otherwise records the score. This record will indicate spares, strikes, cumulative score at each frame, and, if desired, the occurrence of a foul. Moreover, the score may, if wanted, be immediately projected for viewing by the players and spectators.

Since the United States alone contains over 200,000 operating bowling alleys which can make use of this type of equipment, the apparatus of the invention fills a real need. It provides the first practicable and workable scorekeeping system available for immediate purchase at a cost not out-of-line with its saving in labor and in-

crease in the number of games which may be bowled in a single lane. Because of the involved logic circuitry, the apparatus of this invention may at first appear quite complex; nevertheless it is simple and reliable enough to provide the first practical system capable of quantity manufacture at a low enough cost to make universal distribution possible.

The details of the apparatus will be best understood from the following detailed explanation, with reference to the following drawings:

FIGS. 1, A–C, when laid side-by-side, show a logic diagram of the logic circuitry used in this invention;

FIG. 2 is a block diagram of the entire apparatus of the invention;

FIG. 3 is a pictorial illustration having parts cut away, showing the desk unit used for moving the scoresheet to allow the score to be printed in the correct frame;

FIG. 4 is a side elevation view, somewhat in section, showing the desk unit including the printing surface, the sheet of protective material between the printing surface and the printing element, and the projection lenses and screen;

FIG. 5 is a fragmentary cross-sectional view showing the tray of the desk unit in printing position;

FIG. 6 is a front view, partially broken away, showing the tray position indicator and tray slide arm in more detail;

FIG. 7 is a side elevation view, partially broken away in section, showing the printer-counter and the printing surface and support;

FIG. 8 is a sectional rear view of the printer-counter taken in the plane 8—8 of FIG. 7;

FIG. 9 is a sectional plan view taken in the plane 9—9 of FIG. 7;

FIG. 10 is a fragmentary cross-sectional view of the spare-strike wheel in the strike-printing position;

FIG. 11 is a fragmentary cross-sectional view of the spare-strike wheel in the spare-printing position;

FIG. 12 is a bottom view looking up at the spare-strike wheel;

FIG. 13 is a sectional elevation view showing the rotator for the spare-strike wheel, taken in the plane 13—13 of FIG. 9; and

FIG. 14 is a schematic diagram of the frame indicator and tray position indicator switches, showing associated circuitry for one tray and indicator position.

The system of this invention is shown in block diagram in FIG. 2. The system is comprised of three main sections: the pin detector **400**, the logic circuitry **100** including memory **102**; and the recorder and tabulator **300**. The logic circuitry **100** and memory **102** are shown in detail in FIGS. 1, A–C, and will be fully described henceforth. The recorder **300** may vary substantially according to the dictates of the alley operators. For example, the score may be printed to provide a record for the bowler; it may be fed into a data storage apparatus to be transmitted throughout the country in the case of nationwide bowling competitions; or it may be projected for viewing within the alley so that bowler and spectators may immediately see the frame results. Sometimes all of the above may be done.

Pin detector **400**, in this invention, is an optical scanning device which provides a chain of output pulses, one for each standing pin. These pulses are achieved by means of a plurality of flashing lights which illuminate a part of the pins, e.g. the heads. Photocells are used to sense the lights after they are reflected from the heads of the pins.

Preferably a plan of "group sensing" is used to make maximum use of each photocell. To accomplish this, lights are reflected off the heads of each of a group of pins in sequence. The reflected beam from each pin in such group is directed at a single photocell. Thus, if the group has four pins, for example, a sequence of four flashes would be used, one directed at each pin. If all four were standing, the photocell would emit four sequential pulses; if one pin had been felled, only three pulses would be emitted, and so on. Enough photocells are employed to be certain of detecting the presence of all ten pins for a ten pin bowling system to which the embodiment described in this specification is directed. However, it will be obvious that simple changes in the pin spotters and logic circuitry can be made to adapt the apparatus to other systems using different numbers of pins (e.g. the German system), or for Duck Pins, using three balls rather than two.

The photocells emit a series of pulses called "STAND" pulses, one for each standing pin, which are passed to the logic circuitry. They are emitted before the pinsetter drops to pick up fallen pins (after the first ball) or drops to sweep away all the pins (after the second ball). This type of optical sensing is therefore a great improvement over sensing using the pinsetter itself. Pinsetter sensing requires the pinsetter to drop after the second ball to pick up standing pins for the count, and then drop again for the sweep. Thus an appreciable delay of the game results.

A more detailed explanation of the photoelectric pinspotter used in this invention can be had by reference to the above noted U.S. Patent 3,140,872. One set of pin groups are clearly illustrated in FIG. 1 of that application.

Turning to the logic circuitry of the invention, reference is now made to FIGS. 1, A–C. Throughout the FIGS. 1, A–C, certain conventions of nomenclature and symbol are adhered to. An "AND-gate" is shown by an empty semicircle; and an "OR-gate" is shown by a semicircle with inputs extending through its interior. An inverter is shown by a box containing the letter "I," and a delay is indicated by a box containing the letter "D." A flip-flop is shown by a box containing the designation "FF."

The signals used are abbreviated by the following symbols:

Spare	S
Strike	ST
First Ball	B1
Second Ball	B2
Spare Memory	SM
Strike Memory	STM
Two-Strike Memory	2STM
Foul	F
Print COUNT (Cumulative Score)	PC
Print MARK	PM

A symbol carrying a bar above it is a conventional logic symbol meaning NOT e.g., $\overline{SM}$=NOT a spare memory; $\overline{B1}$=NOT ball one, or NOT a first ball).

As a further aid to the reader, all elements found on FIG. 1A have a number from **1–99**; elements on FIG. 1B have numbers from **100–199**; and elements on FIG. 1C have numbers from **200–299**. All references will be to the numbers, and the location of any particular element will be indicated by its reference numeral.

Referring to FIG. 1, a BALL input signal is fed to the complement input flip-flop **1** each time a ball reaches the end of the alley. The initial state of this flip-flop is such that a B2 is indicated. As soon as a BALL signal has been received at the complement input, the state of the flip-flop changes, indicating B1. When the next BALL signal is received, the flip-flop returns to its original state, again indicating B2. Although the flip-flop **1** following a ST (all pins down in B1), will first change from B2 to B1, as a result of the Print MARK signal generated by the ST, it will be reset to B2 immediately thereafter (following the delay from delay **2**) by the pulse into the reset input of delay **2** from OR-gate **2***a*. OR-gate **2***a* receives a pulse each time a MARK is recorded (a S or ST symbol). If the MARK was a ST, flip-flop **1** will be reset to B2 from B1; if the MARK was a S, flip-flop **1** will receive a "reset to B2" pulse, but will already be set on B2, so the pulse will have no effect. OR-gate **2***a* will also receive a pulse

on FRAME 11 to reset flip-flop 1 to B2 at the end of a game.

When the STAND count input to the apparatus of this invention (the number of pins standing after a ball is rolled) is obtained from a pin sensor of the type described in U.S. Patent 3,140,872 mentioned above, the pin signals will appear in four distinct groups. The first group may contain as many as four pulses (assuming that there were four standing pins remaining), the second group three pulses, the third group two pulses, and the last group one pulse. The total possible number of pulses is a maximum of ten. To avoid any interference among the pulse groups, each group is delayed by delays 3, 4, 5, and 6 by an amount sufficient to insure complete serialization of the ten pulses. Through this means, the input to OR-gate 7 from the four delays becomes a series of pulses, one for each standing pin up to the possible maximum of ten.

Two different types of arrows have been used in the FIG. 1 to designate input signals. The first type is a double-sided arrow which indicates an input signal which constitutes one or another binary level. The higher or positive level will alert the gate (in the case of an input to an AND-gate) and the lower level will not. The second type is a single-sided arrow, indicating a short duration pulse which will always pass through an OR-gate or through an alerted AND-gate.

The series of pulses from OR-gate 7, indicating the STAND, is transmitted directly through AND-gate 8 into counter 9 whenever no foul has been committed. In the absence of any foul signal, AND-gate 8 is alerted by the $\overline{F}$ level signal from flip-flop 10. Counter 9 is a conventional binary counter consisting of a plurality of flip-flops. As will be fully explained later, the counter counts to eleven in the binary number system, requiring for this four flip-flops. A four flip-flop binary counter can actually count up to a maximum of 16 (not including 0); since a count of eleven is all that is required for this invention, five counting positions are eliminated by use of regulation or feedback. The eleventh count can be referred to as zero, since there are eleven counts from zero and to ten.

As soon as the last of the STAND pulses has been transmitted to counter 9 (assuming no FOUL) a START COUNT signal is sent to delay 11. This delay insures that the STAND pulses will all have been reviewed and counted by the counter before the count cycle is begun. The pulse emitted from delay 11 is passed through AND-gate 13 which is normally alerted by the negative output level from AND-gate 14, connected through inverter 15 to make it positive. AND-gate 14 will provide a positive output level only when the B1 level from flip-flop 1 and the F level from flip-flop 10 coincide. Since flip-flop 10 will not normally provide an F level, AND-gate 14 will not normally have a positive output level. The single start-count pulse from delay 11 then passes through alerted AND-gate 13, OR-gate 7, and alerted AND-gate 8 to increase the count in counter 9 by one. This means that the count will now be one more than the number of pins remaining standing after the ball has been rolled, the STAND having previously been stored in the counter.

The pulse from delay 11 also passes into OR-gate 16 to trigger one-shot 17. (A one-shot is a conventional multivibrator which extends the duration of the trigger pulse at its input by a predetermined amount.) When energized by a pulse from one-shot 17, clock pulse generator (or clock) 18 will emit pulses continuously for the duration of the extended pulse. In this case, the duration of the extended pulse is that time which allows emission of ten clock pulses by clock pulse generator 18. These ten pulses will pass through normally-alerted AND-gate 21 (whose purpose will be explained later), OR-gate 7, and AND-gate 8 to counter 9. The ten counts will recycle counter 9 for one count less than a complete cycle (eleven). Thus counter 9 will register a count equal to the number of standing pins, because it had previously been set (by the additional single pulse from AND-gate 13) at a count equal to one more than the standing number.

The output pulses from clock 18 are also passed to AND-gate 19, and will pass through it provided that the gate is alerted at that moment. If it is not, the clock pulses will be blocked. The alerting input to AND-gate 19 comes from flip-flop 20. When flip-flop 20 is set, AND-gate 19 is alerted and will pass the clock pulses. Flip-flop 20 is set by the signal output pulse from AND-gate 13 which, it will be recalled also adds one to the count in counter 9. This signal pulse from AND-gate 13 is emitted in response to each START COUNT signal from delay 11. Flip-flop 20 is reset by an output pulse from AND-gate 22. Such a pulse will occur at the end of the clock pulse causing counter 9 to reach the zero state. Remember that counter 9 counts from zero to ten, totalling eleven counts, and that it was set by the STAND signal to a count equal to the standing pins plus one (from AND-gate 13). Then ten more clock pulses are passed into the counter from clock 18. At some time during these ten clock pulses, counter 9 will reach zero and start a new counting cycle. The zero state of the counter 9 alerts AND-gate 22; at that time, flip-flop 20 is reset by the resulting output pulse from AND-gate 22, and the clock pulses to AND-gate 19 are blocked thereafter. The clock pulse bringing the counter to zero will pass through AND-gate 19, but the remainder of the ten pulses from clock 18 will not.

When a FOUL is committed, the normal sequence is altered. First, a FOUL signal sets flip-flop 10 to "F." The absence of a $\overline{F}$ level at the input to AND-gate 8 then prevents that AND-gate fom passing the STAND pulses to counter 9. As a consequence, pins felled by a ball rolled during the commission of a FOUL are not counted.

The operation of the system is different when a FOUL occurs on B1 than when it occurs on B2. Where a FOUL occurs on B1, AND-gate 14 provides a positive output level to inverter 15, which removes an alerting level from AND-gate 13. The pulse from delay 11 is therefore prevented from being entered into counter 9. Since the FOUL also prevented the STAND pulses from entering counter 9, as described above, the counter 9 will remain at zero (to which it was reset by the B1 ($\overline{B2}$) pulse from inverter 25) after the count resulting from the FOUL roll. Moreover, flip-flop 20 is not set because of the absence of the pulse from AND-gate 13. When clock 18 emits its ten pulses, the counter 9 increases its count from zero to ten. However, the RESET position of flip-flop 20 prevents any of these ten pulses from passing through AND-gate 19 to the score accumulator. It is important that the counter 9 ends up at ten (indicating a PINFALL of zero) in case the next ball is also a FOUL. Then the resulting score of zero for that frame (having two FOULS) in the counter 9 becomes the frame score.

When a FOUL occurs on B2, counter 9 is not reset by the B2. The B2 ($\overline{B1}$) RESET pulse from inverter 24 is gated through AND-gate 23 to the RESET input of counter 9. This AND-gate is inhibited in the event of a FOUL by the absence of the requisite $\overline{F}$ level at one input. Thus, the score from the previous B1 remains in counter 9. If the B1 happened to be a FOUL, it is recalled, this count will be ten—indicating a zero pinfall. Again, of course, the B2 STAND signals are blocked from the counter 9 by AND-gate 8. With a B2 FOUL, AND-gate 14 is not alerted (a B1 pulse is required) and thus AND-gate 13 is not inhibited. The delayed pulse from delay 11 therefore passes through AND-gate 13 to set flip-flop 20. Thus the B1 score stored in counter 9 will be stored in the accumulator as the frame score—the proper result since B2 was a FOUL.

A numerical example should help to clarify the normal operating sequence. In the following discussion, it will

be assumed throughout that the player has not committed a foul in rolling his ball. Supposing that the bowler felled three pins with his first ball (leaving seven pins standing), seven pulses will then pass through OR-gate **7** and alerted AND-gate **8** into counter **9**, setting it from zero to seven. After the STAND signal has been stored, the start count signal from delay **11** will set flip-flop **20** and will send a single pulse through AND-gate **13**, OR-gate **7**, and AND-gate **8** into counter **9** increasing its count to eight. One-shot **17** is triggered and clock **18** begins to send pulses to counter **9** as described above. The third such pulse will place counter **9** in the zero state. That pulse will therefore pass from AND-gate **8** through AND-gate **22** to reset flip-flop **20** at the end of the pulse. Consequently AND-gate **19** will no longer be alerted, and the remaining seven clock pulses cannot pass through. The three pulses previously passed, however, are the exact number of pins felled by the ball. Therefore the number of output pulses from AND-gate **19** represents the PINFALL. This PINFALL signal emerging from AND-gate **19** is used by several other portions of the apparatus, to be described later. The remaining seven pulses from clock **18** will however still reach counter **9**, setting it to seven again (the STAND). This is important in case the next ball rolled happens to be a FOUL.

Counter **9** is reset after each ball has been rolled. This resetting therefore occurs before the STAND input signals are generated. The STAND for B1 is not needed for computation of the STAND for B2 because the felled pins following a B2 naturally include those felled earlier by the B1 (the pins not being reset between B1 and B2). Counter **9** is always reset, therefore, as flip-flop **1** changes from B2 to B1 when B1 strikes the backstop. This change in flip-flop **1** causes an instantaneous pulse, denoted as $\overline{B2}$, to emerge from inverter **25**, and pass to the RESET input of counter **9** to reset the counter.

The apparatus of the invention has a very simple way of determining whether the pinfall was a ST or S (ten pins felled on B1 or B2, respectively). AND-gates **28** and **29** are used for this purpose. At the end of the PINFALL count (when the ten clock pulses have all been emitted from clock **18**), one input of each of AND-gates **28** and **29** is alerted by the positive output level from inverter **30** after one-shot **17** has ceased its extended pulse. Another input of AND-gate **28** is alerted by the B1 level from flip-flop **1**, and another input of AND-gate **29** is alerted by the B2 level from flip-flop **1**. Thus, AND-gate **28** will be alerted after a B1, and AND-gate **29** after a B2.

Where a ST is rolled (after a B1), or a S is rolled (after a B2), the STAND input signal will be zero (no pins left standing). Counter **9** will remain set at zero until advanced one by the pulse from AND-gate **13**, and ten further counts by the ten pulses from clock **18**, thus arriving again at zero after eleven pulses have entered. When counter **9** reaches zero, it provides a positive output level designated as "zero indicator" in FIG. 1A. This level is passed to the inputs of AND-gates **28** and **29**. Inverter **30** provides pulses to both of these AND-gates **28** and **29** at the time when the extended pulse from one-shot **17** ends. The pulse from inverter **30** can occur simultaneously with the presence of the zero indicator level only with a STAND count of zero in counter **9** (all pins down). Otherwise, the zero indicator level will be present and disappear while the extended pulse from one-shot **17** continues and thus no pulse from inverter **30** can be present. AND-gates **28** and **29** will no longer be alerted by the zero indicator level when the pulse from inverter **30** finally appears at the end of the pulse from one-shot **17**.

If flip-flop **1** indicates a B1 with a STAND of zero, the pulse from inverter **30** will pass through AND-gate **28** to indicate a ST; if B2 is indicated, the pulse from inverter **30** will pass through AND-gate **29** to indicate a S. These pulses are used by other parts of the apparatus to be described later.

The memory section of this apparatus remembers sequences of ST's and S's for each player until such information is no longer needed for calculating his score. The output from S-indicating gate **29** is fed into the SET input of spare memory **140** which then produces an output level indicating SM, i.e., the last ball was a S. The spare memory **140** is then reset to $\overline{SM}$ before each possible output signal from AND-gate **29** by a reset pulse to its RESET input from flip-flop **1** indicating a B2 ($\overline{B1}$).

The strike memories are set in the following manner. A ST signal emerges from AND-gate **28** when the bowler scores a ST. Assume, for the moment, that the bowler did not have a ST in the preceding frame. Before the throw, the first-strike memory flip-flop **141** was set at $\overline{STM}$ and the second-strike memory flip-flop **142** at $\overline{2STM}$. AND-gate **43** is therefore alerted by the presence of both the $\overline{STM}$ and the $\overline{2STM}$ inputs to pass the ST pulse from AND-gate **28**. This ST pulse is transmitted to the SET input of first strike memory **141** through OR-gate **44** so that the output level of memory **141** indicates STM—i.e., that the previous ball was a ST.

Suppose now that the player rolls another ST. AND-gate **45** is alerted by the STM output level from first-strike memory **141**. The ST input to AND-gate **45** is passed through the gate to the SET input of second-strike memory **142**. This pulse sets the memory **142** to the 2STM condition, indicating that two consecutive ST's have been scored in the last two rolls. The same signal which sets memory **142** passes through OR-gate **47** to the RESET input of first-strike memory **141**, resetting that memory to the $\overline{STM}$ condition.

If a third ST should now be rolled, AND-gate **48** will not be alerted because, as a result of the third ST, a ST level exists at one of its inputs. Second-strike memory flip-flop **142** will not be reset, and thus it remains in the 2STM condition to remember the last 2 ST's.

Suppose instead that the player rolls a third ball which is not a ST (after obtaining 2 consecutive ST's). This ball will still cause a score to be recorded, as will be explained later. To understand the memory systems, it is important only to know that a PRINT COUNT (PC) signal will be generated because a cumulative score will be recorded on this third ball to maintain the scorekeeping at a current level. At this time, an alerting input level exists at one input of AND-gate **48** because the second-strike memory **142** remains in the 2STM condition. The absence of a ST signal from AND-gate **28** at one-shot **53** results in a $\overline{ST}$ level from inverter **51** which appears at another input of AND-gate **48**. These two inputs now alert the AND-gate **48**, so that the PC pulse will pass through. The resulting output pulse from AND-gate **48** is passed to the RESET input of the second-strike memory **142** to reset the memory. The output pulse from AND-gate **48** is also passed through OR-gate **44** to the set input of first-strike memory **141**, setting it to remember that one strike is still left unscored.

When a non-strike ball is rolled while first-strike memory **141** is still in the STM condition, a similar sequence of events occurs. The $\overline{2STM}$ level from second-strike memory **142** appears at one input of AND-gate **52**. The level from one-shot **53** and inverter **51** (indicating the lack of a ST) also passes to AND-gate **52**, which is therefore alerted. Following printing of the score, the PC pulse is passed through alerted AND-gate **52** through OR-gate **47** to reset the first-strike memory **141** to $\overline{STM}$.

Since the inverted signals $\overline{SM}$, $\overline{STM}$, and $\overline{2STM}$ are often needed in the apparatus, they are produced from the output signals of memories **140**, **141**, and **142** by inverters **153**, **154**, and **155**, respectively.

Thus far, the following signals developed in the apparatus have been described:

a ST signal when the ball is a STRIKE;
a S signal when the ball is a SPARE;
B1 and B2 signals denoting the first or second ball in the frame, respectively;
a PINFALL signal indicating the number of pins knocked down by the ball;
a STM signal when the preceding ball is a ST;
a 2STM signal when the two preceding balls are both ST's; and
a SM signal when the preceding ball is a S.

From the various signals from the above group, and their combination in proper sequence, the cumulative score is determined. The portion of the apparatus which accomplishes this function is described below.

The PINFALL count is added to the cumulative score after each B2. AND-gate **19** provides the PINFALL signal in the form of a chain of pulses, one for each pin knocked down. The PINFALL signal is then gated through AND-gate **54**—alerted by the B2 level—through OR-gate **101** to a suitable score accumulator, one type of which is described later in this specification. The count in the score accumulator is increased by one for each pulse in the chain of PINFALL pulses.

Under certain conditions, the PINFALL must be entered into the score accumulator following a B1. Such a situation arises when the immediately preceding B2 was a S (an SM condition), or the two previous frames were both ST's (a 2STM condition). OR-gate **200** will provide a positive output level whenever such 2STM or SM signals exist. The output level of OR-gate **200** is transmitted to one input of AND-gate **55**. To alert the gate with a B1 level, the PINFALL pulses are transmitted from AND-gate **19** through alerted AND-gate **55** through OR-gate **101**, whence it is transmitted to the score accumulator.

The apparatus must also handle multiple successive ST's, or a ST following a S. The scoring procedure for multiple successive ST's is the following:

A ball is rolled and is a ST. No score will yet be printed, because the total score for that frame will not be ascertained until after the following two balls have been rolled; recording of the cumulative score for that frame is therefore inhibited, as will be explained later. However, a score of ten points must immediately be entered into the score accumulator for the ten pins felled by the ST ball. Although ten pulses will pass through AND-gate **19** from clock **18** because of the ten pins felled, these pulses will progress no further. AND-gate **54** is inhibited because the rolled ball is a B1 (not the required B2), and AND-gate **55** is inhibited because OR-gate **200** has neither a 2STM nor a SM input, as required. Therefore some means other than AND-gate **19** must be employed to enter the ten points in the score accumulator. The solution is the passage of the ST signal from AND-gate **28** through AND-gate **104**. Absence of any entries in the memories at this time leaves the necessary $\overline{SM}$ and $\overline{2STM}$ input levels to alert AND-gate **104**. The ST pulse then passes on to trigger delay **11**.

The pulse from delay **11** generates a new counting sequence. One-shot **17** is triggered through OR-gate **16**, and the count in counter **9** is increased by one as a result of the pulse from delay **11** passing through AND-gate **13**, OR-gate **7**, and AND-gate **8** to counter **9**. This same pulse sets flip-flop **20**, as explained previously. The extended pulse from one-shot **17** causes clock **18** to emit its ten pulses through AND-gate **19**. However, these pulses are blocked at AND-gates **54** and **55**, as described in the first cycle above. During the present cycle, however, the positive ST level from one-shot **53** appears at AND-gate **105**. No strike level appeared during the first cycle because ten counts had to pass in order that a ST pulse might be generated into one-shot **53**. This ST level, along with the $\overline{SM}$ and $\overline{2STM}$ conditions, which are present during the single ST situation, alert AND-gate **105**. The ten clock pulses from clock **18** thus pass through AND-gate **105** and OR-gate **101** to increase the accumulator count by ten.

The identical sequence of events will occur when the next ball rolled is also a strike, except that the first strike memory **141** will be energized prior to the roll (because of the previous ST). However, neither the spare or second-strike memories will yet have a positive level, so AND-gates **104** and **105** will remain alerted by the $\overline{SM}$ and $\overline{2STM}$ inputs. The ST signal from AND-gate **28** will pass through alerted AND-gate **104** to delay **11**. The same signal is also passed through AND-gate **45**, alerted by the STM condition of first-strike memory **141**, to the SET input of second-strike memory **142**, and through OR-gate **47** to the RESET input of second-strike memory **141**. Thus the second-strike memory **142** is set, and the first-strike memory **141** is reset. AND-gate **55** will now be alerted (by OR-gate **200**) to pass the ten resulting pulses from clock **18** to OR-gate **101** and from there on to the score accumulator, increasing its accumulated count to twenty.

Finally, if the third ball rolled is a third successive ST, AND-gates **104** and **105** will no longer be alerted because of the positive level in the second-strike memory **142**. However, this 2STM level will be passed through OR-gate **200** to combine with the B1 level to alert AND-gate **55**. AND-gate **55** will thus be alerted during the initial count-out from counter **9** through AND-gate **19** even before the ST signal has been generated as a result of this initial count-out of ten. The ten clock pulses generated will thus pass from AND-gate **55** through OR-gate **101** to add another ten points to the score accumulator, making the new total thirty. This figure is the proper score to be entered in the first frame, as may be seen from the following recount:

ten points for the initial pinfall on the first ball (ST1);
a ten-point bonus determined by the second ball (ST2) which felled ten pins); and
a further ten-point bonus determined by the third ball (ST3), which also felled ten pins.

A total of thirty points is thus scored in the first frame. The first-frame score, which has so far been suppressed because incomplete, is now completely determined and may be recorded.

When the ST signal is indicated by AND-gate **28** as a result of the third ST, AND-gate **106** was alerted because of the positive levels on its alerting inputs: the first level is a $\overline{FRAME\ TEN}$ level because game has not reached the tenth frame; and the second level is the 2STM+SM level from memory **142**, passed through OR-gate **200**. The ST pulse from AND-gate **28** is thus passed through AND-gate **106** to the SET input of flip-flop **107**, setting that flip-flop. The SET level of flip-flop **107** in turn alerts AND-gate **108** and removes the RESET alerting level from AND-gate **21**.

The PC signal generated to print the cumulative score of thirty is transmitted to delay **109** (which delays it long enough for printing to be completed). After the score has been printed, the pulse at the end of the delay in delay **109** has three functions. First, the pulse is passed to AND-gate **111**, which at that time is alerted by the 2STM level resulting from the two previous ST's, and the $\overline{FRAME\ TEN}$ level (meaning that the game is not in the tenth frame). The $\overline{FRAME\ TEN}$ level is provided by a frame indicator except when that indicator shows frame ten. The output pulse from AND-gate **111** sets flip-flop **112**, and also passes through OR-gate **16** to one-shot **17** and clock **18**. Ten pulses are emitted by clock **18**. The SET levels of flip-flops **107** and **112** now block AND-gate **21** which requires the RESET levels of flip-flops **107** and **112** to alert it. These ten pulses are thus blocked from counter **9** by AND-gate **21**. The ten clock pulses will pass through AND-gate **113** (now alerted by the SET level of flip-flop **112**), and thus ten more counts are added to

the cumulative score through OR-gate **101** making it forty.

The second function of the delayed output pulse from delay **109** is to advance the frame. The delayed pulse from delay **109** thus passes through OR-gate **114** to advance a frame indicator. This frame indicator may be a stepping switch, or other means of keeping track of the frame for which the cumulative score was last recorded. The PC pulse indicated that a cumulative score had been recorded in the previous frame, and that the frame indicator must therefore be advanced one position. The frame indicator also serves to generate frame signals, such as FRAME TEN and the inverse $\overline{\text{FRAME TEN}}$.

The third function of the pulse from delay **109** is to trigger a second delay **115**. The delay of delay **109** lasts long enough to permit addition to the score of the ten which brought it up to forty.

Delay **115** also has three functions to perform at the end of the delay time. The first is to reset flip-flop **112**. This flip-flop was set by the pulse from delay **109** at the end of the delay period of delay **109**, and must be reset when the score has been recorded.

The second function of the pulse from delay **115** at the end of the delay period is to pass through AND-gate **108** (alerted by the SET condition of flip-flop **107**) through OR-gate **16** to trigger one-shot **17**. One-shot **17** causes ten clock pulses to be emitted by clock **18** and these are passed through AND-gate **117** (also alerted by the SET condition of flip-flop **107**) and OR-gate **101** to the score accumulator. Thus, a cumulative score of fifty has now been entered.

At the end of the ten clock pulses from clock **18** when the pulse from one-shot **17** ends, the resulting output pulse from inverter **30** through AND-gate **118** (normally alerted by inverter **119** except during the delay provided by delay **115**) resets flip-flop **107**. It is apparent that a pulse from inverter **30** to AND-gate **118** also appeared after the first ten points was added to the score to increase it to forty; however, at that time a pulse was being emitted by delay **115** through inverter **119** so that AND-gate **118** was not at that moment alerted. Flip-flop **107** therefore remained in the SET condition until the second pulse from inverter **30** at the end of the delay of delay **115**. Again the clock pulses were not passed through AND-gate **21** because the SET condition of flip-flop **107** removed the alerting signal from AND-gate **21**. The score of fifty has now been entered into the accumulator, but has not yet been recorded. One more ball must be rolled to determine the complete score for the second frame.

When a S is rolled (all pins down on B2), the S pulse from AND-gate **29** sets the spare memory **140**. Flip-flop **1** is then at B2. The next B2 striking the backstop and resetting flip-flop **1** to B2 ($\overline{\text{B1}}$) will also reset spare memory **140**.

The situation of a S followed by a ST is handled by the same portion of the apparatus as discussed above for successive ST's. Following the S, spare memory **140** is in the SM condition. The output level of OR-gate **200** combined with the B1 level alerts AND-gate **55**. Now the ten pulse signal from AND-gate **19** as a result of the PINFALL of ten is transmitted through alerted AND-gate **55** and OR-gate **101** to add another ten points to the cumulative score. A cumulative score will always be recorded on the first ball after a spare, because the total score for the spare frame (which requires only one bonus ball) will then have been ascertained. After the ST ball following the S, therefore, a score will be recorded (for the preceding frame), and a PC signal will be emitted from delay **109** which, following the delay, will advance the frame count once through OR-gate **114**. As in the case of successive ST's, flip-flop **107** will be set by the ST signal from AND-gate **28** passed through AND-gate **106** (alerted by the SM and $\overline{\text{FRAME TEN}}$ levels). The SET level of flip-flop **107** in turn alerts AND-gates **108** and **117**. This time, however, AND-gate **111** will not have been alerted because no previous second ST existed to furnish the 2STM level required. Consequently, the only effects of the delay **109** pulse are to advance the frame and to trigger delay **115**.

After the delay period of delay **115**, the delayed pulse passes through alerted AND-gate **108**, and through OR-gate **16** to one-shot **17** and clock **18**. Ten more pulses then add ten points to the score through AND-gate **117** (alerted by the SET level of flip-flop **107**) and OR-gate **101**. The ten pulses cannot pass to the counter **9** because AND-gate **21** is blocked by the SET level of flip-flop **107**. These points represent the ten pins felled in the frame having a S. Now flip-flop **107** is reset by the pulse from one-shot **17** through inverter **30** and normally-alerted AND-gate **118** at the end of the ten clock pulses.

When the frame indicating apparatus indicates that the player is bowling in FRAME TEN, AND-gate **106** and **111** are inhibited by the FRAME TEN pulse and thus prevent any bonus from being added to the score. This step is necessary because the scores obtained from balls rolled after the two frame-ten balls are used only to compute a frame-ten bonus in the event that frame ten produced a ST or a S for the bowler. The pinfall does not count also as a frame score for a succeeding frame, as was the case for the nine earlier frames.

The bonus for a single ST (not immediately followed by another ST) is handled by a different section of the apparatus. The first ten points for the ST are added through AND-gate **105** and OR-gate **101**, as discussed above in the case of the first strike of a series. A symbol is then recorded for the ST (as will be explained later), and the PM pulse used to print the symbol resets ball flip-flop **1** to the B2 state through OR-gate **2A** and delay **2**. The ST pulse from AND-gate **28** also sets the first-strike memory **141** to STM.

When the next succeeding B1 is not a ST, the clock pulses emerging from AND-gate **19** are still blocked. They cannot pass through AND-gate **55** because no 2STM or SM level exists to alert that gate; and they cannot pass through AND-gate **54** because only a B2 alerts that gate. AND-gate **105** is blocked by the lack of a ST, and AND-gates **113** and **117** are blocked because flip-flops **112** and **107**, respectively, are reset. On the second ball however (B2), AND-gate **54** is alerted by the B2 level and the total PINFALL following the B2 is passed through AND-gate **54** to OR-gate **101**, thereby adding this PINFALL to the previously accumulated score. Assuming that the player felled seven pins in this second frame (following the ST in Frame **1** which has already caused ten points to be stored in the score accumulator), a STAND of three would appear in counter **9**. Seven pulses will therefore be passed through AND-gate **19** and AND-gate **54** before the counter returned to zero and reset flip-flop **20** to block AND-gate **19**. These pulses pass through OR-gate **101** to enter the score accumulator as the ST bonus, making the new cumulative score total seventeen. Since this figure represents the complete score for the first frame (where the ST was rolled), it may now be recorded there in response to a PC signal (derived in a manner which will be described later).

Before the termination of the delay in delay **109** triggered by the PC pulse, the PC pulse does two things. First, it advances the frame indicator immediately because the score of seventeen for the strike frame has already been recorded. This rapid frame-advance pulse is achieved through AND-gate **120**. The first-strike memory provides a STM level at one input. Another input, with nothing in the spare memory, has the necessary $\overline{\text{SM}}$ pulse; and a third input is connected through inverter **51** to one-shot **53**. This last positive input level signifies that the ST in the first-strike memory is not new, but occurred on the previous frame. The fourth input comes from delay **109** through inverter **121**. This fourth input is normally alerted except during the extent of the delayed pulse from delay **109**. Since all the inputs are alerted under the conditions existing during a PC pulse

following a first-strike frame, AND-gate **120** will pass the PC pulse directly through OR-gate **114** prior to termination of the delay in delay **109**, and the frame will advance one position.

AND-gate **122** has inputs identical with AND-gate **120** except that a $\overline{\text{FRAME TEN}}$ is substituted for the $\overline{\text{SM}}$. Provided that the player has not reached the tenth frame, this input will also receive signals of the proper levels to alert the AND-gate **122**. The PC pulse is therefore passed through AND-gate **122** to delay **11**. Delay **11** now performs in same manner as it does following a rolled ball. A first pulse passes into counter **9** through AND-gate **13**, OR-gate **7**, and AND-gate **8**. Then ten clock pulses from clock **18** pass through AND-gate **21** (alerted because neither flip-flop **107** nor flip-flop **112** is now SET) into counter **9** which still contains the STAND count of three (for a PINFALL of seven) plus one more added from AND-gate **13** to total four. Seven pulses will pass AND-gate **19**, therefore, before the counter returns to zero and flip-flop **20** is reset. These seven pulses pass through AND-gate **54** (alerted by the B2 level) and OR-gate **101** into the accumulator as a PINFALL score, yielding a new cumulative score of twenty-four. A PC pulse is generated, as will be described shortly, and the cumulative score of twenty-four is recorded at frame two. After this score has been recorded, the delay of delay **109** ends. Completion of the delay sends a pulse to frame-advance OR-gate **114** to advance the frame indicator to the third frame. The pulse from delay **109** also passes to alerted AND-gate **52** and OR-gate **47** to reset first-strike memory **141**. Although delay **115** is incidentally triggered by delay **109**, this has no effect in this sequence. One output of delay **115** is connected to AND-gate **108**, which is not now alerted, and the other output serves only to reset flip-flop **112**, which is already reset.

The next frame pulses necessary to generate the PC and PM signals are generated in the recording portion of the apparatus of this invention. Therefore the description now turns to the detailed explanation of an exemplary type of recording apparatus identified in the block diagram of FIG. 2 as recorder **300**. This recorder may be a desk unit, used to print the cumulative scores and ST and S symbols on a special type of paper. Such a desk unit is shown in FIGS. 3–6. The reference numerals to FIGS. 3–6 are the numbers **301–350**. The corresponding parts shown in more than one of FIGS. 3–6 have been given the same reference number in all figures. The counter, used both as the cumulative score accumulator and printing element, is shown as a block in FIGS. 3–6 and in detail in FIGS. 7–13. The reference numerals to FIGS. 7–13 are the numbers **401–471**.

For the description of the desk unit, FIGS. 3 and 4 are referred to. The desk unit is mounted on a board **301**. Tray **302**, having a plurality of fingers **303**, is adapted to hold a printing surface **304** which is shown only in FIG. 4. In FIGS. 3 and 4, the tray is shown in projecting position. Printing surface **304** is held to tray **302** by four clips **305**. The tray is slidably mounted on supports **306** by means of rigidly fixed bearing blocks **307**. In the projecting position shown, the tray is located above one or more projection lamps **308** which are focused by one or more lenses **309**. One such lamp may provide projection illumination for all five openings between fingers **303** of tray **302**, or each opening may have its own lamp. The lamps are usually located about 6 inches below the printing surface **304** which is clipped to the upper surface of tray **302** in clips **305** as shown in FIG. 4. The projection components are conventional and no further description is believed necessary here.

The sliding tray **302** is moved by arms **310** and **311**. Each of these arms is bent as shown and pivoted to a short extension **312** and **313**, respectively. The unpivoted ends of extensions **312** and **313** are connected to each other by a shaft **314**.

The tray is moved by motor **315** equipped with a magnetic brake **316**. In practice, a small 1/70 H.P., 25 r.p.m. motor is satisfactory. The magnetic brake provides instantaneous stopping of the motor at any desired position of motor shaft **317** the moment the power to motor **315** is turned off. Shaft **317** of motor **315** has an eccentric crank **318** attached to it. The end of this crank **318** is pivotally connected to one end of extension **313** of arm **311**, as shown. As shaft **317** rotates, tray **302** is caused to slide in mounting **306** forward and backward as the motor **315** rotates. The tray alternates between the projecting position shown in FIGS. 3 and 4 and the various printing positions, such as the one shown in FIG. 5. In the printing positions, fingers **303** of tray **302** are interdigitated with printing supports **319**. Printing elements **320** strike downwardly on the printing surface **304** located over the printing supports **319**. The printing elements strike with a reasonably strong force, e.g., about ten foot-pounds, in order to insure a clean impression on the printing surface.

It is preferable that printing supports **319** be slightly resilient to insure a clean impression in spite of slight irregularities in the printing dies or in the orientation in which they strike the printing surface. In the embodiment shown, these supports consist of a plurality of resilient fingers.

Referring to FIGS. 4 and 5, the method of printing may be clearly understood. Tray **302** slides beneath printing element **320**, as shown in FIG. 5, to reach the proper printing position. When the tray is so positioned, solenoid **337** is energized, pulling shaft **338** into the solenoid and swinging printing element **320** on shaft **335** so that its raised characters strike on the printing surface. The motion of printing element **320** is stopped by rod **314**. During the printing operation, spring **339** is loaded and solenoid **337** swings slightly on pivot **341**. After printing is completed, spring **339** returns element **320** to its normal non-printing position.

The sliding position of tray **302** can be sensed electrically. Referring to FIG. 6, a plurality of contacts **321** are mounted on the side of motor **315**. Contacts **321** are contacted by a brush **322** attached to motor shaft **317**. As shaft **317** rotates, brush **322** rotates correspondingly, and at each position of the shaft, brush **322** will touch a different one of contacts **321**. Since the position of shaft **317** also determines the position of the sliding tray, the different electrical signal sent for each different contact **321** touched by brush **322** will indicate the position of the tray. Tray **302** has a position for each frame, and an additional position for projecting.

The generation of the PC signals can be best understood from reference to FIG. 14 along with FIG. 6. The rotating arm **322** and contacts **321** shown in FIG. 6 are shown again in FIG. 14 and labeled "MOTOR CONTACT." Arm **317** rotates with the tray so that the particular contact **321** touched by the tip of arm **322** denotes the tray position. Each such tray position corresponds to a frame on the scoresheet. Frame indicator **500** has been discussed earlier and is used to keep track of the next frame in which a cumulative score is to be recorded. In the position illustrated in FIG. 14, this frame indicator is at "FRAME SIX," indicating that the next frame to have a cumulative score entered will be FRAME SIX. As illustrated, the NEXT FRAME+1 is FRAME SEVEN, and the NEXT FRAME+2 is FRAME EIGHT.

When the motor reaches the NEXT FRAME (FRAME SIX in the illustration), thus indicating that the NEXT FRAME (FRAME SIX) is in printing position, a pulse is generated which will be termed the NEXT FRAME pulse. This may be accomplished in many ways. One such method is illustrated schematically in FIG. 14, using battery **501**. With both the frame indicator **500** and the motor pointer **332** at FRAME SIX, a complete electrical circuit is formed with battery **501**, putting a voltage on contacts **502** to provide a pulse. A similar circuit can be

employed between the FRAME SIX contact on the frame indicator and the FRAME SEVEN contact on the motor to provide a NEXT FRAME+1 pulse. The same circuit between the FRAME SIX contact on the frame indicator and the FRAME EIGHT contact on the motor provides the NEXT FRAME+2 pulse. Each of these pulses designates the tray to be at the appropriate frame (NEXT FRAME, NEXT FRAME+1, etc.). The same circuitry may be used for all the remaining frames. These pulses will be used by the logic circuitry to generate the PC and PM pulses in a manner to be described later.

A complete cycle of operation of the desk unit includes both printing and projecting. Referring again to FIG. 3, after the printing portion of the cycle has been completed, the tray returns automatically to the position shown in FIG. 3 for projecting. When the tray reaches its maximum outward swing away from printing supports **319**, arm **313** hits switch **323** to stop the cycle. The score is then projected on screen **342** by illumination from lamp **308** passing through lenses **309** and **343** and reflector **344**. The printing and projecting cycle is repeated when the next printing signal is received by the motor. Such a signal provides exactly the required amount of power to motor **315** to move tray **302** to the next printing position.

In the embodiment shown in FIG. 4, scoresheet **304** has a paper cover **345** held apart from the scoresheet **304** during projection by hinged plate **346** and fixed plate **347**. Handle **348** is connected to plate **346** which is hinged at hinge **349**. Lifting this handle to the position shown in dotted lines allows for easy insertion of paper **345**. During the printing operation, paper **345** slides out from between plates **346** and **347** as tray **302** moves beneath printing element **320** as shown in FIG. 5. While tray **302** slides back to the projecting position in FIG. 4, paper **345** slides back between plates **346** and **347**. During the printing stroke, printing surface **304** is covered by paper sheet **345** so that the raised characters **336** cannot contact the printing surface directly, but strike instead upon paper cover sheet **345**. This prevents characters **336** from being covered with the coating removed from printing surface **304**.

The printing surface is made of translucent material, such as glass, polyester film, polyethylene, vinyl, or the like. It should be tear-resistant, and preferably heat-resistant so that it is not softened by heat from the projecting lamp. It should, therefore, have a softening point above about 60° C., unless the projection system is insulated from the printing surface or adequate cooling is available. A thickness of about 0.002–0.005 inch has been found satisfactory in practice. Since a great many scoresheets are required, this material should also be inexpensive.

The printing surface is coated on the side facing the printing element with a removable opaque coating, such as carbon, wax, or the like. This coating should be thin enough to be capable of being completely removed when struck by the printing element, leaving a translucent impression of the printed character. About 0.0005 to 0.001" of coating has been found adequate. The coating should be soft enough to be entirely removed by the printing element, but hard enough so that it is not removed in handling, otherwise dirty fingers result.

If desired, the printing surface may be joined to the paper cover at one edge **350**, as shown in FIG. 4. This allows complete scoresheet assemblies to be prefabricated, and eliminates the need for a separate cover paper to be inserted in the clip along with each scoresheet. The joined edge **350** is inserted in clips **305** on the edge of tray **302** facing resilient supports **319**. The non-joined edge of the printing surface is inserted in clips **305** on the edge of tray **302** away from resilient supports **319**. The non-joined edge of the paper cover is inserted between plates **346** and **347** as described above.

The printer counter units are used both as the printing element shown as block **20** in FIG. 4 and as the score accumulator discussed above. This unit is shown in detail in FIGS. 7–13. Referring to FIG. 7, the printing element is rotatably mounted on support **402** by shaft **432**. The raised characters to be printed are disposed on printing wheels, of which one (the spare-strike wheel **403**) is shown. A solenoid **404** is contained in shell **405**, and is used to cause printing element **401** to print. When an electric printing signal is received by solenoid **404**, shaft **406**, which is pivotally connected to printing element **401** at pivot **407**, is pulled toward solenoid **404** by the action of the solenoid. This motion causes printing element **401** to pivot on shaft **432**, extending spring **408**, so that the selected printing wheels strike printing surface **409**. In the position in which the spare-strike wheel **403** is shown in FIG. 7, called "neutral," neither the raised strike symbol **461** nor the raised spare symbol **462** can print; only a numerical (cumulative) score will print. This will be more fully explained later. When a spare or a strike (i.e., a "MARK") is scored, spare-strike printing wheel **403** is moved into printing position by pulley **410** connected to the spare-strike wheel **403** by belt **411**. Shell **405** is pivoted at point **412** to prevent its hindering the printing motion of element **401**.

After completion of the printing, shaft **406** is released from solenoid **404** and printing element **401** is returned to the neutral position by loaded spring **408**. If the next impression is to be made in a different location, tray **409** is moved so that the desired portion of the surface is located beneath the printing element, as was discussed above in the description of the desk unit. Preferably, the support **413** beneath printing surface **409** is slightly resilient to absorb the shock as printing element **401** strikes the printing surface.

The counting or score accumulator portion of printing element **401** may be best understood by reference to FIG. 8. Three score wheels **420**, **421**, and **422** are used to represent the hundreds digit, the tens digit, and the units digit, respectively, of the cumulative score. In this view it may be seen that when the spare-strike wheel **403** is in the neutral position illustrated, the raised numerals on score wheels **420**, **421**, and **422** extend radially beyond the spare and strike symbols in the lowermost, or printing, position. In this position, the score wheels, but not the spare-strike wheel, will strike the printing surface during the printing motion and so print.

The score wheels **420**, **421**, and **422** are rotated in such a manner that the cumulative score is always disposed lowermost (i.e., in printing position). This score is represented by the units digit disposed on wheel **422**, the tens digit on wheel **421**, and the hundreds digit on wheel **420**. To increase the cumulative score by a count of one, pinion gear **424**, which is linked to pinion gear **427** (which in turn is linked to wheel **422**) is rotated one position by a mechanical linkage to solenoid **423**. Such a linkage is well known in the art. Solenoid **423** is energized to cause this rotation by an electric signal. These signals come from OR-gate **101** in FIG. 1B. Each successive electric signal causes pinion gears **424** and **427** and units wheel **422** to rotate one position, increasing the number disposed lowermost on units wheel **422** by a count of one. Whenever this lowermost units number changes from nine to zero, tens wheel **421** is rotated one position by pinion gear **426** so that the number disposed lowermost on it is increased by a count of one; and in turn, when tens wheel **421** changes from nine to zero, pinion gear **425** causes hundreds wheel **420** to increase the number disposed lowermost on it by a count of one.

The pulses to solenoid **423** need not be single pulses; a chain of pulses may be used to increase the cumulative score indicated by the numbers disposed lowermost on score wheels **422**, **421**, and **420** by the number of pulses in the chain. For example, if the score wheels indicate a value of one hundred twenty-one (121), and a count of nine (9) is to be added, the signal to solenoid

423 would be a chain of nine pulses, and would energize the solenoid nine separate times. This rotates units wheel 422 nine places, from one to zero; as the zero moves into printing position on units wheel 422, tens wheel 421 rotates one place, from two to three. The hundreds wheel 420 would not rotate, because the tens wheel 421 did not pass from nine to zero. Thus, the new cumulative score of one hundred thirty (130) will be set for printing. A signal to printing solenoid 404 then causes the printing operation, as explained above.

As the bowling continues, the scores are added continually to the cumulative score shown by the counter in the manner described above, until the game is finished. When a spare or a strike is bowled, the procedure is varied slightly, because one or two of the next balls are counted twice in scoring; the frame score is therefore not completed until these later balls have been bowled. Instead of an immediate score, then, the symbol "/" (for a spare) or "X" (for a strike) is printed. These symbols are located on spare-strike printing wheel 403. Whenever these symbols are printed, score wheels 420, 421, and 422 cannot print (for reasons described later). In the case of a strike, the frame is completed as soon as two more balls have been bowled; for a spare, one more ball is necessary. After these balls have been bowled, the score for the frame is finally printed, next to the spare or strike symbol.

A very important feature of the printer-counter is the method by which the printing force is applied. To obtain a clear, undistorted impression of the raised characters, a fairly heavy striking force is required. With conventional printers, compromise has always been necessary between the desired striking force and the danger of damage to the shaft containing the printing wheels. Where this shaft is pivotably mounted in the sides of the printing element, all the striking force is transmitted to the ends of the shaft, and it has not been uncommon for it to bend, eventually, under the heavy continual force.

In FIG. 8A, it may be seen that shaft 428 is slidably mounted in slot 429. The shaft is normally held in the lowermost position in slot 429 by springs 428*a*. When the printing operation begins, printing element 401 is moved downwardly against the printing surface. When one of the printing wheels (such as counting wheel 422, shown in FIG. 8A) strikes the printing surface, shaft 428 is caused to slide upwardly in slot 429. This sliding motion is stopped by backing bar 440, shown in both FIG. 8 and FIG. 8A. This backing bar is rigidly fastened, as by casting to the sides of printing element 401 (as shown in FIG. 8). The numeral (on wheel 422) which lies diametrically opposite from the one about to be printed will strike against backing bar 440. Thus, the striking force, instead of being transmitted through the ends of shaft 428 as was the case with prior printing elements, is transmitted diametrally through the printing wheels themselves. When the element is not printing, springs 428*a* hold the wheels away from backing bar 440 to allow them free rotation during the counting or scoring process.

In prior printing elements, this large force exerted on the ends of shaft 428 required that the shaft have considerably greater diameter than the shaft used in this invention. In addition, bearings were frequently needed in the mounting. These features increased the driving power required to rotate the score wheels while decreasing the speed of their rotation. The shaft of this invention, not being subject to such heavy force, can be made long enough to accommodate a large number of wheels without any danger of its buckling under the printing stress. Diametral transmission of force through the wheels has been found to provide a very clear printed image of the desired character. Further description will be found below in connection with the spare-strike wheel.

The operation of spare-strike wheel 403 may best be seen from FIGS. 9, 10, and 11. In FIGS. 10 and 11, the spare-strike wheel 403 is shown in position ready to print one of its two symbols. When wheel 403 is in either of its printing positions, the strike symbol and the spare symbol extend radially beyond the raised numerals of score wheels 420, 421 and 422. In FIG. 10, the strike symbol 461 is shown in contact with printing surface 409. Its greater radial extension prevents score wheels 420, 421, and 422 from coming in contact with printing surface 409. In FIG. 11, the spare symbol 462 is shown in contact with printing surface 409; its greater radial extension has the same effect.

Referring now to FIG. 9, spare-strike wheel 403 is rotated from neutral position to the spare or strike position by the action of solenoids 470 and 471. When solenoid 470 is energized, shaft 432 and pulley 410 are rotated counterclockwise. Pulley 410 is connected to pulley 460 on spare-strike wheel 403 by belt 411. As shown in FIGS. 10 and 11, belt 411 is prevented from moving, relative to pulley 460, by a knife-like extension 446 on pulley 460. Belt 411 may be a spring, as illustrated, or other conventional elastic belt. Knife-like extension 446 is wedged between the coils of the spring and holds it securely to pulley 460. The counterclockwise rotation of pulley 410 thus causes a similar counterclockwise rotation of pulley 460, bringing the spare symbol 462 into printing position. Solenoid 470 used to bring the spare symbol into position, is energized by a pulse from AND-gate 214 shown in FIG. 1C. This pulse is generated when a MARK is to be printed, and that MARK is a S.

Conversely, when solenoid 471 is signalled, shaft 432 and pulley 410 are rotated clockwise, bringing strike symbol 461 into printing position. The rotation of shaft 432 and pulley 410 is again transmitted to spare-strike wheel 403 by belt 411. This solenoid is analyzed by a pulse from AND-gate 213 of FIG. 1C. The signal to one or the other of these solenoids is maintained during printing; then it is stopped and the energized solenoid 470 or 471 is held in its neutral position by leaf spring 433.

Summarizing with reference to FIGS. 10, 11, 12, and 13, a spare signal to solenoid 470 rotates pulley 460 counterclockwise, as shown in FIG. 11. Spare symbol 462 is then in printing position. A strike symbol to solenoid 471, on the other hand, rotates pulley 460 clockwise, as shown in FIG. 10. Strike symbol 461 is then in printing position. After the desired symbol has been printed, the energized solenoid 470 or 471 is released, allowing extended leaf spring 433 to return to its normal position, thereby holding spare-strike wheel 403 in the neutral position shown in FIG. 12. Because of the force with which the spare-strike wheel 403 strikes the printing surface 409, it is advantageous for production of a clear image that this force be transmitted through a diameter of printing wheel 403; this also minimizes strain on the wheel. For this purpose, printing wheel 403 has raised portions 451 and 452 located diametrically opposite from the strike and spare symbols 461 and 462, respectively. The printing force is then transmitted from abutment 440 through a diameter of printing wheel 403 extending from raised portion 451 or 452 to symbol 461 or 462, respectively (depending upon whether a strike or a spare is to be printed). This diametral transmission of force produces a very clear and distinct image of the spare and strike symbols on the printing surface 409.

Stops 443 and 444 are used to locate the spare and strike symbols for precise printing. A strike is printed when stop 443 of printing wheel 403 hits against 440 (shown in FIG. 10); a spare is printed when stop 444 of printing wheel 403 hits against abutment 455.

At the close of the game, after the final score has been printed through the action of printing element 401, score wheels 420, 421, and 422 must be reset to zero for the

next game. This is accomplished by a conventional re-setting mechanism contained in the counting portion of printing element **401** shown in FIG. 8. Such mechanisms are well known in the art, and therefore no further description is believed necessary here. Re-setting may be accomplished manually, or by an electric signal, as desired.

Returning to the logic circuitry shown in FIG. 1, a signal must be generated to start the motor of the desk unit, described above, into action to that the proper frame position will be moved beneath the printer-counters for printing.

Such MOTOR START signal is given at the end of each frame—in some instances it will also be given after a B1. The B1 signal needed is instantaneous, not continuous. Such a B1 signal is obtained by inverting the B2 level from flip-flop **1**, which provides such a B1 ($\overline{B2}$) pulse as it changes from the B2 to the B1 condition when B1 hits the backstop. This inversion is carried out by inverter **25**. AND-gate **201** has one input for B1 ($\overline{B2}$) from inverter **25** and the other input from OR-gate **200** which provides a positive, alerting output level when a SM or a 2STM condition exists (these being the conditions which require a recording operation on a B1). A SM condition indicates that the score must be recorded for the frame immediately preceding the current frame; with a 2STM condition, the score must be recorded for the next previous one (second before the current one). The output pulse from AND-gate **201** is passed through OR-gate **202** which in turn is connected to the START switch of motor **315** shown in FIG. 3. OR-gate **202** has another input connected from the output of AND-gate **203**. AND-gate **203** in turn has one input connected to inverter **24** which receives the B1 signal from flip-flop **1** to provide the $\overline{B1}$ pulse. The inverted B1 signal ($\overline{B1}$) indicates that the flip-flop has just changed from B1 to B2—that is, the second ball has just struck the backstop. The other input to AND-gate **203** is the ST pulse from AND-gate **28**, indicating that a ST has been rolled. The consequence of this arrangement is that OR-gate **202** will provide a MOTOR START pulse each time a B2, a ST, or a B1 with a previous S (SM), or two previous ST's (2STM). Motor **315** (FIG. 3) is therefore started under any of these conditions.

Once the motor has been started, it must be stopped precisely where either a MARK or a COUNT is to be recorded. Signals are generated by the switches shown in FIG. 14 and discussed above when the scoresheet reaches the position next following the position where a COUNT (not a MARK) was last recorded, when the scoresheet reaches the frame following that one, and also for the next succeeding frame. The NEXT FRAME signal (indicating that the scoresheet is positioned in the frame immediately following the one where a COUNT was last recorded) appears at the input of one-shot **204**; the NEXT FRAME+1 signal appears at the input of one-shot **205**; and the NEXT FRAME+2 signal appears at the input of one-shot **206**. For example, if the bowler has had two previous strikes, and then rolls a third ST, a MARK for the ST should be printed in the NEXT FRAME+2 from the last score, and a cumulative score (through the first of the three strikes) in the NEXT FRAME. The PC and PM signals generated from these "NEXT FRAME" signals, used for stopping the motor for proper positioning of the scoresheet to receive the scores and marks, are generated by the equipment next described.

The PM (PRINT MARK) signal is generated by AND-gates **207**, **208**, **209**, **210** and **211**, and OR-gate **212**. Each AND-gate generates a pulse upon the fulfillment of a specific set of conditions requiring the printing of a MARK. AND-gate **207** will provide an output pulse when both SM and STM conditions exist. This will occur only when a S has been immediately followed by a ST (so that the STM has been energized before the SM has been deenergized), or when a ST has been immediately followed by a S (so that the SM has been energized before the STM has been deenergized). Under either of these conditions, a mark (either ST or S) should be recorded in the second frame past the frame where a COUNT was last recorded (NEXT FRAME+1). Hence an output from one-shot **205** (NEXT FRAME+1) is connected to an input of AND-gate **207**; an output pulse from this AND-gate then provides a PM signal such that a MARK will be printed in the NEXT FRAME+1 to record one of the above conditions.

When a player rolls his second ST, a successive MARK should be recorded (but no COUNT as yet). AND-gate **125** has one input from AND-gate **28** denoting a ST, and the other input from the first-strike memory **141** denoting the STM condition. Since a ST pulse on a first ST is always emitted before the first-strike memory **141** is energized, this positive alerting level from the first strike memory (the STM level) must be the result of the previous ST. The ST pulse at one input of AND-gate **125** coinciding with the STM level must be a pulse denoting a second ST. Therefore the output pulse from AND-gate **125** denotes a second ST.

When three consecutive ST's have been rolled, the PM signal for the third ST comes from AND-gate **208**. This AND-gate has one input level from one-shot **53** which indicates that a ST has just been rolled. Another input level comes from the second-strike memory **142** which, when positive, indicates activation of the second-strike memory. The third input comes from AND-gate **125** through one-shot **124** and inverter **123**. When this inverted level is positive, it indicates that the ST was not a second ST because AND-gate **125** and one-shot **124** had no positive output as they would on a second ST. Hence the positive level from the second ST memory must have been the result of a third ST (instead of having been just energized by a second ST). As soon as the frame indicator reaches the NEXT FRAME+2 position, the signal from one-shot **206** passes through alerted AND-gate **208** to provide the PM pulse, and the ST symbol is for the third ST recorded in that position.

AND-gate **209** provides the PM signal to print the ST symbol at NEXT FRAME+1 on the second ST. AND-gate **209** receives a pulse from one-shot **205** (denoting second ST) on the NEXT FRAME+1; therefore it generates a PM pulse to print the ST symbol in the NEXT FRAME+1.

AND-gate **210** generates a PM to print the S symbol in the NEXT FRAME when a S has been rolled. AND-gate **210** has an input from the SM (indicating either that a S has just been rolled, or that the previous roll was a S). However, the additional B2 input assures that the S was in fact just rolled. (Had the S been the previous roll, then the present roll would be a B1.) The $\overline{STM}$ input assures that the previous roll was not a ST (if it were, the signal would come from AND-gate **207**, as described above). The last input to AND-gate **210** comes from one-shot **204**. A signal is generated from one-shot **204** and passed through AND-gate **210** as the frame advances to the NEXT FRAME, where the S symbol is to be printed.

AND-gate **211** generates a PM signal to print the ST symbol following a first ST (no carry-over ST's or S). Inputs showing $\overline{STM}$ and $\overline{SM}$ levels indicate the lack of any pre-existing ST or S. The ST input indicates the rolling of the current strike. The input pulse from one-shot **204** provides a pulse at the NEXT FRAME which is passed through alerted AND-gate **211** to OR-gate **212** in order that a ST symbol may be printed at the NEXT FRAME under the single ST condition.

All of the individual PM signals from the other AND-gates **207**, **208**, **209** and **210**, are also passed through OR-gate **212**, whose output becomes the collective PM signal. This signal passes to AND-gates **213** and **214**. AND-gate **213** also has a continuing ST input from one-

shot **53**. When it receives a PM pulse immediately following the rolling of a ST, AND-gate will provide an output pulse to the ST solenoid discussed above so that the MARK printed will be a ST. Conversely, AND-gate **214** has a SM input level indicating the ball just rolled required a S MARK to be printed. The ST assures that the SM was not left over from the previous roll; otherwise the PM signal might be the result of a ST following a previous S. The output signal from AND-gate **214** is passed to the S solenoid discussed above to cause a S symbol to be recorded.

For printing a COUNT, AND-gates **216**, **217**, and **218** are used. A COUNT is normally printed each time it is ascertainable—after a **B2**, or after a **B1** following a S or two ST's. However, there are also certain conditions under which printing a COUNT should be inhibited and only a MARK should be printed. These occur after a first ST (and no previous S), after a S (and no previous ST), or after a second ST. The pulse from AND-gate **218** causes the COUNT to be printed. When printing is withheld under one of the above conditions, one alerting input to AND-gate **218** will be missing. One such input to AND-gate **218** comes from one-shot **124** through inverter **123**. A positive input level from one-shot **124** is the result of a second ST, for the one-shot is triggered from AND-gate **125**. When this level from one-shot **124** is passed through inverter **123**, however, it becomes negative to remove an alerting level from AND-gate **218** and prevents a COUNT from being printed in the NEXT FRAME on the occurrence of a second ST.

AND-gate **216** inhibits printing a COUNT upon occurrence of a first ST. The ST signal provides one alerting input to AND-gate **216**. On the first ST, the STM is energized by the ST signal. When the PC pulse from one-shot **204** is received at AND-gate **218**, the necessary STM level will be present. A positive output level from AND-gate **216** through inverter **220** removes an alerting level from AND-gate **218** to prevent a COUNT being recorded. AND-gate **216** also has an input level indicating $\overline{SM}$. On a first ST following a S, a COUNT must be printed (for the S). This input from the spare memory to AND-gate **216** assures that the printing of the COUNT will not be inhibited if the ST followed a spare.

AND-gate **217** prevents the COUNT from being printed following a S. The **B2** and SM inputs together indicate that a S has been rolled (and was not the product of a previous roll which would yield a **B1** signal). The STM input to AND-gate **217** shows that the S did not follow a previous ST (because if it did, a printed COUNT would be required). Therefore the positive output level from AND-gate **217** into inverter **221** removes an alerting level from AND-gate **218** to prevent printing a COUNT for a S not preceded by a ST. If not inhibited in one of the ways discussed above, the PC signal on the NEXT FRAME passes from one-shot **204** through AND-gate **218** to various parts of the system mentioned earlier in the description.

In order to stop the motor and allow the printing of a COUNT or MARK, each PM or PC pulse passing through OR-gate **212** or AND-gate **218**, respectively, is transmitted to OR-gate **222**. The pulse emerging from OR-gate **222** is used for stopping the motor for printing. The pulse is then passed to one-shot **223**, which transmits a pulse to the magnetic brake **316** shown in FIG. 3 to stop the motor **318** long enough for printing. The pulse from OR-gate **222** is also passed through delay **224** (to insure that the tray and motor are totally stopped before printing); the pulse from delay **224** at the end of the delay period passes to the print solenoid **404** shown in FIG. 7. If a S or ST (a MARK) is to be printed, the appropriate solenoid **70** or **71** (FIG. 13) will already be actuated by a pulse from one of AND-gates **213** or **214**. If a COUNT is to be printed, the actuation of the print solenoid will cause the COUNT presently in the counter to be printed, as has been fully explained above.

It is understood that while printing of a score has been used in the specific embodiment shown, where a printed record is not required, other recording means may be used, such as a counter, magnetic tape, or the like. Moreover, other types of printers may be employed without departing from the invention.

The apparatus of the invention may be used for more than one player in the same game. Certain portions of the apparatus, of course, must be duplicated for each player; such portions include all the memories and the frame indicator. Conventional switching systems are used to disconnect from the system the frame indicator and the memories used for each player and to connect the apparatus for the next player in its place. Switching takes place after each player has bowled one frame, in response to a signal from OR-gate **225**.

For changing players, a signal is transmitted from OR-gate **203** upon completion of a frame—on a **B2** ($\overline{B1}$) or a ST. The output of OR-gate **203** passes through AND-gate **226** and OR-gate **225** into delay **227** which delays the changing of the players' subsystems until all calculations and recording has been completed for the current player's frame. The only time players do not change following a **B2** occurs under certain conditions in the tenth frame, where an extra ball or two may need to be rolled to complete the scoring for a S or an ST; the PLAYER setting should not advance until the required scores have been completed.

To inhibit the player advance during FRAME TEN in order to allow a player to roll extra bonus balls where necessary to complete his score, AND-gates **228**, **229**, and **230**, along with OR-gate **231** and inverter **232** are employed. AND-gate **226** is normally alerted except in FRAME TEN to advance the player at the end of each frame, as discussed above, by a combination of a $\overline{\text{FRAME TEN}}$ level and a level from inverter **232**. The $\overline{\text{FRAME TEN}}$ pulse is generated by the frame indicator except where the cumulative score has been recorded in the ninth frame so that the indicator reads FRAME TEN. When this exception exists, then the player advance is inhibited.

However, there are conditions where a player is in fact in FRAME TEN but the frame indicator does not so read. These conditions will occur where the score has not yet been recorded in FRAME NINE, or in one instance has not been in either FRAME EIGHT or in FRAME NINE, i.e., when the player has a ST or a S in FRAME NINE or ST's in both FRAMES EIGHT and NINE. If the player rolled a ST or a S in FRAME NINE, the frame indicator will show FRAME NINE even though the player is playing in FRAME TEN. If a player has rolled ST's in both FRAMES EIGHT and NINE, the frame indicator will show FRAME EIGHT even though the player is actually playing in FRAME TEN. To account for these conditions, and to inhibit the player advance when they occur, AND-gates **228**, **229**, and **230** along with OR-gate **231** and inverter **232** are used. If the first-strike memory **141** has a positive level (STM), and the frame indicator reads FRAME NINE, AND-gate **228** will have a positive output level, which is passed through OR-gate **231** and inverter **232** to inhibit AND-gate **226** and thus block the player advance. This inhibition of player advance occurs because, although the frame indicator reads FRAME NINE, the player was actually in FRAME TEN (the ST in FRAME NINE prevented the recording of the cumulative score in that frame).

Similarly, AND-gate **229** operates to inhibit the player advance where the frame indicator reads FRAME NINE and a SM or a 2STM condition exists. These conditions show that the player is in FRAME TEN, but no score was recorded in FRAME NINE because of a S in FRAME NINE or a ST in both FRAMES NINE and TEN. In the same manner, AND-gate **230** inhibits the player advance when the player is in FRAME TEN, but

the frame indicator reads FRAME EIGHT because of ST's in both FRAMES EIGHT and NINE.

As soon as FRAME TEN is completed (and the score recorded therefor), the frame indicator will advance to FRAME ELEVEN, and OR-gate **225** will receive an input pulse to advance the player through delay **227**.

Summarizing the operation of the entire apparatus of the invention, consider the situation wherein there is a previous cumulative score of two (2); the player now knocks down a total of one pin on the next frame (having bowled both his balls). His new score, as a result of this frame giving him one additional point, is three (3). A one-pulse electric signal is automatically transmitted from the pin-sensing apparatus to the logic circuitry. This one pulse is interpreted by the logic, which in turn sends a one-pulse electric signal from OR-gate **101** (FIG. 1B) to solenoid **423** (FIG. 8). This signal moves units wheel **422** in FIG. 8 (which was previously set at two) one place, thus setting it to three. This action takes place virtually instantaneously. Immediately thereafter, the logic circuitry sends a second electric signal from delay **224** (FIG. 1C) to solenoid **404** (FIG. 7) which causes printing element **101** in FIG. 7 (with the spare-strike wheel **403** in neutral position) to print the number "3" which has been set in the score wheels. The "PC" pulse causing the print advances frame indicator **500** (FIG. 14). The printing surface **409** (FIG. 7) is automatically advanced by a MOTOR START pulse from OR-gate **202** (FIG. 1C). It stops at the next frame, as directed by the frame indicator.

Now suppose that on the next two balls the player bowls a spare (all ten pins knocked down after the second ball). A continuous pulse is sent from AND-gate **214** (FIG. 1C) to solenoid **470** (FIG. 13), placing spare symbol **462** (FIG. 12) in printing position; immediately thereafter, an electric signal is sent to solenoid **404** (FIG. 7) and the spare symbol is printed. The pulse to solenoid **470** then ceases and spare-strike wheel **403** (FIG. 7) is returned to the neutral position by the action of leaf spring **433** (FIG. 9). Printer-counter **404** (FIG. 7) is then returned to the non-printing position; this time, however, the frame indicator **500** (FIG. 14) is not advanced, because a spare permits the bowler one additional score (the next ball is counted twice, once for this spare frame and once for its own frame). However, the start-count signal into delay **11** (FIG. 1A) causes the PINFALL of ten for the spare to be added to the counter **401** (FIG. 7) as discussed earlier, through OR-gate **101** (FIG. 1B).

Suppose further that the next ball bowled (in the following frame from the spare frame) resulted in a knockdown of seven more pins. The additional seven points are now added to the counter **401** (FIG. 7) from OR-gate **101** (FIG. 1B), completing the cumulative score of twenty for the frame having the spare. Solenoid **404** (FIG. 7) then receives a print signal from delay **224** (FIG. 1C), and causes the score "20" to print, adjacent to the "/" symbol in the spare frame, as shown in FIG. 9. The frame indicator again advances, and printing surface **409** (FIG. 7) will next stop at the following frame.

The second ball in the current frame is now bowled (the first ball having knocked down seven pins, as discussed above), and knocks down two more pins. The logic circuitry sends nine pulses to counter **401** (FIG. 7)—the PINFALL after B2 being nine—increasing its setting to twenty-nine. A print signal to solenoid **404** (FIG. 7) follows, and the cumulative score "29" is printed in the new frame. Printer-counter **401** (FIG. 7) is now returned to the non-printing position and the frame indicator is again advanced to the next frame.

Note that the score of seven for the first ball in the frame immediately following the spare frame was added twice. In computing bowling scores, one extra score is earned by a spare; however, instead of bowling an extra ball to determine this score, the first ball of the following frame is used to determine the count. For this reason, the first ball of the following frame (the one following the spare frame) is counted twice—once for the spare bonus and a second time for the frame in which it was actually bowled. Similarly, a strike earns two extra scores, so that both balls in the following frame count twice, once for the strike bonus and once again for the frame in which they are bowled. Should the first bonus ball be a strike, also, the first ball of the next succeeding frame would be counted for the bonus points on the first strike.

Although the above example is only one specific sequence, it will be found that all possible bowling sequences are handled by the apparatus described. Furthermore, although printing is referred to, many other forms of recording the score may, if desired, be substituted. It will be equally apparent that many modifications may be made in the details of the circuitry which may result in changes or improvements upon this invention which are well within its spirit and scope. Therefore the only limitations to be placed on that scope are those expressed in the claims which follow.

What is claimed is:

1. Apparatus for automatically computing bowling results and for providing a cumulative running record of each game as it is played, said results being computed from the output of a standing pin sensing device which provides a plurality of electric pulses on several lines, the sum of which pulses represents the standing pin count, which comprises:

(a) a means for combining said plurality of electric pulses on said several lines into a single rapid series of electric pulses representing the standing pin count, said combining means operating in a continuous electronic process, directly in response to the receipt of said plurality of electric pulses, upon said electric pulses without mechanically making or breaking any electrical circuit connections;

(b) a first input means for receiving a signal indicating that a ball has been rolled;

(c) a second input means for receiving a signal indicating that a player has committed a foul;

(d) an electronic switching means including a counting means for accumulating the pulses in said single rapid series of pulses, said switching means further including means responsive to the signals at said first and second input means upon the rolling of a ball and to the nonoccurrence of a foul, respectively, and responsive to said counting means for deriving from said accumulated pulses a number of pulses representing the fallen pin count and means for computing from said derived pulses a correct running cumulative score for the player rolling said ball for each frame including the recognition of spares and strikes and the inclusion of the bonus points resulting therefrom; and

(e) means for recording the results of each frame, said results including the cumulative score at each frame, and an indication of spares and strikes at the frame where same occurred, said recording means operating in response to signals from said electronic switching means.

2. The apparatus of claim **1** further characterized by said combining means including a plurality of electronic delay elements each connected to one of said several lines and a summing element having input terminals connected to the output terminals of each of said delay elements.

3. The apparatus of claim **1** further characterized by said electronic switching means including:

(1) a clock pulse generator for the conversion of said rapid series of pulses representing a standing pin count to a second series of pulses representing the pinfall; and

(2) a plurality of logic elements for the detection of spare and strike conditions and the determination of the magnitude of the bonus addition count to be

added to the cumulative score when spares and strikes are rolled.

4. The apparatus of claim 3 further characterized by said counting means including a plurality of flip-flops for storing the first ball pinfall and making same available for the computation of the score in the event a foul occurs on the second ball.

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