

Strip of animated drawing cartoon, showing the action of an automobile vacuum-feed system. The "mechanigraph" employed for this film is shown below

## Putting Motion Into Mechanical Drawings

How Motion Picture Films of Hidden Mechanisms Are Made for Industrial and Educational Purposes

By Howard Greene

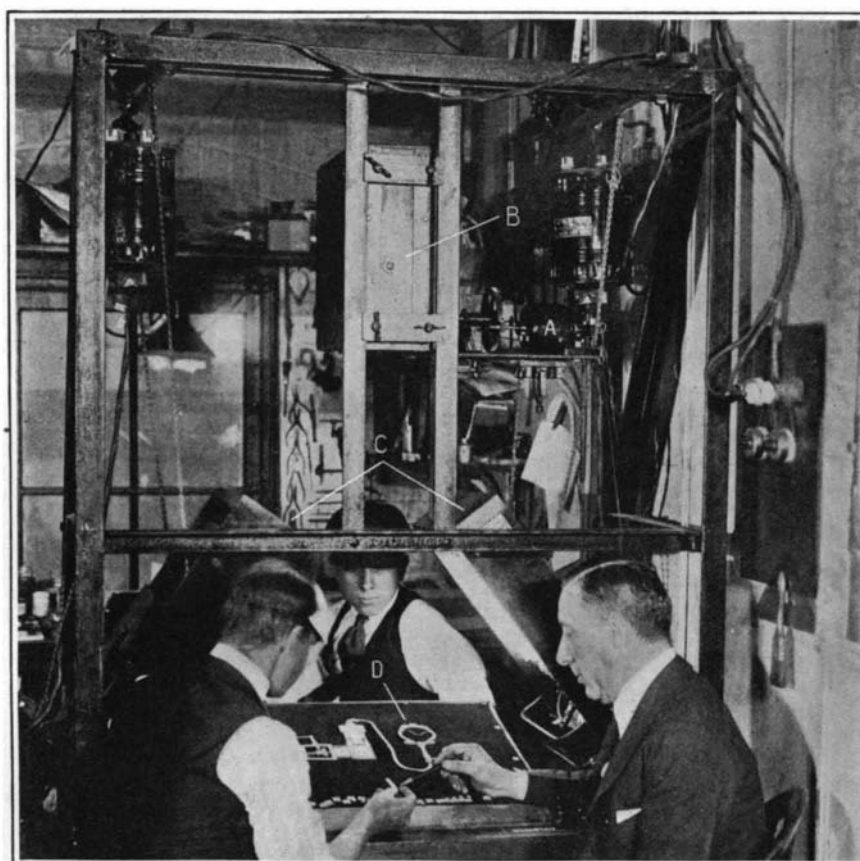
OF all the methods that ever have been devised for instructing and entertaining the public, the motion picture stands first in adaptability and flexibility. The public have become accustomed to trick photography, which seems to make impossible things happen before their eyes: the wildest flights of imagination can readily be made realities—photographically, at least.

While the fullest advantage has been taken of all these facilities of motion pictures in providing amusement for the audiences that throng the motion picture houses, there has been far less activity than there might have been in making use of "movies" for educational and advertising purposes. A certain conservatism, where conservatism might least be looked for, has manifested itself, with the result that the most potent of all methods of making complex matters simple has been neglected to an astonishing extent. Not that there are no films made for instruction and advertising; it is quite true that some have been produced and that they have admirably fulfilled their missions. But this simply makes it all the more a matter of wonder that the supply of films of this nature is as slender as it is; for the field is limitless and the possibilities almost beyond imagination.

Let us explore a little in one corner of the vast field that will some day be completely covered through the agency of the motion picture. A manufacturer of automobiles, we will assume, desires to get before the public the complete story of his car. Or an institute of technology or some other educational institution desires to make the construction and operation of the automobile absolutely clear and understandable. It is desirable to save time in imparting knowledge and to create an impression that will be lasting and accurate and that will not be the result of tedious mental drudgery. How is it to be done?

A specialist in the making of mechanical motion pictures is consulted, the objects sought explained, the data supplied. The making of the picture is commenced.

It is a simple enough matter to make, in the usual way, moving pictures of all parts of the car that are visible. It is equally simple to dismantle the engine, or the gearset, or any other unit, then to photograph the various parts and, in some cases, to show them in motion. But to make clear the actual action under working conditions is a different matter altogether. Take, for example, the familiar vacuum system for keeping the carburetor supplied with gasoline. All that is visible is a little tank and a few pipes. Lay bare the working parts and they will not work. Some recourse must be had to a series of drawings, supplemented by verbal or printed explanations. In the last analysis the whole mat-



Overhead at B, is the camera, and just to the right of it, A, is the electric motor, reduction gear, trip mechanism and reversing switch. The mercury-vapor lamps in suitable and adjustably mounted reflectors appear at C. The "mechanigraph" is shown at D. A counter, chain-driven from the shaft, indicates number of exposures made

### How the mechanigraphs are filmed by means of the animating stand

ter simmers down to the ability of the instructed to use the imagination and so mentally to visualize the apparatus. And it requires something more than an average imagination first to comprehend the analysis and then mentally to construct and finally mentally to operate the system.

Your motion picture engineer makes it his business to sweep away these difficulties, to eliminate the mental drudgery and to get at once to the heart of the subject—to show what the machine is for, what it consists of and how it works when the car is running.

And, be it said, in doing this, he takes upon his shoulders a task of no mean magnitude, which has a good deal to do with the fact that such pictures are not more common than they are.

At this stage of the proceeding another consideration enters. When the motion picture was in its early youth any picture that moved on the screen was acceptable. After the proverbial nine days, however, people became more discriminating; they demanded—and were given—pictures with an appeal beyond that of mere moving photography. Later there appeared the animated cartoon—the comic line drawing in which the characters and "props" moved in a more or less lifelike way. As a novelty, this was popular for a time, but the novelty soon wore off, and the animated cartoon is fast giving way to pictures that, while still designated as cartoons, have all the earmarks of being motion photographs of real things. They are produced by highly complex systems of double exposure, rephotographing photographs and so on. The old line drawing idea has had its day, and its place has been taken by a picture that looks precisely like what it is intended to represent.

So it is with the instructive and educational mechanical picture. In its best-known form it has been chiefly an animated line drawing. While satisfactory in some respects, such a picture is lacking in the very important element of reality. It is a representation of an idea, rather than a picture of the thing itself. Consequently, the present endeavor is to incorporate in the picture every possible appearance of actuality. And, to go back to the vacuum fuel-feed system, the end

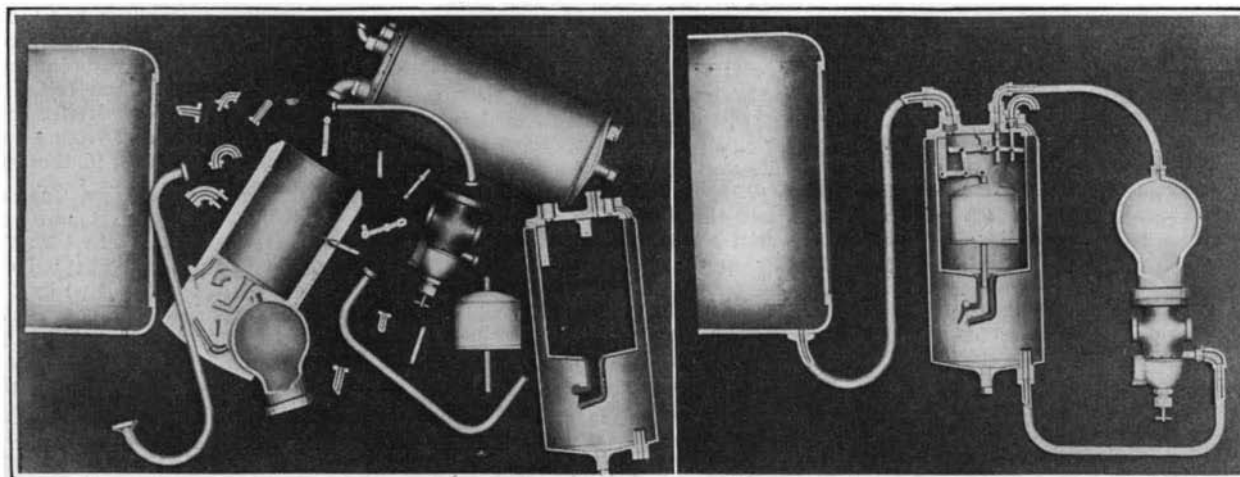
is accomplished as follows:

A drawing is made showing the system in cross-section, taken at a point that exposes all the working parts. Separate drawings are made of all the moving parts, all exactly to scale and of the correct form. All the parts are painted until they look quite real. Here a special knowledge of tone values is highly important. The tinting and shading that make an excellent half-tone cut, for instance, will often fall short of the appearance of reality when photographed under the motion-picture camera. For that reason, illustrations

of the work are usually far less convincing in appearance than the images projected on the screen.

All the parts are assembled, joints and bearings being used so that they will move as they should. It is usual to make also toned drawings showing all exteriors, to show the external appearance of the apparatus at the beginning of the picture. These exteriors are "dissolved out" later, exposing the working parts.

Photographing the  
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Parts of vacuum-feed system mechanigraph, properly drawn and tinted, and assembly of parts ready for filming

## The Yangtse Shallow-Draft Steamer "Anning"

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a hinged flap. In Fig. 2, the vessel is at shallow draft and the flap automatically takes up the best possible position for efficiency. In Fig. 3 the flap is shown with the vessel at deeper draft. In this case the flap has gone up to the top of the tunnel and the propeller efficiency is secured by taking full advantage of the increased draft of water.

A large number of vessels have been fitted with this system, including 16 small gunboats 120 feet long by 20 feet beam for the "Tigris," and 12 large gunboats 230 feet long by 36 feet beam for the "Tigris," "Danube," etc.

In navigating such rivers as the Yangtse between Ichang and Chungking the tunnel system steamer has a further advantage over the ordinary type of screw steamer, for when passing through rapids where there is broken water the propeller in the tunnel is not nearly so liable to be affected by the disturbances. This has been proved by experience gained with the "Shu-Hun," a predecessor of the "Anning," which has been run on the Yangtse since 1913 and is to this day recognized as the best steamer on that reach of the river.

Owing to the civil war along the banks of the Yangtse, in which north and south China have been engaged, a certain amount of interruption of the steamer navigation has taken place, more particularly where Chinese vessels were concerned. It is understood that conditions have somewhat improved in this respect recently, and it is expected that there will be great developments in the shipping on this reach of the river. There is no doubt but that many vessels similar to the "Anning" could be most profitably employed there.

## Putting Motion Into Mechanical Drawings

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job involves special apparatus in the shape of an "animating stand." The animating stand consists, first, of an angle-iron framework in the lower part of which is a broad table, at convenient working height, upon which the drawing—called a "mechanigraph"—now that it is finished—is placed. The camera is carried overhead, with its lens pointing down toward the table, and is mounted on slides so that it can be moved up or down to permit covering any size of field.

The motion picture camera has two shafts for operating its shutter and film-moving mechanism. When the shaft ordinarily used is rotated, each rotation causes eight exposures to be made. The second shaft causes one exposure to be made at each revolution, and is known as the "stop-motion" shaft. This is the shaft used in making mechanigraphs. Instead, however, of being driven by hand through a crank, it is driven by a small electric motor. In photographing a job the motor is allowed to run continuously. It does not turn the shutter shaft, however, unless a trip is operated by hand or by foot. When the trip is operated a positive clutch engages the shutter shaft, gives it one turn and makes one exposure, and then automatically disengages, the motor running idle until the trip is again operated. Needless to say the clutch is so adjusted that when idle the shutter is closed.

The mechanigraph is placed on the table and adjusted as to position so that it is in proper relation to the field of the lens, the camera's height is adjusted so that all or as much as may be desired of the drawing is in the field, the lens is focused, the stop or opening set, and the camera loaded with film and closed. With everything ready for work the lights are turned on. These are mercury-vapor

lamps suspended adjustably on each side of the table, so that the field is brilliantly and evenly illuminated by the greenish glow.

In the case of the vacuum fuel-feed system, the picture is started by showing the exterior of the apparatus. There is no motion to be registered, so the trip is held in the operating position and the camera shaft is turned continuously until a sufficient length of film has been exposed. Then the exterior parts are "dissolved out." The most effective way of doing this is to use a "cross dissolve." By pressing a button on the camera a mechanism is engaged which gradually closes the shutter while the motor rotates the camera shaft. The result is that the light admitted through the lens is decreased slightly in each successive exposure until finally the shutter is completely closed and no light enters. If this film were developed the result would be a gradual fading of the picture until it would disappear completely.

At this point the drawings representing exteriors, which have been temporarily laid over the sectional drawings, are removed, bringing the working parts into view. Then with the shutter closed the film is run back to the exact point where the "fade" was commenced. The motor is then run forward and the fade is repeated, going over the same film as before—with one important difference. Where the shutter, on the "fade-out," began to close it now begins to open, and when the point is reached where the shutter was completely closed on the fade-out, it is wide open on the fade-in. This is called a "cross dissolve" or an "overlap dissolve." On the screen, the result is that the exterior view dissolves—there is not a better word—into the interior.

A few feet of film are then run through showing the working parts stationary, after which the real work of the "animator" begins. The parts must be photographed in such a way as to show their movement. They cannot, however, be moved and photographed while they are moving, as in the familiar process of "straight" motion picture work. The parts are moved by hand a small fraction of an inch. Then the trip is operated and the motor causes the camera to make a single exposure. In motion picture parlance, one "frame" is exposed. Then the parts are moved another fraction of an inch and another exposure is made, and so on—a little movement and one exposure, another movement and another exposure, still another and another until the parts have completed a movement, or a series of movements. All movements must be equal when a steady motion is required; otherwise there will be a jump on the screen. In the case of the subject in question the movements were each about a thirty-second of an inch.

A curious feature of this work is that it is not really motion picture photography at all. It is simply a series of "still" photographs showing a succession of different positions of the object photographed. On the screen, however, the illusion of movement is perfect. Even if the animator, through an error of judgment, moves the parts too far at each exposure, the projected picture still maintains the illusion of motion rather than a succession of "stills," but the motion will be a series of very rapid jerks or jumps.

One of the difficulties of mechanical animation becomes evident when there are several parts to be moved and it is impracticable so to connect them that they will move together. They must be moved separately, and the movements must be so gaged that the proper relative positions will always exist. Usually this involves a schedule, prepared after all the movements have been exactly calculated and tabulated.

There is a good deal more to be done, however, before the work is finished. The object sought is not merely to show how

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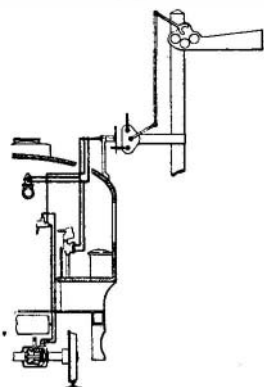


## RECENTLY PATENTED INVENTIONS

(Continued from page 476)

in construction, composed of comparatively few parts and arranged to permit of easily making repairs without requiring removal of the axle from the car. This invention permits the use of a stationary axle or similar support, hence axle journals and bearings as now generally constructed may be dispensed with.

**AUTOMATIC TRAIN CONTROL.**—E. H. CHABOT, 23 Temple St., Nashua, N. H. This invention relates to means for automatically stopping trains if for any reason the engineer fails to observe the signals which are set against him. The device has for its object



A DIAGRAMMATIC VIEW SHOWING THE SIGNAL MECHANISM

to provide simple and effective means whereby it is impossible for a train to pass a signal that is set to stop or caution position without having the controlling mechanism operate to shut off the steam or apply the air brake, or both, to bring the train to a stop.

### Pertaining to Recreation

**TOY.**—E. C. RICHARDSON, 8 Pershing Court, Ridgefield Park, N. J. Among the objects of the invention is to provide a toy of the nature of what is commonly known as a "see-saw." A further object is the construction of a certain operating provision by means of which the see-saw may be moved, and which will further serve as a grip whereby the children may grasp the see-saw so that danger of their falling off is reduced to a minimum.

### Pertaining to Vehicles

**VEHICLE WHEEL.**—M. BENZ, Box 2, South Chicago, Ill. An object of the invention is to provide a vehicle wheel having means in itself for absorbing and dissipating the shocks and jars. A further object is the provision of a device in which a solid tire is engaged by a pair of outer rim members and a pneumatic tube is arranged between the solid tire and the hub, thereby safeguarding the pneumatic tube from puncture without lessening the resiliency of the wheel.

**DEVICE FOR CONTROLLING FROM A DISTANCE THE WINDOWS OF MOTOR CARS AND OTHER VEHICLES.**—P. SEURIN, 84 Rue Lauriston, Paris, France. This invention relates to an air pressure device for controlling or operating from a distance the windows or glass panes of doors, front frames and partitions of motor cars, which device can be used for controlling the movable windows of vehicles such as motor buses, railway cars and the like.

**GAS ENGINE CUT-OUT MUFFLER.**—H. M. WRIGHT, JR., 144 W. Newell Ave., Rutherford, N. J. An object of the invention is to provide a gas engine cut-out fitted with a double cut-out means such as a motorcycle or automobile engine cut-out and muffler, which may readily be attached to a motorcycle or other internal combustion motor vehicle and which may be installed to replace the ordinary type of muffler usually employed.

**TRUCK.**—F. E. CARTER, Box 165, Yuma, Colo. The invention relates more particularly to a truck for handling the wheels of heavy motor vehicles. The object is to provide a truck which may be easily positioned to receive the wheel, and which may be adjusted to accommodate various size wheels, and may be positively set or locked in engagement with the wheel to thereby support and carry the same.

**ANTISKID DEVICE.**—J. R. BAUDE, 2705 Jackson Blvd., Chicago, Ill. Among the objects of the invention is to provide a form of antiskid device that can be quickly attached to the rim of a wheel whereby skidding forwardly, backwardly and laterally will be prevented. A further object is to provide such a device as can be attached or detached without the use of any tools; the device takes up little room in transportation.

**PNEUMATIC JACK AND PUMP.**—C. STEPHENS, Rosendale, Mo. The particular object of the invention is to provide a device adapted for use with automobiles. Another object is to provide a device in which the pump may be used to supply fluid pressure to the jack or by a single manipulation may be adapted for use as a pump for inflating a tire or for general purposes.

**TIRE CASING.**—C. W. MIEGEL, 323 Lambeck Ave., Jersey City, N. J. This invention has for its object to provide a casing especially adapted to be proof against blow-outs, rim cuts, and side wall breaks, and to add resiliency to the tire. In case of a puncture of the outer portion of this tire the inner portion will immediately reinforce the outer portion.

**LENS FOR HEADLIGHTS.**—L. and H. BENZER, 141 Roebling St., Brooklyn, N. Y. The invention relates to lenses for projectors, and it pertains more particularly to lenses adapted for use in connection with headlights of motor vehicles. It is the primary object to increase the intensity of the side or "ditch lights," this result being obtained by the transversely concave surfaces of the lens.

**WHEEL.**—G. YATES, 3215 Carnegie Ave., Cleveland, Ohio. This invention has for its object to provide a wheel construction wherein roller bearings are arranged between the wheels and the journal box, the wheels being rigidly connected. With this construction the housing ring may be removed, and the rollers also removed without taking the wheel off the axle.

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## NEW BOOKS, ETC.

**EMINENT CHEMISTS OF OUR TIME.** By Benjamin Harrow, Ph.D. New York: D. Van Nostrand Company, 1920. 8vo.; 248 pp.; 21 illustrations.

As Dr. Harrow says, the pioneers in chemistry have inspired a few biographers, but our modern chemists are largely ignored by permanent literature. Hence this popular volume of life-stories dealing with Perkin and his coal-tar dyes, Mendeléef and the periodic law, Remsen and the rise of chemistry in America, and eight other eminent moderns whose claim to attention is indisputable. The high lights of their careers are picked out with precision, their discoveries are carried forward into present-day development and practice in a most interesting way, and a rich gallery of portraits enables us to meet these notables, as it were, face to face.

**PELOUBET'S SELECT NOTES ON THE INTERNATIONAL UNIFORM SUNDAY SCHOOL LESSONS FOR 1921.** By F. N. Peloubet and Amos R. Wells. Boston: W. A. Wilde Company. 8vo.; illustrated.

Each year more and more Bible students recognize the inspiration and almost indispensable help to be derived from this commentary, with its suggestions to teachers, its judicious treatment of doctrinal questions, its fresh viewpoints, and its maps and illustrations. Its selection and arrangement of material and the manner in which it spurs and sustains the interest speak volumes for the ability of the compilers.

**PATENT LAW.** By John Barker Waite. Princeton, N. J.: Princeton University Press, 1920. 8vo.; 316 pp.

Professional men and men of business often find it necessary to ascertain their rights in respect to inventions and patents. Professor Waite's new text-book covers the substantive law of patents, their nature, validity and effect, and their characteristics as property. He has canvassed every issue passed upon by the courts, and his work discloses a close-knit structure of facts and interpretations that the layman, as distinguished from the patent practitioner, will find exceedingly helpful.

the parts move, but rather to create a picture showing the effects caused by these movements as well. In the present instance this involves showing the flow of gasoline from the main tank to the vacuum tank, through the valves, from the upper to the lower tank and out to the carburetor. The principle used in creating the illusion of the rising or falling of liquid in a tank, or its flow through a pipe, is simple and can be applied in a number of ways. In the case of a tank, a piece of transparent celluloid is cut that will fit in the tank drawing, and provision is made for moving it up and down while showing only that portion which should properly be shown in the tank; the exact method will depend upon the nature of the job. On the celluloid lines are drawn, much as in drawing the conventional water of the drawing-board. When this is moved and photographed as described, the lines are "lost" on the screen and there is left the illusion of movement of a transparent body. By using celluloid the tank can still be seen through the liquid, making the illusion so much more complete. Other equally simple tricks are employed to show the liquid falling in a broken stream and splashing foamily into the tank.

Part of the animator's stock in trade consists of unlimited patience. Such a picture as that of the vacuum fuel-feed will run about 400 feet. With sixteen frames per foot, this means a total of 6,400 frames. Some of these are run off rapidly under the camera, where there is no motion to be shown. There remain, however, about 5,000 frames that must be exposed individually, each after a careful setting of a number of parts. Small wonder, then, that the making of a film that will show on the screen for three or four minutes may involve anywhere from two days to two weeks of work under the animating camera—to say nothing of the time required for the preparation of the mechanigraphs by the draughtsmen and artists.

There are cases where it is necessary to show movement that cannot be simulated by the methods already referred to. For instance, suppose it is desired to make a mechanigraph of a power-driven tire pump, such as is used in automobiles. In order to get the whole pump in section at the same time it is necessary to draw it in the plane of the crankshaft. This gives an edgewise view of the gears and crank; yet their motion must be shown. In the case of the gears the "three-position" trick, well known to animators, is used. A drawing of the gear is made with the teeth carefully placed and spaced. Then a second is made precisely similar, but showing the teeth advanced through a distance equal to one-fourth of a tooth and a space, and a third shows a similar advance over the second. The first gear is laid in position and photographed—a single frame. Then the second, and then the third. Then the first is laid down again, and the second and third, and so on, for as many feet of film as may be necessary. If the drawing has been properly done the projected picture will show perfect motion. The person who is informed on the subject of motion pictures will recognize at once the connection between this procedure and the various illusions which are encountered in photographing the wheels of a moving vehicle.

The crank has to be handled differently, for it changes its appearance as well as its apparent length with every move throughout its swing. A separate drawing is made for every position of the crank, and cut out. The cut-outs are laid down one at a time and photographed, the piston and connecting-rod positions being changed each time the crank is changed. When the connecting rod moves back—that is, away from the spectator—it naturally goes into the shadow of the cylinder and crankcase. So a separate piece, precisely like the connecting rod but

darker, is laid on when the rod is in the shadow. This gives the impression that the rod swings back and forth, when in reality it simply moves straight up and down.

There are innumerable other tricks and devices that are called into play by the mechanical animator, and many pieces of special apparatus are devised to attain specific results. Many of these ideas are more or less jealously guarded as "trade secrets," but the truth is that once a picture is shown on the screen, a good animator can figure out pretty accurately how it was made, and can generally do the same thing himself. There are few set rules and processes in the type of mechanical animation described. Every job brings its own individual problems, and solving them involves ever new schemes and tricks—it is just one little invention after another. But this very fact makes the work more than fascinating in spite of its difficulties, and the greatest reward an animator can ask is a perfect picture on the screen. This brings with it a thrill even beyond that of the author who sees his work in type for the first time.

## Counting Electrons

(Continued from page 465)

tral, but has a positive charge of one or two or more electronic units, according as one or two or more electrons have been detached by the passage of the alpha rays through it. If then this atom is just underneath the drop of oil, it is thrown instantly by the electric field into the latter; and then if you are observing you see something interesting.

Suppose you look through a telescope with a scale fixed in the eyepiece? The drop of oil shows up like a very minute star on a dark background. You wait a few seconds after turning the lever which exposes the gas to the alpha rays. Bing! You have bagged an electron, or possibly two. These are the positive electrons of the nucleus of the atom whose negative satellites were knocked off by the alpha ray. Instantly the atom, carrying now its extra positive electron or electrons, strikes the oil drop. The drop begins to move up—very slowly and regularly, for the laws that govern falling bodies are suspended in the case of minute droplets in a gas, and the speed of the oil drop remains constant. From the rapidity with which it moves you can see at once whether you have caught one or two electrons, for in the latter case the drop will move just twice as fast as in the former one.

In his lecture on the structure of the atom Sir Oliver Lodge has stated that we may well fear future wars if the terrible secret of how to utilize the energy contained in the atom falls into the hands of an uncivilized power. Not only human life, but the whole planet, could be destroyed, he asserts. Radium discharges alpha particles with sufficient force to carry them around the world in a fraction of a second—at a velocity that is really only a little bit slower than that of light. This power is dormant in each atom; if we ever learn how to release and control it for our own purposes the fuel shortage will mean nothing at all in our lives, and the invention of ways for making synthetic gasoline out of water plus a mysterious green powder at a cost of a cent and a half a gallon will go wholly out of vogue, because such fuels will be ruinously expensive alongside the atomic source of energy.

## A Steam Locomotive as a Punch-Press

(Continued from page 467)

drilling machine driven by compressed air, suspended from a jib and maintained at the right level by a counterweight. The cup cooling was so devised as not to water-harden the metal; it merely imparted to it sufficient resistance to prevent the punch from driving through the base of