BOUNCE SUPPRESSING ARRANGEMENT FOR ELECTRICAL CONTACTS

Filed Sept. 26, 1962

FIG.1.

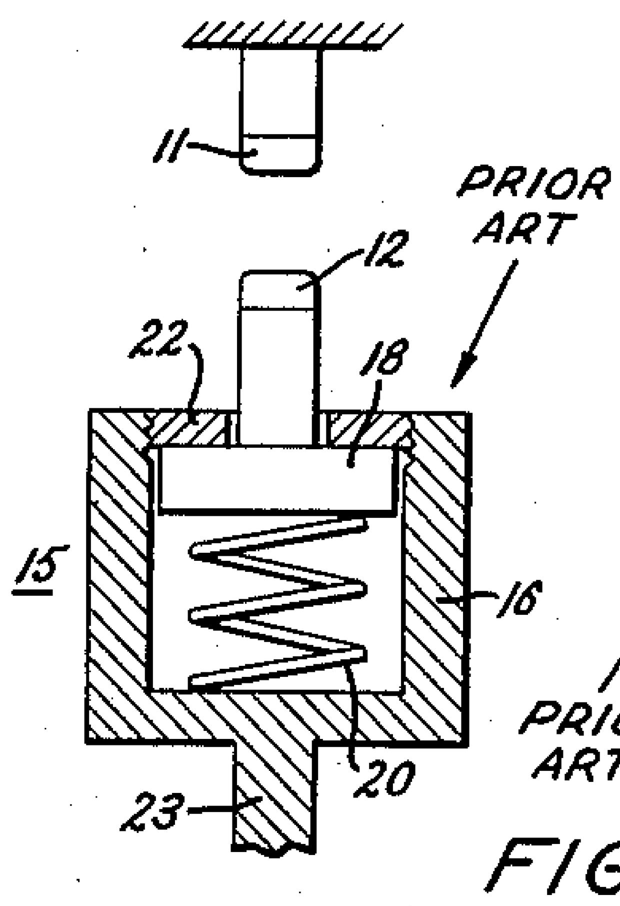


FIG.2.

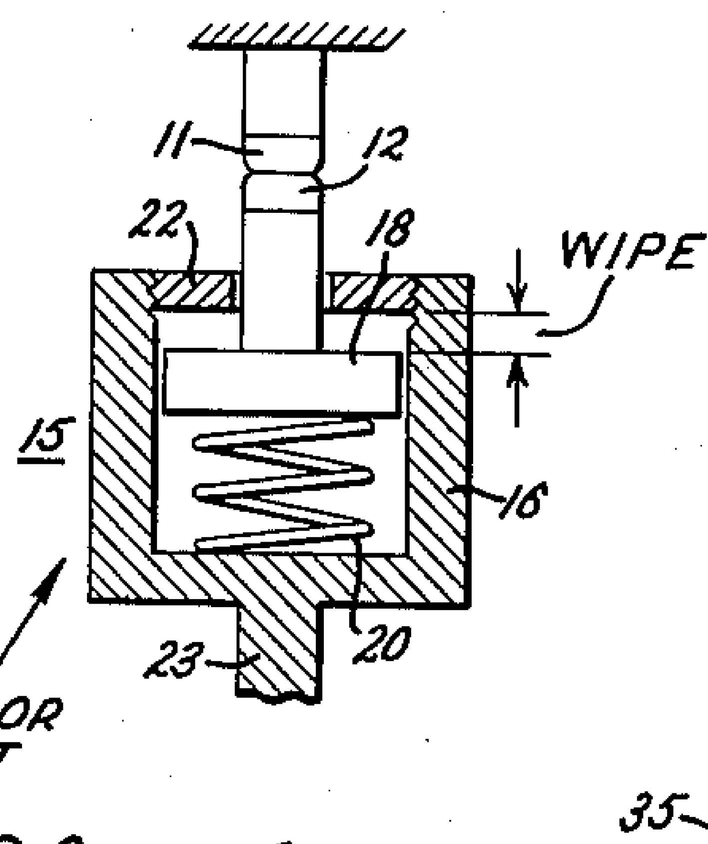


FIG.4.

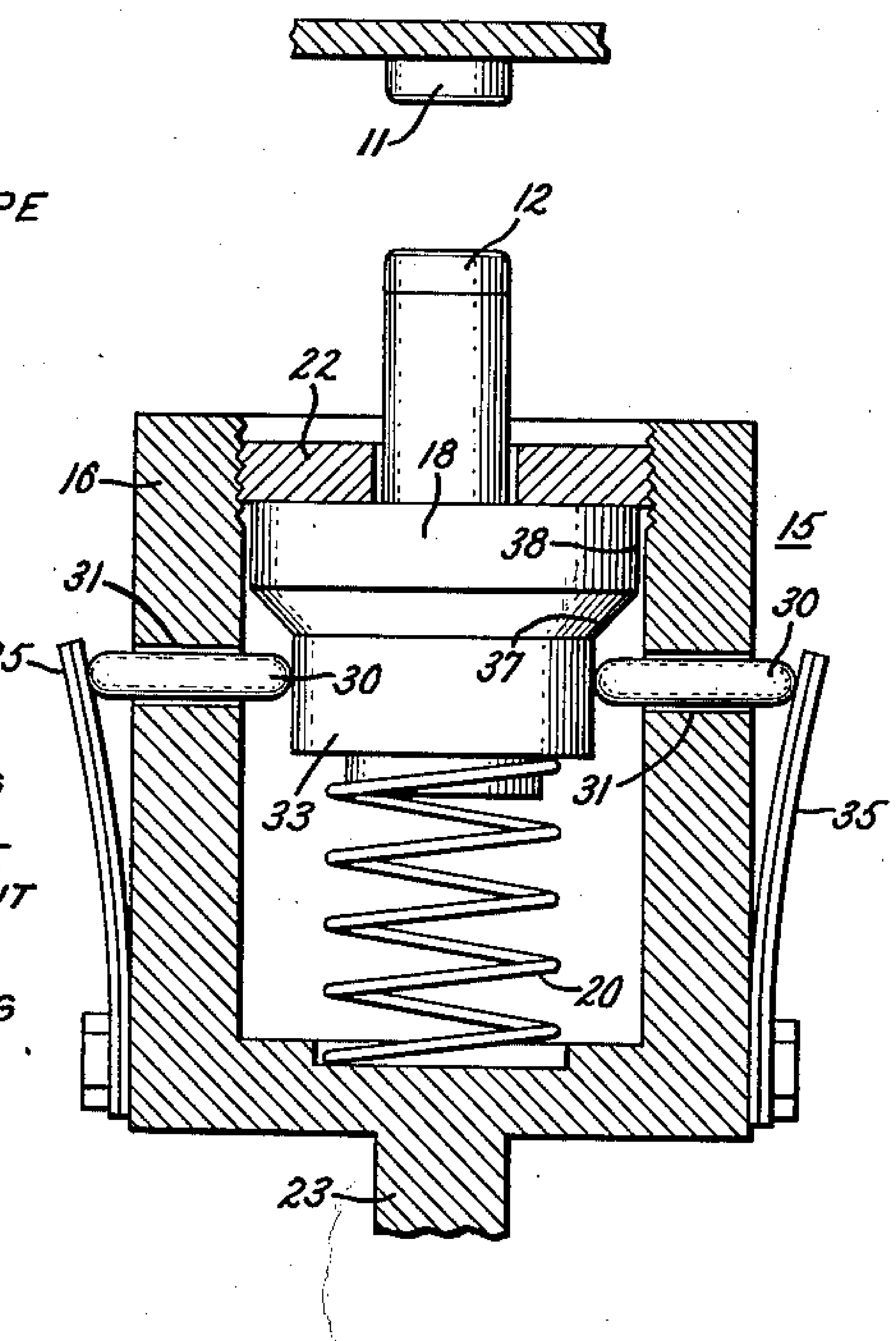


FIG.3.

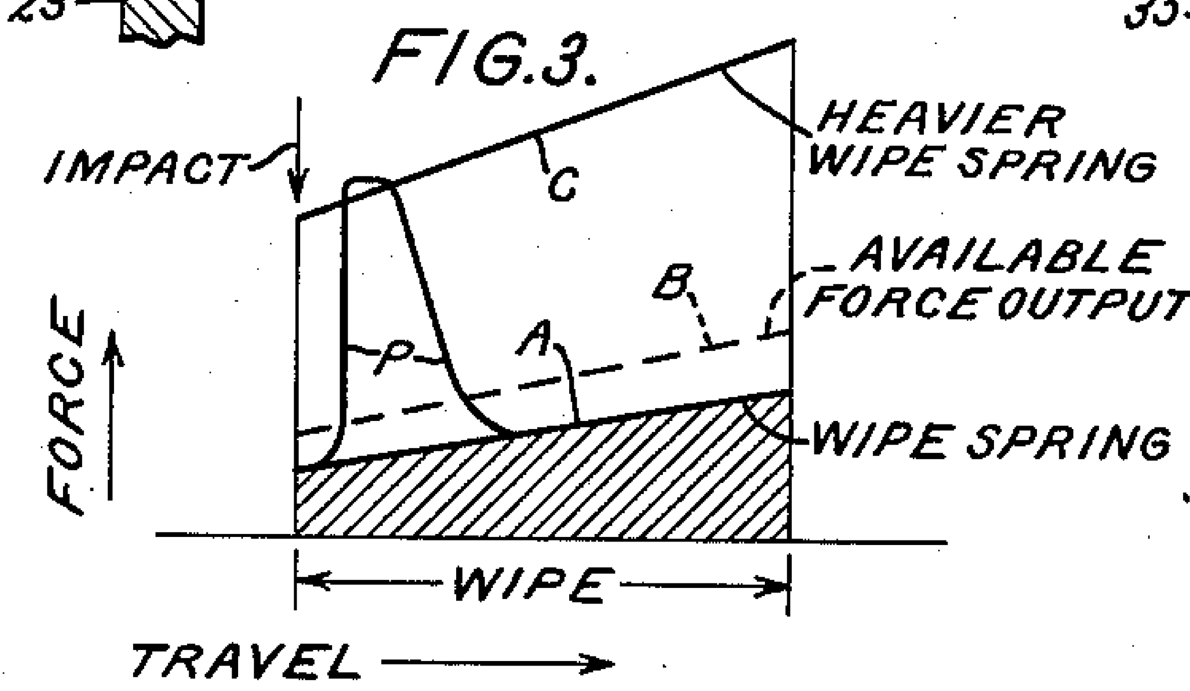


FIG.6.

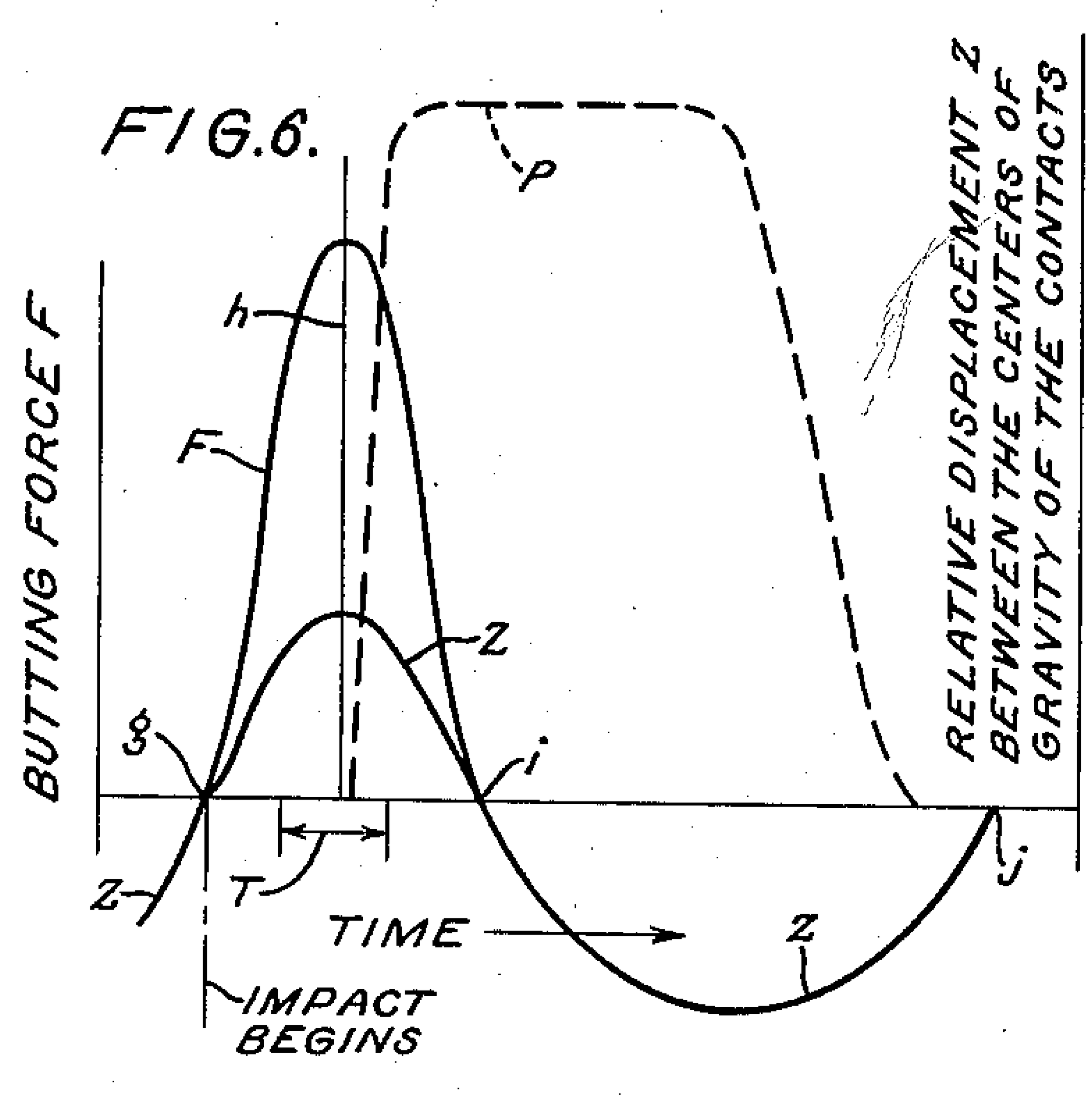


FIG.5.

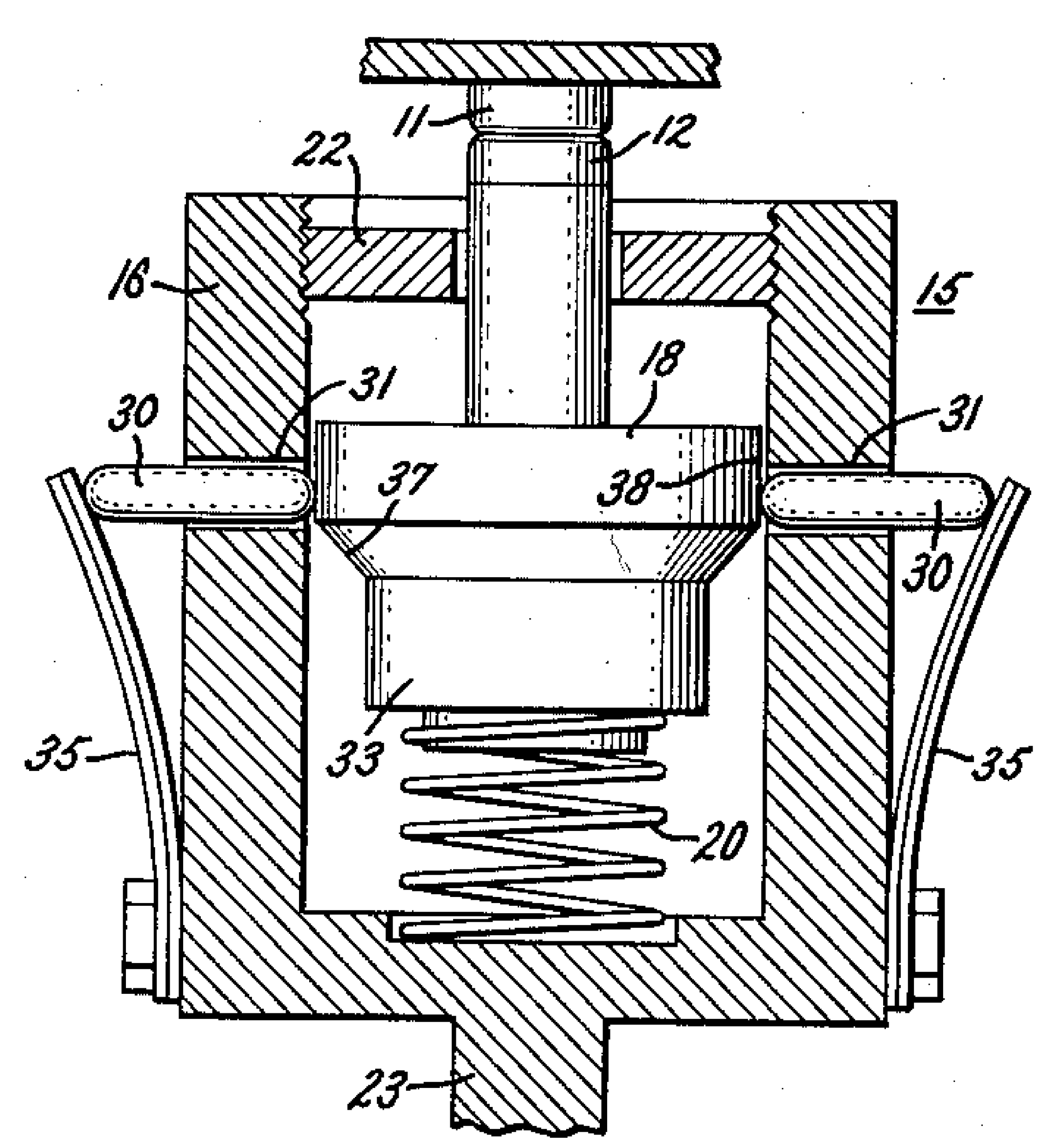


FIG.7.

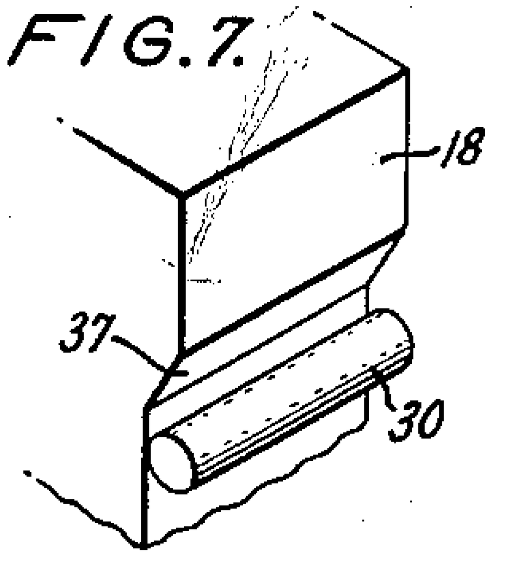
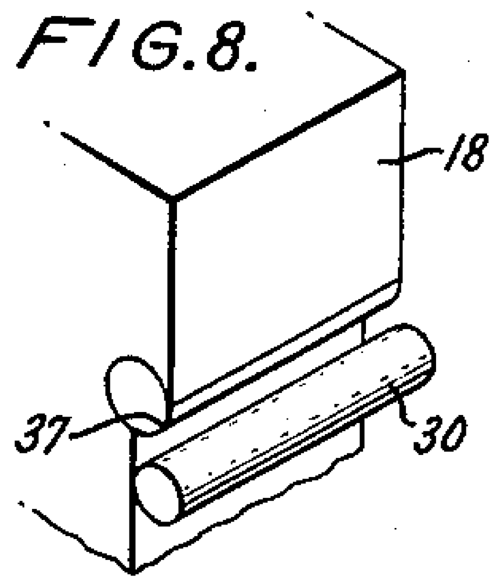


FIG.8.



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BOUNCE SUPPRESSING ARRANGEMENT FOR ELECTRICAL CONTACTS

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This invention relates to an arrangement for and a method for suppressing the tendency of electrical contacts to bounce apart when one contact strikes the other at the end of a high velocity contact-closing stroke.

When the movable contact of an electrical circuit interrupter strikes its mating stationary contact at the end of a high velocity contact-closing stroke, there is a tendency for the contacts to bounce, first apart and then together in a repetitive fashion. If the contacts are closed on an energized circuit, there will be an arc established between them each time they separate during the bounce period. As is well known, such arcs can produce objectionable contact erosion and can also produce objectionable contact welding.

Numerous schemes have been proposed to suppress contact bounce and thus eliminate the above-described erosion and welding problems, but these schemes have generally been subject to serious disadvantages. For example, many of the proposed schemes have not been very effective; many have been quite complicated; and many have necessitated larger and more powerful operating devices for closing the contacts.

An object of the present invention is to provide a simple and compact bounce-suppressing arrangement that can perform its intended function without necessitating any substantial increases in the size of the contact-closing device over that otherwise required.

Another object is to provide bounce-suppressing means that operates by applying a transient force pulse to the movable contact immediately after it strikes the stationary contact.

Still another object is to apply this transient force pulse at such a time that a pulse of relatively low amplitude can be utilized to provide effective bounce-suppression.

In carrying out our invention in one form, we provide an electric circuit interrupter comprising a movable contact and a generally stationary contact. Operating forces are transmitted to the movable contact by means of a mechanism comprising a driven part coupled to the movable contact and a driving part coupled to the driven part. The driving part is movable in one direction to supply contact-closing force to the driven part and is movable in an opposite direction to supply contact-opening force to the driven part. One of said parts is slidably mounted on the other of said parts, and this allows the driving part to move through continued contact-closing travel, referred to hereinafter as wipe travel, after the contacts engage during a contact-closing operation. Operatively connected between the driving and driven parts is spring means that is stressed by said wipe travel and that provides a first force urging said movable contact into engagement with said stationary contact during said wipe travel. Bounce-suppressing means associated with the driving and driven parts provides an additional force that urges said contacts together and supplements said first force during a portion of the wipe travel closely following initial impact between the contacts. This additional force is in the form of a transient force pulse that decays to a relatively low value before said wipe travel is terminated.

In a preferred form of our invention, the transient force pulse is applied to the movable contact after a time delay following initial impact. The time delay is sufficiently short, however, to permit the force pulse to be applied well ahead of the instant that the contacts, in the absence of the force pulse, would have initially bounced out of engagement following said initial impact. The force pulse is caused to persist substantially past this latter instant.

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For a better understanding of our invention, reference may be had to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a cross sectional view of a prior art contact wipe device for controlling the motion of the movable contact of a circuit interrupter. The parts are shown in a contact-open position.

FIG. 2 is a cross sectional view of the device shown in FIG. 1 except the parts are shown in the contact-closed position.

FIG. 3 is a graphical representation of certain force-travel relationships.

FIG. 4 is a cross-sectional view of a contact-wipe device embodying one form of our invention. The parts are shown in a contact-open position.

FIG. 5 is a cross-sectional view of the device of FIG. 4 except the parts are shown in a contact-closed position.

FIG. 6 is a graphical representation of certain force and displacement relationships associated with bounce-suppression.

FIG. 7 illustrates a modified form of the invention.

FIG. 8 illustrates another modified form of the invention.

Referring now to FIG. 1, there is shown an electric circuit interrupter comprising a stationary contact **11** and a movable contact **12** shown in their open or fully-separated position. This circuit interrupter can be closed by moving the contact **12** in an upward direction into engagement with the stationary contact **11**. FIG. 2 shows the parts in their closed position. Opening of the circuit interrupter is effected by moving the contact **12** in a downward direction from its closed position of FIG. 2 into its open position of FIG. 1. It should be understood that these opening and closing operations are performed at a relatively high velocity.

The contacts of the interrupter shown in FIG. 1 are of the butt-type. When contacts of this type are used, it is customary to provide some means for providing contact wipe and for creating and maintaining a hold-closed force on the contacts despite contact-wear. A conventional wipe device for performing these functions is shown at **15**. This wipe device **15** comprises a driving part **16** and a driven part **18**. The driving part **16** is in the form of a cylindrical carriage, and the driven part **18** is in the form of a piston slidably mounted within the bore of the cylindrical carriage. Also disposed within the bore of the carriage **16** is a precompressed wipe spring **20** which urges the piston **18** upwardly into engagement with an annular stop **22** carried by the carriage **16**. A suitable closing device or operator (not shown) is coupled to the carriage **16** through a rod **23** to provide the force for driving the carriage through its closing stroke.

When the carriage **16** is driven in the upward or closing direction from its position of FIG. 1, the piston **18** also moves upwardly, thereby carrying the movable contact **12** toward the stationary contact **11**. During this closing stroke, the precompressed spring **20** holds the piston **18** in engagement with the annnlar stop **22** until the movable contact **12** engages the stationary contact **11**. This engagement between the contacts terminates upward movement of the contact **12** and piston **18**; but the carriage **16** continues moving upwardly, further compressing the spring **20** and separating the stop **22** from the piston **18** until motion of the carriage **16** is finally terminated. This upward travel of the carriage **16** that occurs after the contacts engage is referred to hereinafter as "wipe" or "wipe travel." This wipe travel serves to provide a force that holds contacts in engagement after closing despite limited wear of the contacts that might have previously occurred. Thus, even if the contacts engage at a slightly later point in the closing stroke because of such contact wear, there will still be some wipe travel after contact engagement; and this will act to make available the force stored in the spring 20 and any additional force produced by further compression of the spring 20 during wipe.

When the movable contact 12 strikes the stationary contact 11 during the above-described high velocity closing stroke, there is a tendency for the contacts to bounce, first apart and then together, in a repetitive fashion. This tendency becomes more pronounced as the impact velocity is increased and as the mass of the moving contact is increased. One way of reducing this tendency is to increase the amount of force that the spring 20 exerts on the moving contact.

This is disadvantageous, however, because increasing the spring force will markedly increase the closing energy requirements of the system and thus require a larger closing device. In this connection, the energy stored in a wipe spring such as 20 is frequently a large proportion of the total closing energy so that any increase in the wipe spring force results in a similar increase in the closing energy requirements.

To illustrate some of the above points, the graphical representation of FIG. 3 has been provided. The cross-hatched area underneath the curve A, designated "wipe spring," represents the energy required to compress the wipe spring 20 during contact-wipe. Typically, the closing device will have an available force output only slightly exceeding the force required to compress the wipe spring, as depicted by the dotted line curve B. Assume now that an effort is made to suppress contact-bounce by using a heavier wipe spring 20 requiring force such as depicted in curve C for its compression. This required force exceeds that available from the closing device, and thus the heavier wipe spring would necessitate a larger closing device for performing the closing operation.

An object of our invention is to effectively suppress contact-bounce by means which can be included without necessitating a significantly larger closing device than was needed in the absence of the bounce-suppressing means. This object is achieved by providing bounce-suppressing means that applies a transient force pulse to the driven member 18 during a crucial period, soon to be explained, after initial impact occurs between the contacts 12 and 11. This bounce-suppressing means is illustrated in FIGS. 4 and 5, where a wipe device corresponding to the wipe device 15 of FIGS. 1 and 2 has been modified to include the bounce-suppressing means.

Corresponding parts of the two wipe devices have been given corresponding reference numerals. The bounce-suppressing means of FIGS. 4 and 5 comprises a series of detents 30 that are slidably mounted in circumferentially-spaced openings 31 that extend radially through the carriage 16. These detents 30 are preferably in the form of pins having rounded inner ends that are shown in FIG. 4 bearing against a lower portion 33 of the piston 18. The detents 30 are urged into their illustrated position by suitable springs, such as leaf spring 35 secured to the carriage at their lower ends. When the carriage 16 moves through its upward wiping motion relative to the piston 18 after the contacts 12 and 11 engage, the pins 30 first slide for a short distance along the constant diameter dwell portion 33 of the piston, after which they encounter a steeply-sloping cam portion 37. This engagement with the cam portion 37 forces the pins 30 radially outward against the spring 35 as the carriage 16 continues its upward motion relative to the piston 18. After further upward motion of the carriage 16 relative to the piston 18, the pins 30 are located in alignment with another constant diameter dwell portion 38 of the piston 18. The pins 30 slide along this constant diameter portion 38 until the upward motion of carriage 16 is terminated. The position of the parts when the upward motion of the carriage 16 is terminated is illustrated in FIG. 5.

The total force that upward wiping motion of the carriage imposes upon the driven member or piston 18 is depicted in FIG. 3. This total force has two components, one of which is the force imposed by the wiping spring 20 and the other of which is the force imposed by the detents 30. The force imposed by the wiping spring 20 during this upward motion is the same as in the device of FIGS. 1 and 2 and is also depicted by the curve A. The force imposed by the detents 30 takes the form of a force pulse illustrated at P superimposed upon the spring force. This force pulse P begins when the pin detents 30 encounter the cam surface 37 and continues until the detents 30 pass onto the constant diameter dwell portion 38, at which time the pulse is terminated. While the detents 30 are sliding along the smaller constant diameter portion 33 prior to encountering the cam portion 37, they impose no substantial added force on the piston 18. It is only when the cam portion 37 is encountered that this force pulse P begins. In effect, the surplus energy that is represented between the curves B and A of FIG. 3 is utilized for producing the transient force pulse P.

The time at which the force pulse P should be applied can be best understood by considering the curve F of FIG. 6, which represents the butting force that would be applied to the contacts if the bounce suppressing means 30 were not present. After initial impact occurs at a point *g*, the butting force builds up sinusoidally to a peak occurring at an instant *h*, after which the butting force decays sinusoidally to zero at an instant *i*. During the force build-up period from *g* to *h*, the centers of gravity of the two contacts are approaching each other as indicated by the curve Z, which depicts relative displacement between these centers of gravity. During this period from *g* to *h*, kinetic energy is being converted into strain energy in the contact structure. Part of this converted energy is dissipated, but part is reconverted into kinetic energy that soon forces the centers of gravity of the two contacts away from each other, as is indicated by the portion of curve Z extending from *h* to *i*. At the instant *i* there is zero butting force on the contacts, and the centers of gravity of the two contacts have moved apart to a point where the contacts actually separate. This period when the contacts are out of engagement occurs during the time that the curve Z is negative in FIG. 6. The externally applied closing force eventually reverses the direction of movement of the movable contact and thus forces the movable contact back into engagement with the other contact at an instant *j*. Thereafter, the butting force builds up and decays again in a manner similar to that depicted by curve F. This might be repeated several times before being completely damped out, it being understood that each successive force build-up is to a lower peak value.

By applying the force pulse P of FIG. 3 to the driven member 18 at the proper instant, we can oppose the contact-separating force that is acting on the contacts between instants *h* and *i* and thus effectively neutralize this force and render it incapable of forcing the contacts completely apart. The optimum time for initiating the force pulse P is during the second-occuring third of the period of time extending from *g* to *i* in FIG. 6. This optimum interval is designated as T in FIG. 6. This timing gives the force P an opportunity to oppose the contact-separating rebound force that is acting between instants *h* and *i* to force the centers of gravity apart, yet without adding unduly to the compressive force that drives the centers of gravity of the two contacts together between *g* and *h*. Adding to this compressive force is undesirable because the higher this compressive force, the higher is the rebound force that becomes available between instants h and i to force the contacts apart. By opposing this rebound force with a force pulse P of sufficient magnitude, the effective rebound force is reduced to such an extent that it cannot cause the contacts to separate between i and j.

The force pulse P should persist at least until the instant i at which the butting force F would have returned to zero in the absence of the force pulse or, stated otherwise, until the instant at which the contacts would have moved out of engagement in the absence of the force pulse. Otherwise sufficient rebound force might remain to separate the contacts despite the force pulse P.

As explained above, the ideal instant at which to initiate the force pulse P is during the second-occurring third of the initial period (g to i) that the contacts would have remained in engagement in the absence of the force pulse P. But appreciable bounce suppression can still be obtained even if the force pulse begins as early as the instant of impact, providing that the force pulse persists until the instant i of FIG. 6. Beginning the force pulse at the instant of impact adds to the compressive force on the contacts as the centers of gravity move together after impact, and this disadvantageously tends to increase the severity of the rebound, but this tendency is more than offset by the tendency of the persisting force pulse P to oppose the rebound force between the instants h and i and by the tendency under these higher force conditions to dissipate a greater percentage of the impact energy without returning to to the system. If the force pulse begins at the instant of impact, its amplitude must be considerably higher than that of a force pulse beginning during the interval T in order to obtain equal bounce-suppression from the two pulses. In addition, more energy from the closing operation is needed with the force pulse that begins at the instant of impact.

The bounce-suppressing means **30** performs an important function during contact-opening as well as during contact-closing. This can be better understood by considering the performance of the parts during contact-opening. Such opening is initiated by driving the carriage **16** downwardly at high speed from its position of FIG. 5. After a predetermined amount of such downward movement, the stop **22** engages the piston **18** and forces it to move downward to separate the contacts. Before this occurs, however, downward movement of the carriage **16** has shifted the detents **30** downwardly into a location where the springs **35** can return the detents radially inwardly to their normal position beneath the cam surface **37**. Thus, when contact separation occurs, the detents **30** are positioned ahead of the cam surface **37** as shown in FIG. 4. When contact-opening motion is terminated by the carriage engaging a suitable stop, such as **40** in FIG. 3, there is a tendency for the piston **18** to overrun the carriage **16**. This tendency is suppressed, however, by the presence of the detents **30** ahead of the cam surface **37**, which apply a high retarding force to the piston **18** as it begins overrunning the carriage **16**. This limits compression of the wipe spring **20** by such overrunning and thus lessens the chances for erratic contact motion resulting from such overrunning. Another reason why it is desirable to limit overtravel is that there might be only a limited clearance space available ahead of parts (not shown) that are coupled to the movable contact. The limited nature of this clearance space together with excessive overtravel could cause one of these parts to collide with some other part, thus possibly damaging one of the parts.

Although we have shown our detents in the form of pins with rounded ends, it is to be understood that other forms of detents can alternatively be used, e.g. ball detents or conically-shaped detents or even cylindrical detents. It should also be understood that the shape of cam **38** can be varied to provide desired variations in the shape of the force pulse P. To illustrate these points, FIGS. 7 and 8 have been provided. In FIG. 7, the piston **18** is made of a polygonal form, and the detent **30** is the form of cylinder **30**, the periphery of which is adapted to act against a flat cam surface **37** on the piston **18**. FIG. 8 differs from FIG. 7 in that the cam surface **37** is formed by another cylinder, this one fixed to the piston **18**. These arrangements of FIGS. 7 and 8 are advantageous in permitting higher loads to be carried by the detent without permanent deformation.

While we have shown and described particular embodiments of our invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from our invention in its broader aspects, and we, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In an electric circuit interrupter comprising a generally stationary contact and a movable contact; mechanism for transmitting operating force to said movable contact comprising:
   (*a*) a driven part coupled to said movable contact,
   (*b*) a driving part coupled to said driven part and movable in one direction to supply contact-closing force to said driven part and movable in an opposite direction to supply contact-opening force to said driven part,
   (*c*) means for slidably mounting one of said parts on the other,
   (*d*) said driving part being movable through a predetermined wipe travel after said contacts engage during a contact-closing operation,
   (*e*) spring means between said driving and driven parts that is stressed by said wipe travel and that provides a first force urging said movable contact into engagement with said stationary contact during said wipe travel,
   (*f*) and bounce-suppressing means for providing an additional force that urges said contacts together and supplements said first force during a portion of the wipe travel closely following initial impact between said contacts,
   (*g*) said additional force being in the form of a transient force pulse that decays to a relatively low level before said wipe travel is terminated.

2. The mechanism of claim 1 in which said bounce-suppressing means includes means for causing said force pulse to be initially applied to said driven member after a time delay following initial impact but prior to expiration of the initial period that the contacts would have remained in engagement in the absence of said force pulse, said force pulse persisting at least until the expiration of said initial period.

3. The mechanism of claim 1 in which said bounce-suppressing means includes means for causing said force pulse to be initially applied to said driven member after a time delay following initial impact and during the second-occurring third of the initial period that the contacts would have remained in engagement in the absence of said force pulse, said force pulse persisting at least until the expiration of said initial period.

4. The mechanism of claim 1 in which said bounce-suppressing means comprises a cam carried by one of said parts and a detent element carried by the other of said parts, and biasing means urging said detent element and said cam into engagement with each other, said cam being shaped to provide for transmission of said force pulse from said driving part to said driven part during said portion of the wipe travel closely following initial impact between said contacts, said cam being further shaped to include a dwell portion that substantially terminates said force pulse after a predetermined wipe travel of said driving part sufficient to locate said detent element on said dwell portion.

5. The mechanism of claim 4 in combination with means for rendering said bounce-suppressing means ineffective to produce said force pulse until a predetermined finite portion of said wipe travel has occurred following initial impact.

6. The mechanism of claim 4 in combination with means for rendering said bounce-suppressing means ineffective to produce said force pulse until a predetermined finite portion of said wipe travel has occurred following initial impact, said predetermined finite portion being of such a length that said force pulse is initiated prior to expiration of the initial period that the contacts would have remained in engagement in the absence of said force pulse.

7. The mechanism of claim 1 in which said bounce-suppressing means comprises a cam carried by one of said parts and a detent element carried by the other of said parts, and biasing means urging said detent element and said cam into engagement with each other, said cam being shaped to provide for transmission of said force pulse from said driving part to said driven part during said portion of the wipe travel closely following initial impact between said contacts, said cam being further shaped to include a dwell portion that substantially terminates said force pulse after a predetermined wipe travel of said driving part sufficient to locate said detent element on said dwell portion, said cam being still further shaped to include a second dwell portion along which said detent element moves during a portion of the wipe travel preceding initiation of said force pulse.

8. The combination of claim 1 in which said bounce-suppressing means comprises a detent mechanism between said driving and driven parts that also operates to oppose overrunning of said driven part relative to said driving part upon termination of a contact-opening stroke.

9. A method of controlling a movable contact so as to suppress its tendency to bounce following impact with a stationary contact comprising the steps of:

(*a*) applying a spring force to said movable contact from the initial instant of impact until movable contact has settled down to a static equilibrium condition in which it engages said stationary contact, said spring force being insufficient by itself to prevent said movable contact from rebounding temporarily out of engagement with said stationary contact following initial impact,

(*b*) applying a transient force pulse to said movable contact that supplements said spring force,

(*c*) controlling said force pulse in such a manner that it is initiated following initial impact but prior to expiration of the initial perod that the contacts would have remained in engagement in the absence of said force pulse,

(*d*) and terminating said force pulse substantially before said movable contact has settled down to said static equilibrium condition but after expiration of said initial period that the contacts would have remained in engagement in the absence of said force pulse.

10. The method of claim 9 in which said transient force pulse is initiated after a time delay following initial impact.

11. The method of claim 9 in which said transient force pulse is initiated after a time delay following initial impact and during the second-occurring third of said initial period that the contacts would have remained in engagement in the absence of said force pulse.

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