CHAPTER 9

Geneva Mechanisms

INTRODUCTION

The Geneva is one of the earliest of all intermittent motion mechanisms and when input is in the form of continuous rotation, it is probably still the most commonly used. Genevas are available on an off-the-shelf basis from several manufacturers, in a variety of sizes. They are cheaper than cams or star wheels and have adequate-to-good performance characteristics, depending on load factors and other design requirements. Figure 9-1 shows a typical, four-slot external Geneva.

Advantages of Genevas

Genevas may be the simplest and least expensive of all intermittent motion mechanisms. As mentioned before, they come in a wide variety of sizes, ranging from those used in instruments, to those used in machine tools to index spindle carriers weighing several tons. They have good motion-curve characteristics compared to ratchets, but exhibit more "jerk," or instantaneous change in acceleration, than do better cam systems (the Geneva, you will remember, is a special type of cam system).

The Geneva maintains good control of its load at all times, since it is provided with locking ring surfaces, as shown in Fig. 9-1, to hold the output during dwell periods. In addition, if properly sized to the load, the Geneva generally exhibits very long life. One machine tool manufacturer told me that their Genevas will last 20 years, indexing once every few seconds, on a threeshift basis, driving a spindle carrier weighing one ton. This particular Geneva was about 18 inches in diameter.

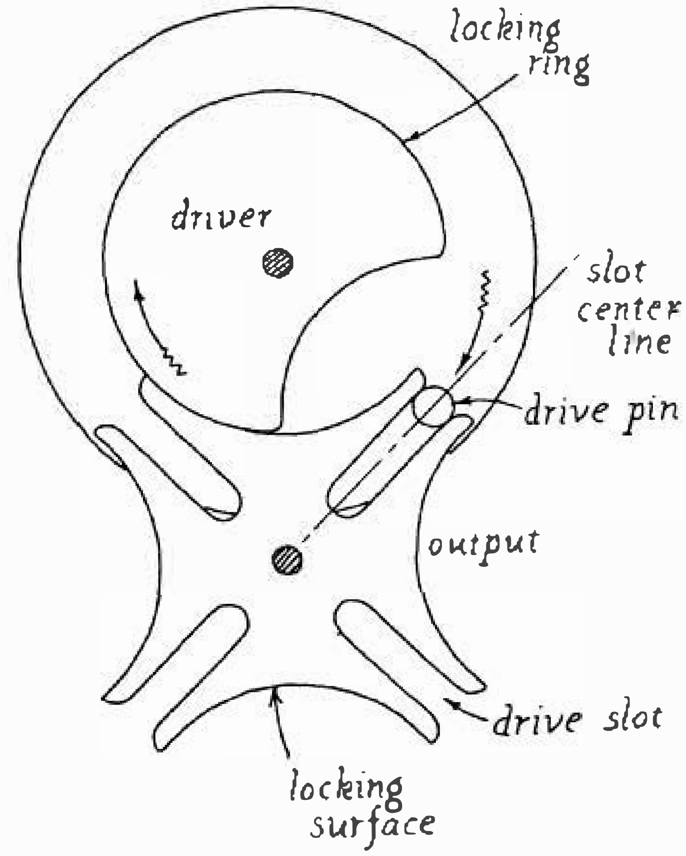
Disadvantages of Genevas

The Geneva is not a versatile mechanism. It can be used to produce no less than three, and usually no more than 18 dwells per revolution of the output shaft. Furthermore, once the number of dwells has been selected, the designer is well locked into a given set of motion curves. The ratio of dwell period to motion period is also established once the number of dwells per revolution has been selected. Also, all Geneva acceleration curves start and end with finite acceleration and deceleration. This means they produce jerk.

Types of Genevas

There are three types of Genevas: (1) external, which is the most popular, and which is represented by the device shown in Fig. 9-1; (2) internal, which is also very common and is illustrated by Fig. 9-2; and (3) spherical, Fig. 9-3, which is extremely rare. We will take a closer look at some external and internal Genevas later on, but will not spend more time on the spherical type.

Genevas are also combined with a wide variety of other mechanisms, such as four-bar linkages; clutch-brake combinations; noncircular gears; etc., to modify the motion curves and dwell-motion ratios obtained from a pure Geneva. We will see several different examples of these later.



Drawing courtesy of MACHINE DESIGN Magazine: Dec. 23, 1965: p. 121 ff

Fig. 9-1. Fourslot external Geneva.

Motion Curves

The motion curves for several external Genevas are shown in Fig. 9-4; and for internal Genevas, in Fig. 9-5. As can be seen, the two curve sets differ quite drastically in shape. Figure 9-6 shows the motion curves for fourslot internal and external Genevas superimposed for comparison.

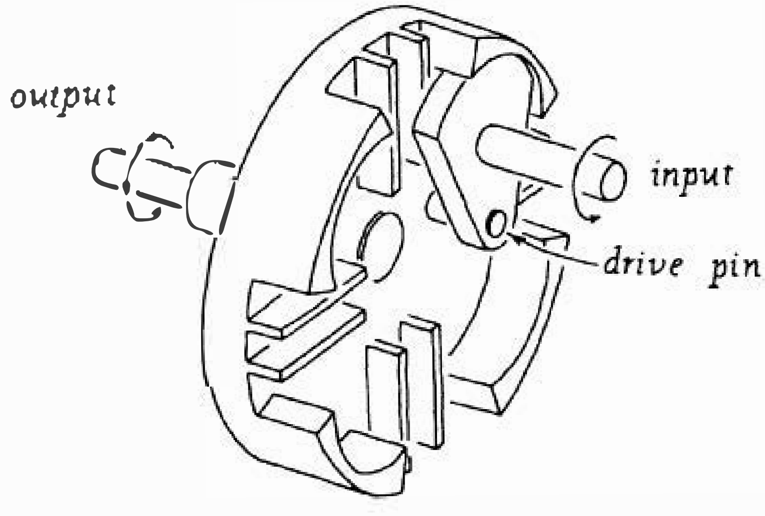


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Fig. 9-2. Fourslot internal Geneva.

A few general comments can be made about these motion curves.

1. For an external Geneva, the dwell period always exceeds the motion period.
2. For an external Geneva, the dwell period always lasts longer than the time required for 180 degrees of motion of the input driver.
3. For an internal Geneva, the motion period always exceeds the dwell period.
4. For an internal Geneva, the dwell period is always shorter than the time required for 180 degrees of input.

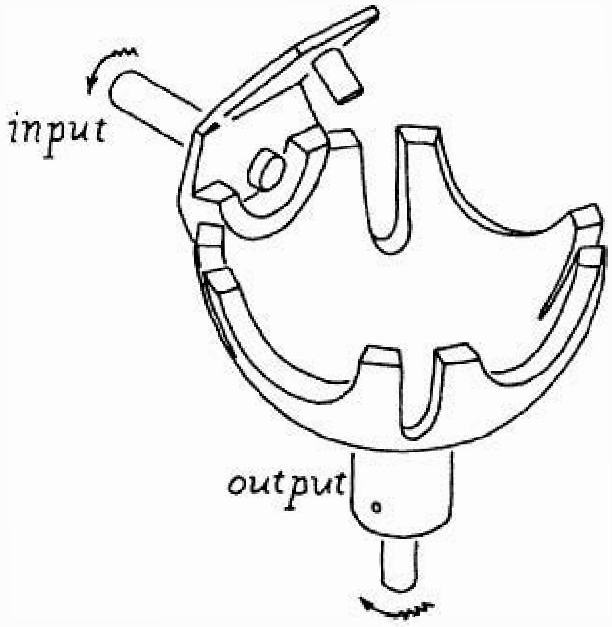

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Fig. 9-3. Four-slot spherical Geneva.

5. For a spherical geneva, the dwell period equals the motion period, and equals the time required for exactly 180 degrees of input.
6. The magnitude of peak acceleration and deceleration, velocity, etc., obtained with a Geneva, is a function of the number of slots or dwells. This is true of all types.

As the ratio between the diameter of the wheel and the diameter of the driver gets larger (more slots or dwell periods per revolution of the output), maximum accelerations and velocities decrease (for a given driver speed). This makes sense because the indexing angle of the output decreases as the number of slots increases.

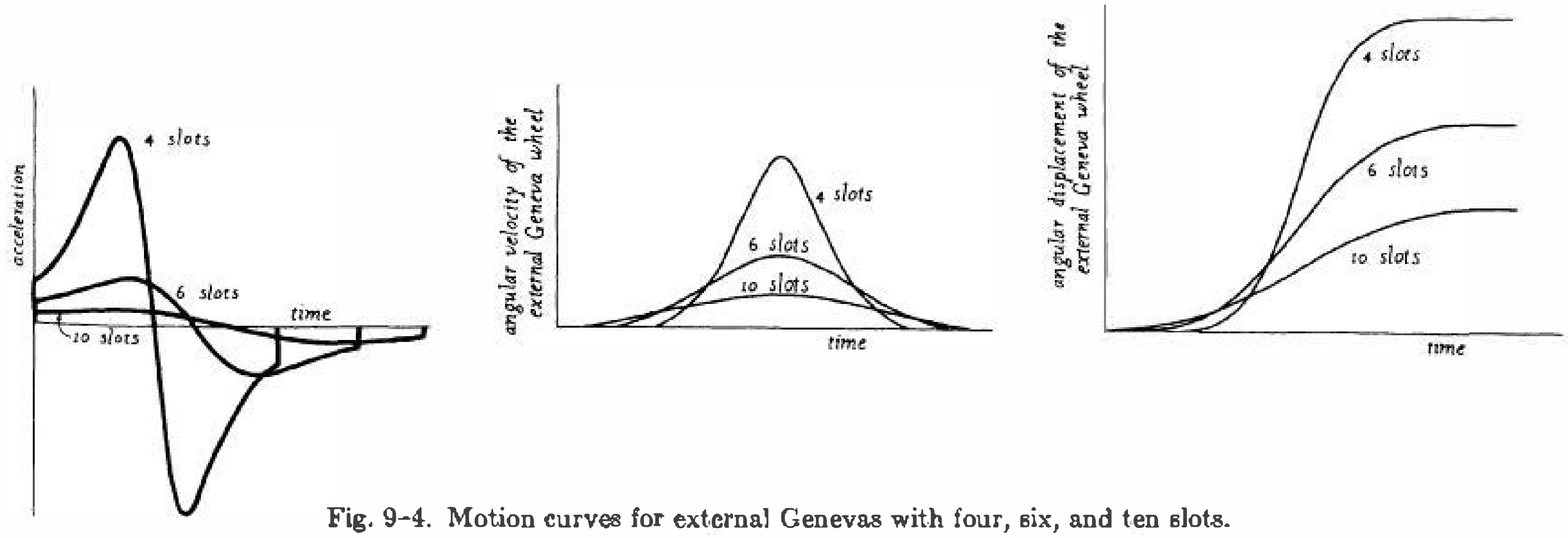


Fig. 9-4. Motion curves for external Genevas with four, six, and ten slots.

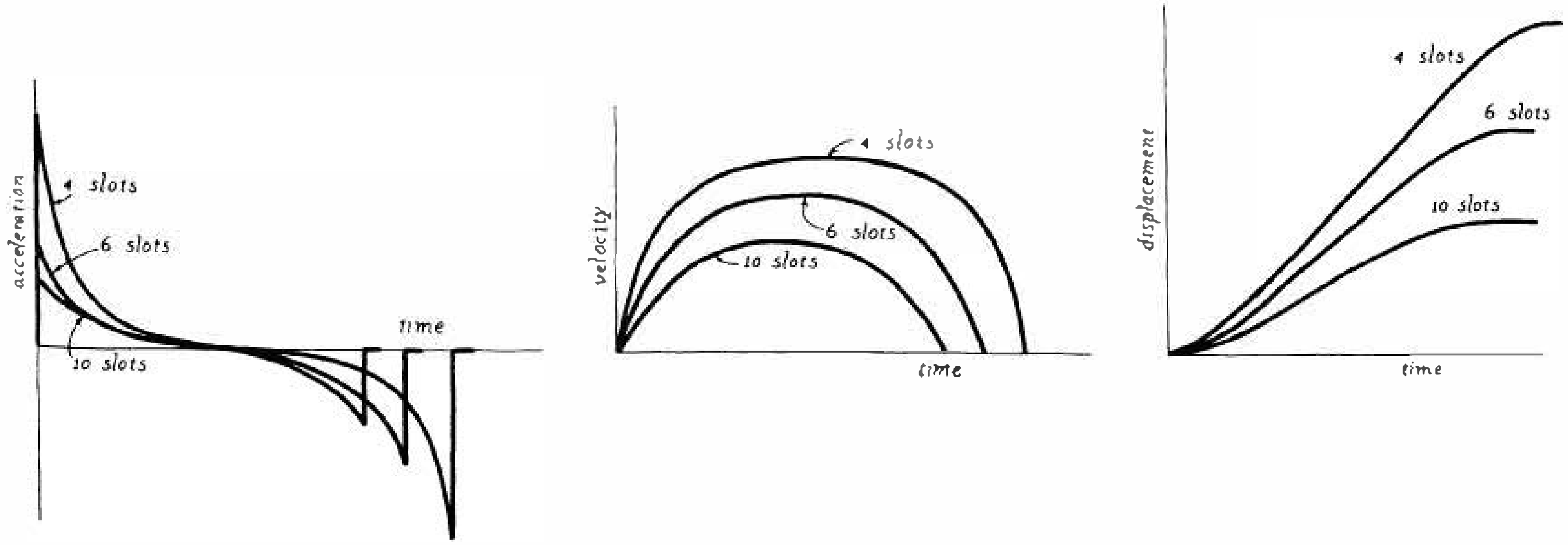


Fig. 9-5. Motion curves for internal Genevas with four, six, and ten slots.

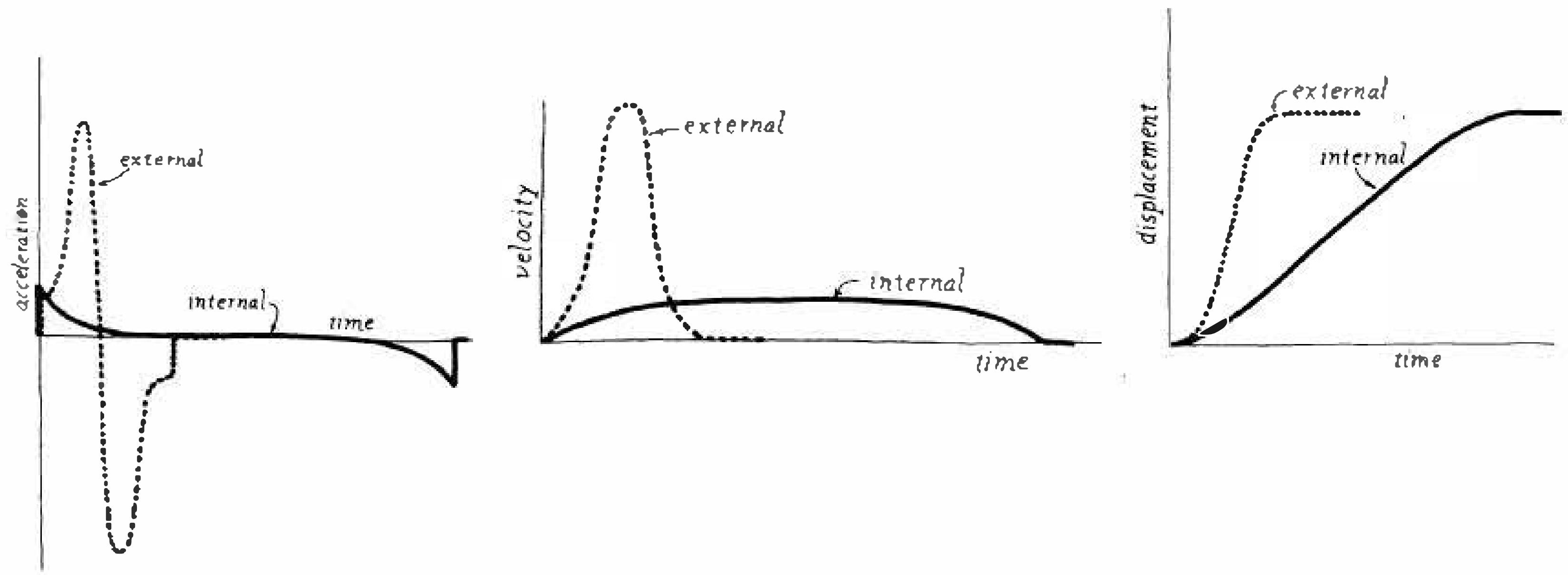


Fig. 9-6. Comparison of the motion curves of internal and external Genevas with four slots.

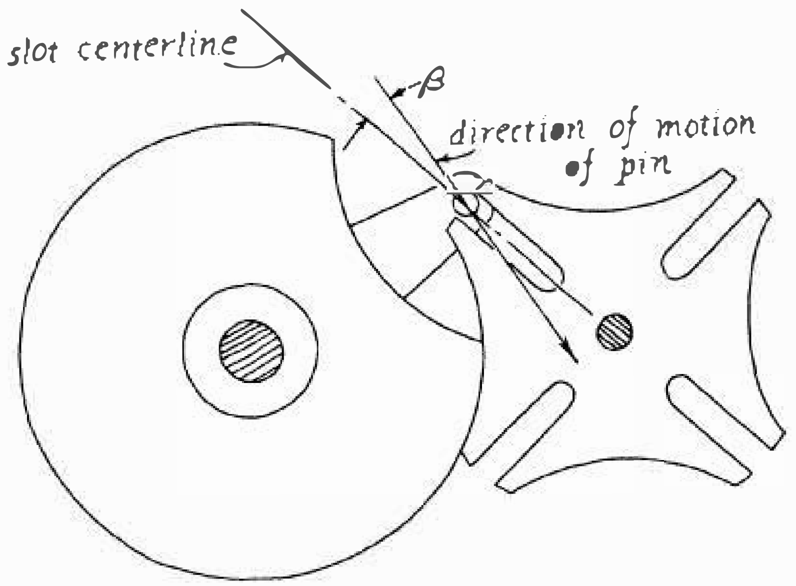


Fig. 9-7. The drive pin of the Geneva should enter the slots in the driven wheel along an arc that is tangent to the centerline of the slot, rather than along a line which deviates from the slot centerline by some angle β, as shown here.

Miscellaneous Comments

In a well-designed Geneva the drive pin will enter the slots of the output wheel along an arc that is tangent to the centerline of the slot, as shown in Fig. 9-1. If the direction of motion of the pin deviates from the slot centerline by an angle β, shown in Fig. 9-7, impact can result. This will either be a positive or negative impact (that is, it will produce either a positive or a negative torque on the driver) depending upon whether the slot is at some angle above the tangent line of the pin's motion or at some angle below it. (Figure 9-7 shows a situation where the tangent line is below the pin's motion line.)

Figure 9-8 shows the displacement curves that result from three situations: the deviation (angle β) is ±5 degrees or 0 degrees (tangent). There does not seem to be much difference between these three curves, each of which represents only the first few degrees of motion of the output member rather than the complete displacement curve, as per Fig. 9-4. The velocity curves for these three situations, also shown in Fig. 9-8, do not appear to have changed much either.

If we now plot the acceleration curves, however, we will find that we have introduced impact when the slot's centerline was above or below the line tangent to the pin's motion. This is because the angular velocity in each case starts at a finite positive or negative value; and instantaneous change in velocity means an infinite acceleration which, in turn, means impact. In practice, of course, a small initial velocity would mean a relatively small impact (even though theory says any instantaneous change means an infinite acceleration) and would cause no trouble. If the machine is operated at high speeds, however, or under heavy loads, or with elastic connections between parts, even a small, sudden change in velocity can cause severe impact, stress, vibration, lost motion, jamming, etc. Figure 9-9 shows the acceleration curves for the three situations.

As discussed in Chapter 5, a high-speed or heavily loaded Geneva can also get into difficulty if the pin is not a good running fit in the slots in the output

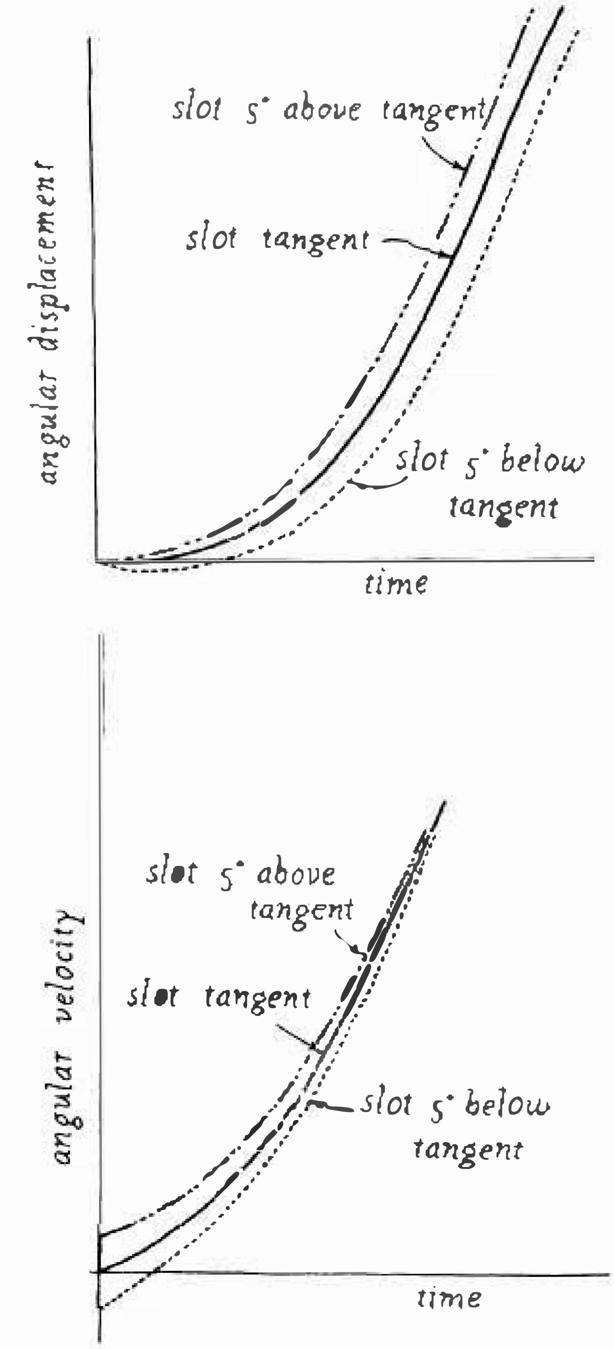


Fig. 9-8. Displacement and velocity curves of an external Geneva when the direction of motion of the drive pin is tangent to the slot; when the slot is 5 degrees above the tangent line; and when it is 5 degrees below it (the latter situation is shown in Fig. 9-7).

wheel. Elasticity in the system may allow the pin to chatter from one side of the slot to the other as it drives the wheel, producing a series of impacts which can cause all sorts of trouble. (See Figs. 5–9 and 5–10 for the resultant motion curves.)

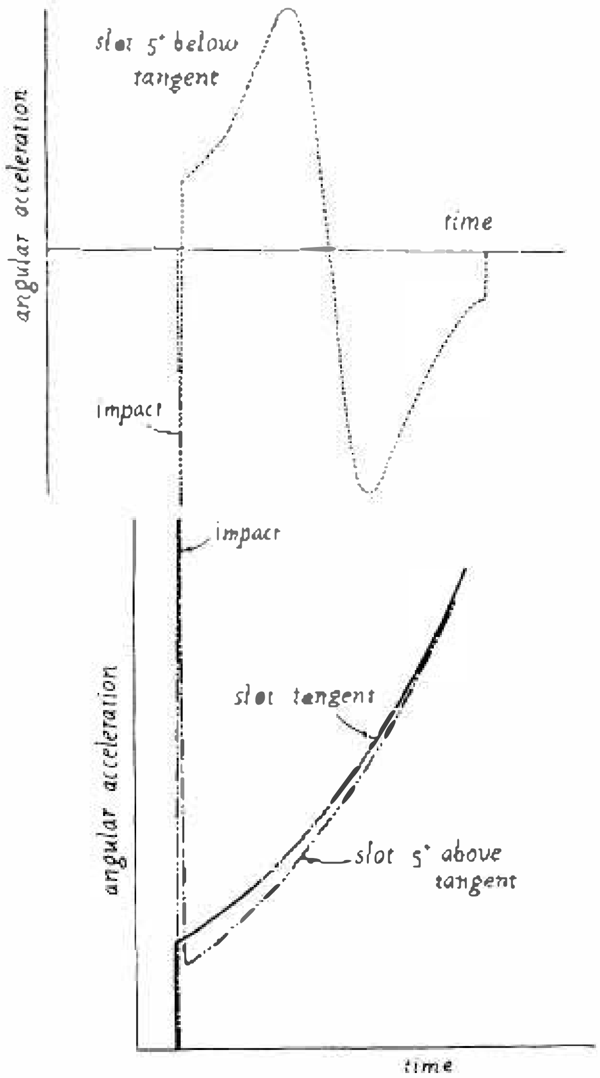


Fig. 9–9. Acceleration curves for tangent and ±5 degrees misaligned slots.

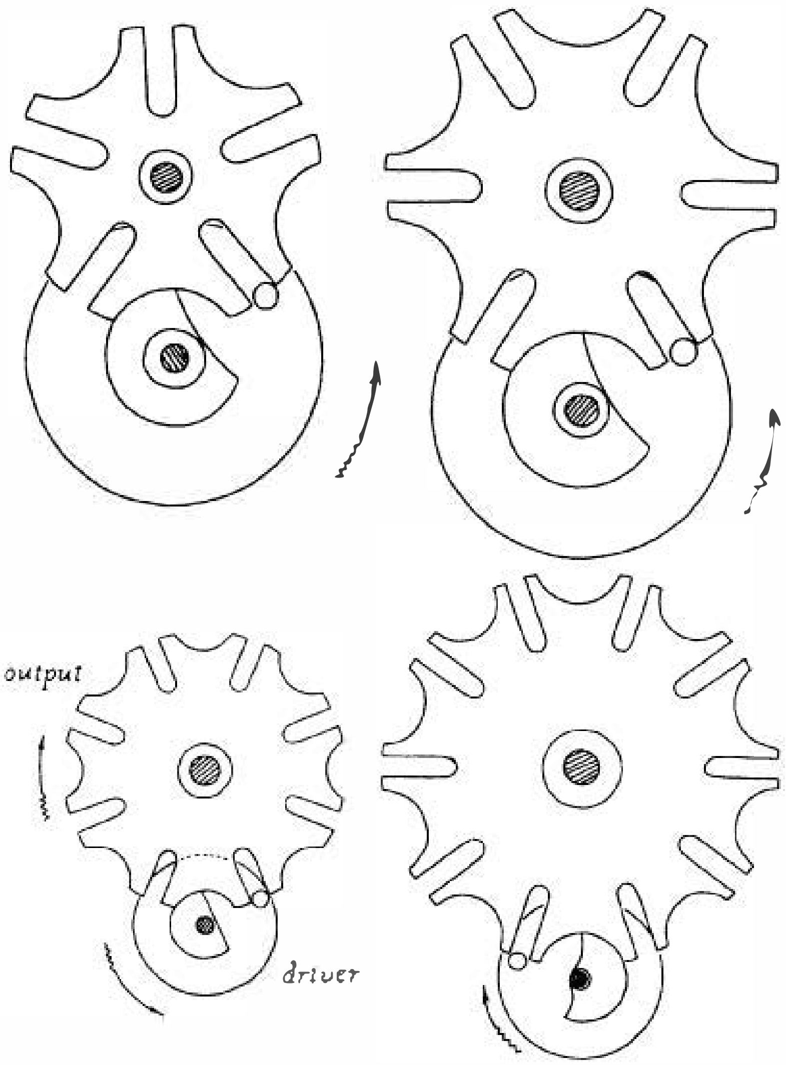


Fig. 9–10. External Genevas with five, six, eight, and ten slots, respectively.

Four sketches of external Genevas with five, six, eight, and ten slots, respectively, are shown in Fig. 9–10. Notice how the ratio between the diameter of the driver and the diameter of the wheel decreases as the number of slots increases. Notice also, that the indexing angle decreases.

Three internal Genevas with four, eight, and twelve slots are illustrated in Fig. 9–11. Again, notice how the ratio of driver diameter to output wheel-diameter decreases as the number of slots increases. Notice too, that the driver must be mounted on a cantilevered shaft in each case, whereas the external Geneva of the previous illustration could have both input and output members mounted on through

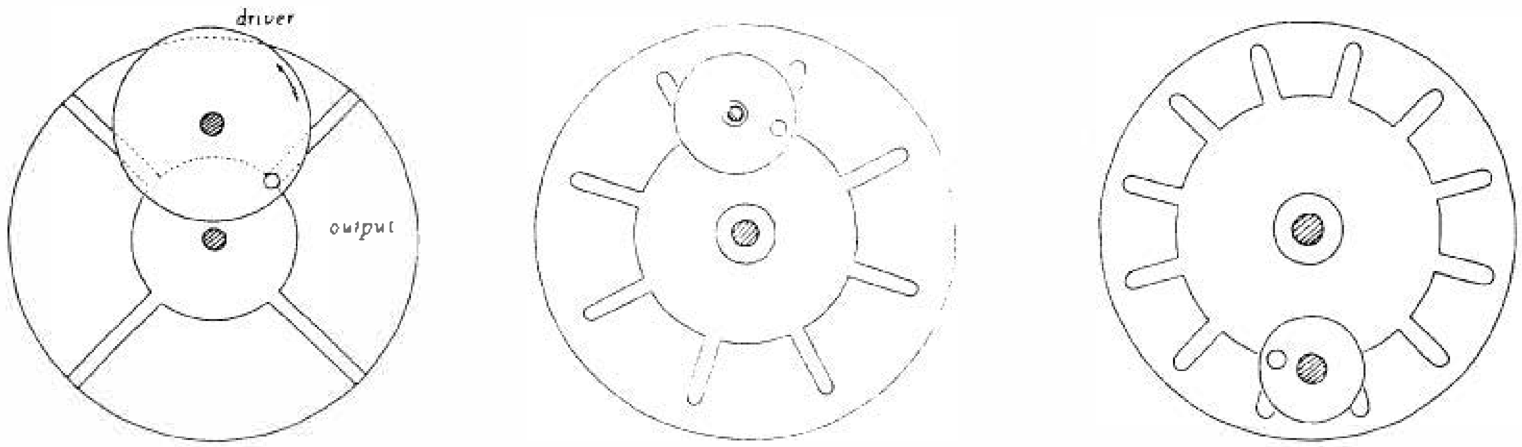
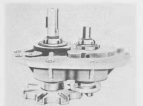


Fig. 9–11. Internal Genevas with four, eight, and twelve slots.



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shafts. Some designers [illegible] disadvantage [illegible]

F[illegible] 9–12 shows a package[illegible] Four, five, six, or eight slot designs are available in several sizes. Various manufacturers provide ready-made [illegible]

In Fig. 9-13, a Geneva [illegible] n be seen between the first and second wheels of a small instru[illegible] ce impacts [illegible] d otherwise be obtained [illegible] use of mutilated pinions (described in Chapter 10) in the machine. The counter is about three inches long.

The drawings of Fig. 9-14 show a Geneva mechanism used in the indexing system of a large multiple-spindle machine tool. This mechanism is a five-step [illegible] The drive slots [illegible] adjustable members to allow perfect alignment between the slot centerline and the direction of motion of the drive pin as it enters a slot. A Geneva is used for rough indexing of the spindle, while fine indexing is accomplished by cam-driven locating fingers that are not shown in this illustration. (See Fig. 1–1.)

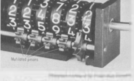
A six-slot external Geneva mechanism (Fig. 9–15) is used for light-duty instrument applications. The configuration of both driving and driven members has been altered to provide a longer locking surface [illegible] driven w[illegible] ould be [illegible] wit[illegible] [illegible]tional six [illegible] a. In ot[illegible] [illegible] higher p[illegible] [illegible] one result of the changes, [illegible]ver, the drive [illegible] must now enter t[illegible] th[illegible] driven [illegible]heel at [illegible] angle, rather than enter them tangent to the slot [illegible] ave seen, this will cause impact, etc.; therefore, this design could only be used at slow speeds or with light loads. Furthermore, the entrance to the slot has been chamfered, so that the drive pin will tend to align the output member as it enters the slot, if there has been any preliminary motion or misregistration in the driven member.

Output to input motion ratios can be altered by providing multi-pin drivers, as with the four-slot external Geneva with a three-pin driver, shown in Fig. 9–16. Although the designer will find that he does not have a great deal of flexibility—two, three, and sometimes even four pins are possible.

Figure 9–17 shows a four-slot Geneva driven by a two-pin driver. In the arrangement shown, the output will dwell for a long period and a short period, alternately, as the input rotates.

Very long dwell periods can be obtained if the drive pin is mounted on a chain, as shown in Fig. 9–18, instead of on a wheel. One of the pins in the chain is replaced by an extra-long pin which serves as a driver. More than one chain pin could, of course, be replaced by a drive pin. Most links in the chain [illegible] provided [illegible] ~~locking surfaces for the Geneva during dwell periods.~~ [illegible] ew links [illegible]

The external Geneva [illegible]stration, Fig. 9–19, [illegible] by [illegible] disc. This accomplishes several things. The dwell period of the Geneva is increased with respect to [illegible] tial and f[illegible] ccelerations



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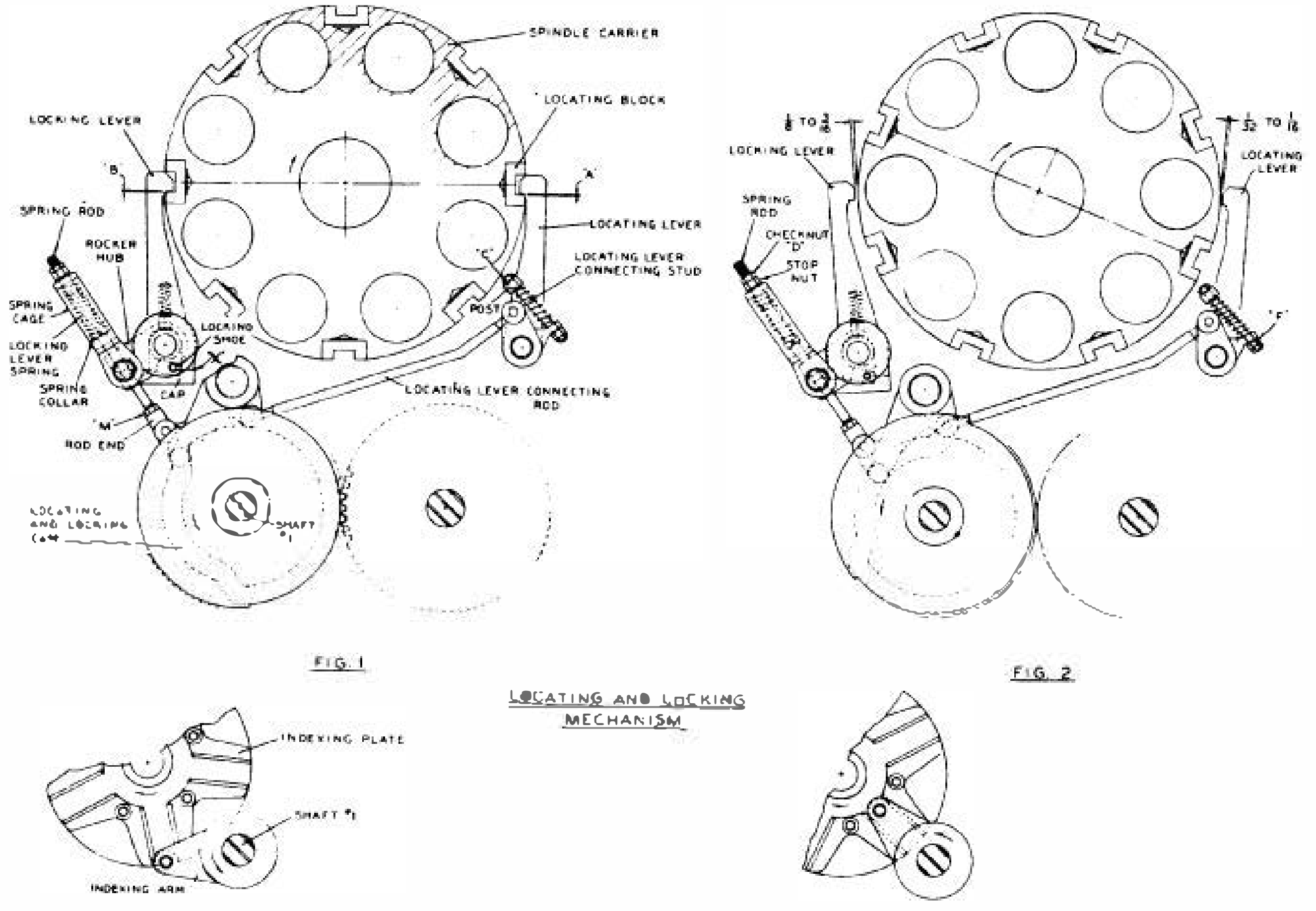

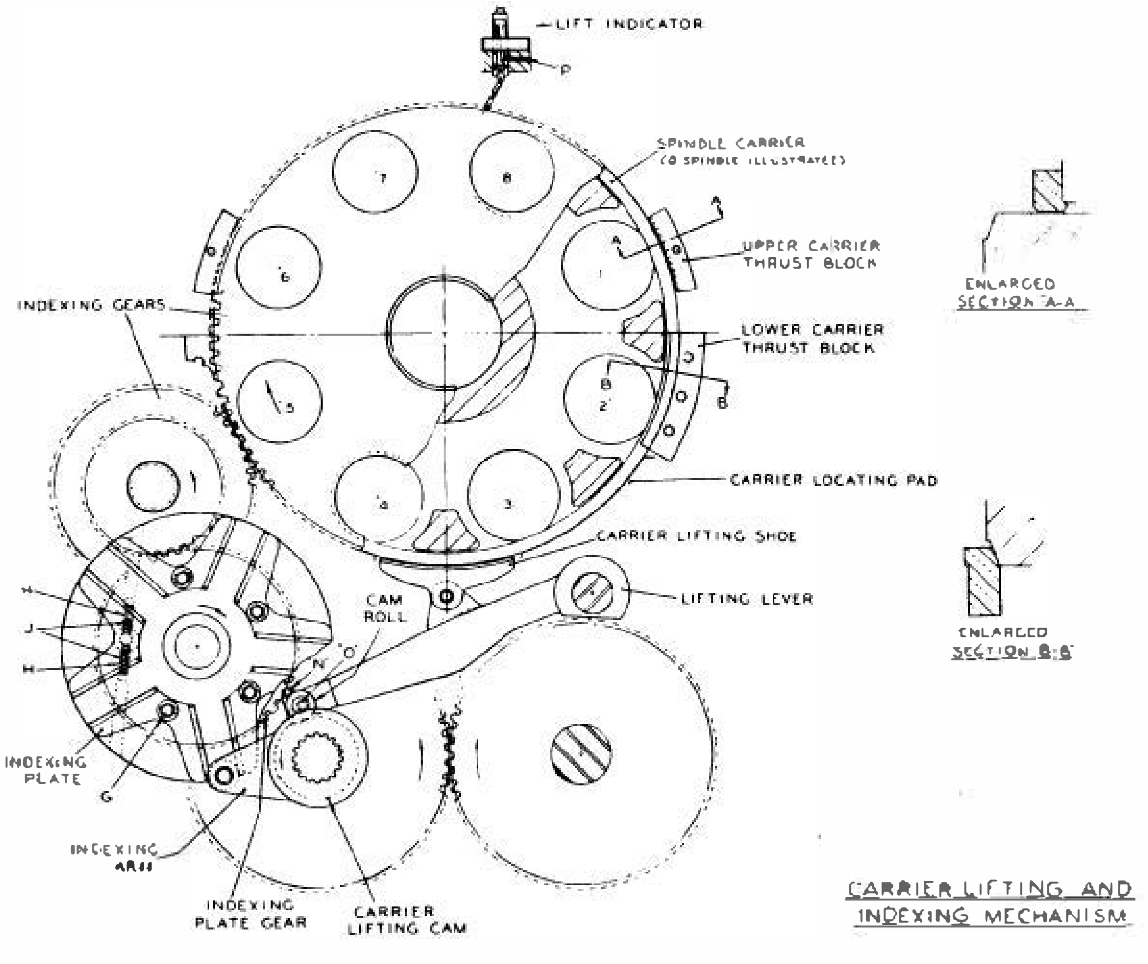

Drawing courtesy of the New Britain Machine Company

Fig. 9-14. Five-step Geneva mechanism used in the indexing system of a large multiple-spindle machine tool.

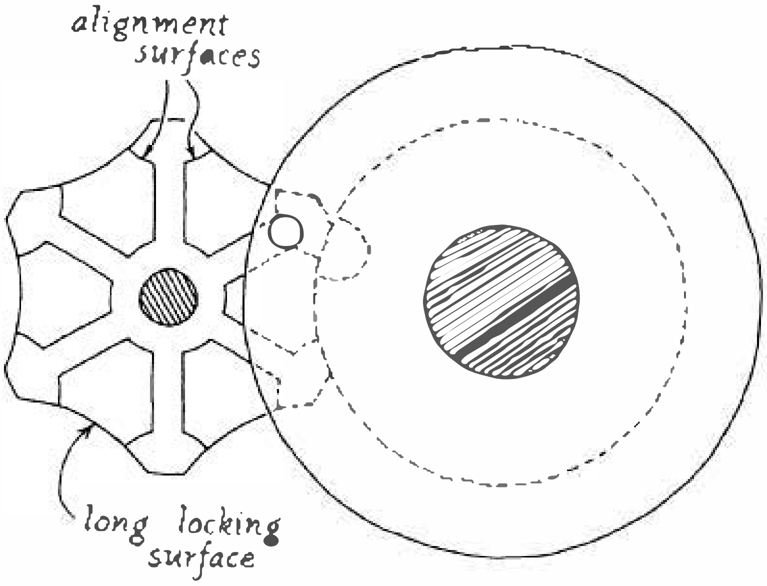

Fig. 9-15. Six-slot external Geneva used for light-duty instrument applications.

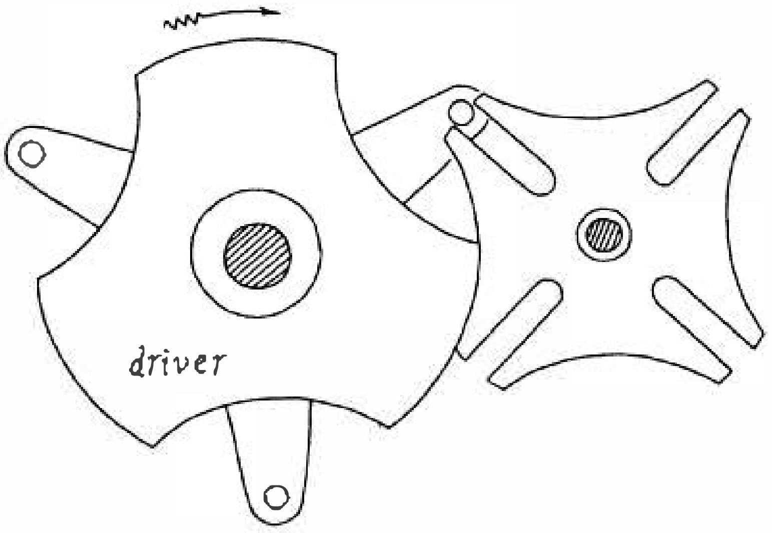

Fig. 9-16. Four-slot external Geneva with three-pin driver.

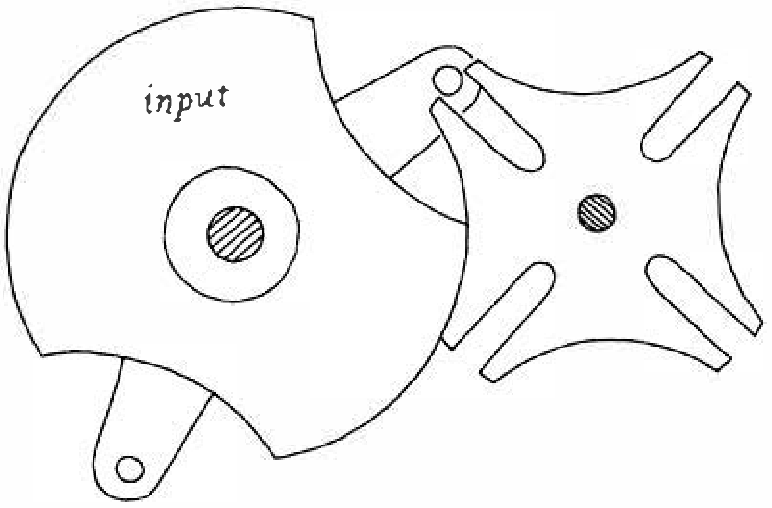

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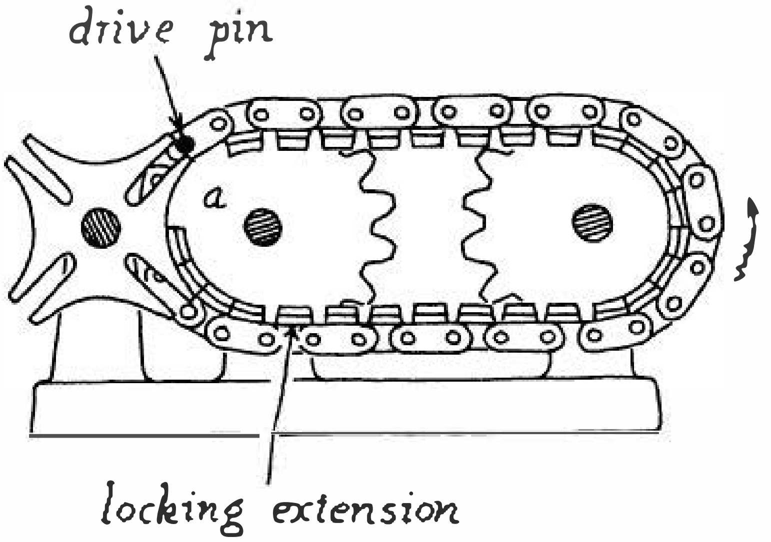
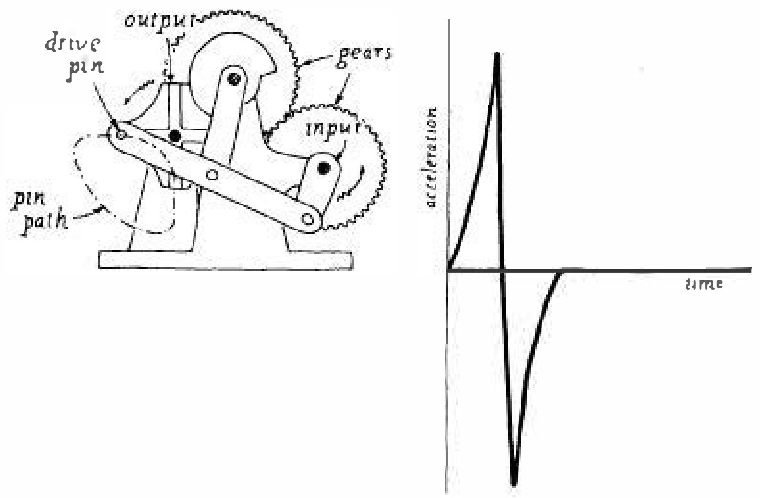
Fig. 9-17. Four-slot Geneva driven by a two-pin driver.



Drawing courtesy of PRODUCT ENGINEERING Magazine; June 8, 1964: pp. 67, 68

Fig. 9-18. Chain-mounted drive pins with blocks for locking during dwells.



Drawing courtesy of PRODUCT ENGINEERING Magazine; June 8, 1964: pp. 67, 68

Fig. 9-19. (*Left*) External Geneva driven by a four-bar linkage. (*Right*) Acceleration curve.

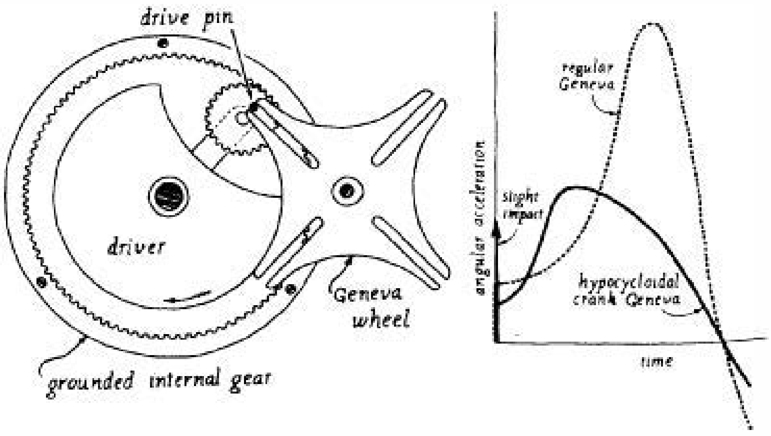


Fig. 9-20. (*Left*) Four-slot external Geneva driven by a hypocycloidal crank mechanism. (*Right*) Comparative acceleration curves.

are zero, not finite, thus eliminating the jerk associated with a conventional Geneva. Since the four-slot Geneva wheel must still rotate 90 degrees with each drive cycle, however, and is now doing it in a shorter length of time (longer dwell period), peak accelerations and velocities are greater here than for a conventional Geneva, as suggested by the acceleration curve.

A four-slot external Geneva driven by a hypocycloidal crank mechanism is illustrated in Fig. 9–20. A gear train is used to reduce the velocity of the drive pin at the moment it enters the slots in the Geneva wheel. The acceleration curves provided here show that there is a "theoretical" slight impact as the drive pin starts the Geneva in such a situation, but in actual practice this impact probably would not be noticeable. A hypocycloidal drive also reduces peak acceleration as can be seen by comparison with the acceleration curve for a regular four-slot Geneva.

Dec. 3, 1968 G. H. ARNOLD 3,413,874

SHAFT CYCLING MECHANISMS

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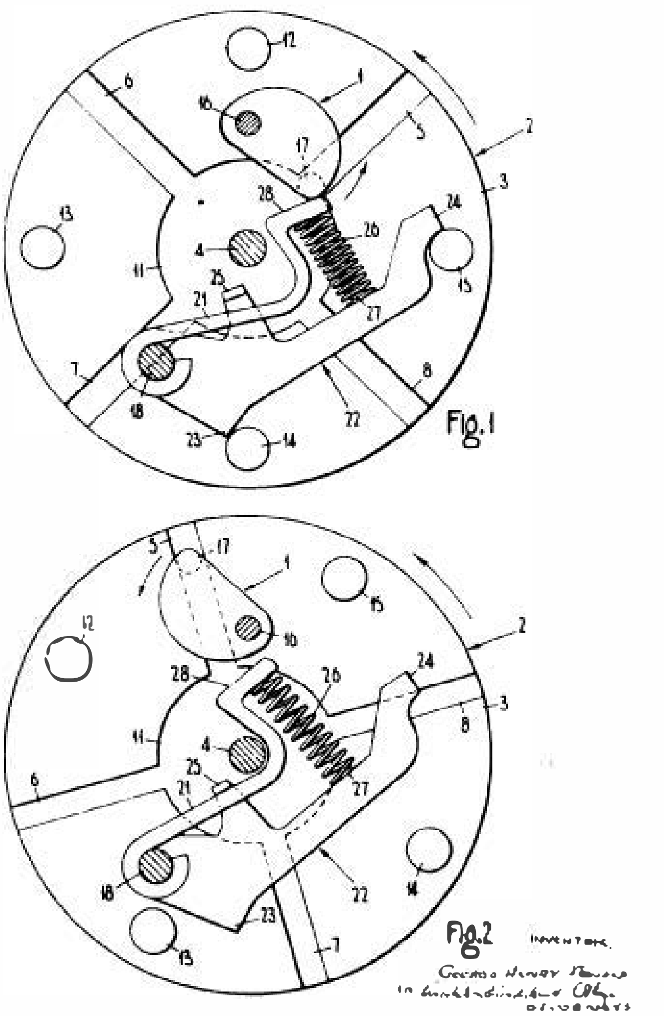
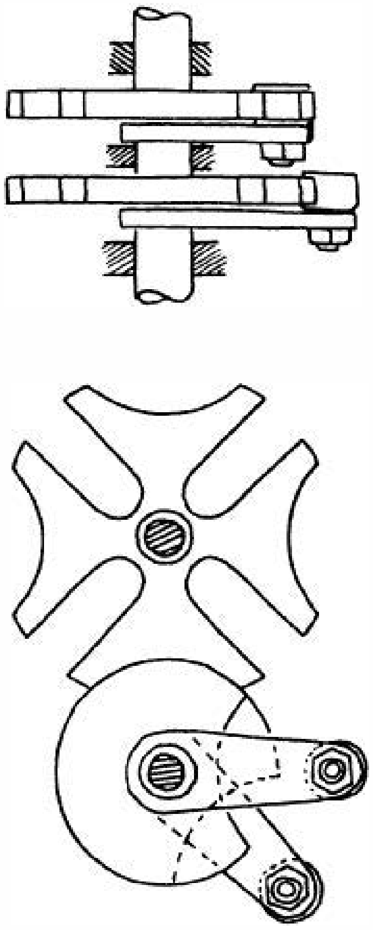


Fig. 9–21. Four-slot internal Geneva with friction grip control of output. (U.S. Patent 3,413,874; G. H. Arnold.)



Drawing courtesy of PRODUCT ENGINEERING Magazine; Oct. 26, 1964; pp. 109, 110

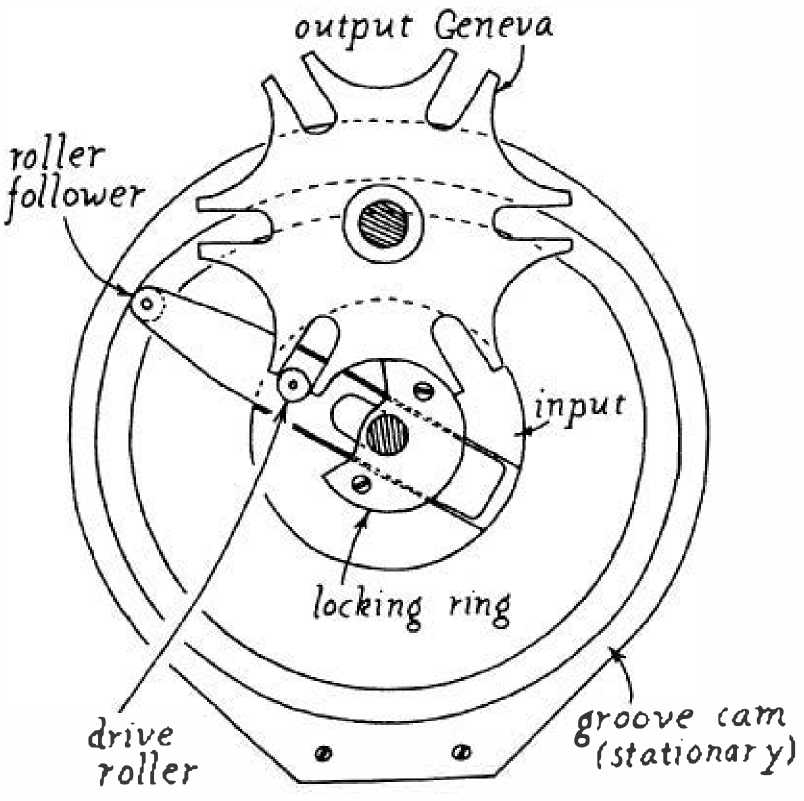
Fig. 9–22. Twin Geneva drive. Note in the top view that the two Geneva wheels are in exactly the same position.

In the illustration here, only half of the acceleration curve is shown for each device.

A friction grip is sometimes used instead of a locking ring to control the output member during dwell periods. In the diagram (Fig. 9–21) of a four-slot internal Geneva, the locking member *28*, engages the output shaft *4*, to which the output wheel *2*, is connected. Cam *1*, containing drive pin *17*, regulates the motion of the locking member. This friction lock would probably only be satisfactory for light-duty applications.

Figure 9–22 illustrates a twin Geneva drive. The output from one Geneva can act as a driver, or input, to a second. Gears can also be introduced between the two, or on the output of the second to modify the motion even further. Tricks of this kind allow the designer to extend dwell periods, etc.

The drive pin in the groove-cam Geneva design shown in Fig. 9–23 does not operate on a fixed radius of the input member. Instead, its radius (and hence its tangential velocity) is controlled by a groove cam which moves the drive pin radially inward or outward, at the option of the designer, to



Drawing courtesy of PRODUCT ENGINEERING Magazine; Oct. 26, 1964: pp. 109, 110

Fig. 9–23. Groove cam Geneva.

modify the acceleration and deceleration characteristics of the Geneva quite significantly.

The locking slide Geneva, Fig. 9–24, is a variation of the four-bar drive system shown in Fig. 9–19. A pin on the slide crank engages the Geneva to lock the output member during dwell periods.

A modification of a four-slot internal Geneva is the internal groove Geneva shown in Fig. 9–25. With this design each roller exits and enters the driving slots tangentially, which is always desirable but sometimes difficult to accomplish with a conventional internal Geneva.

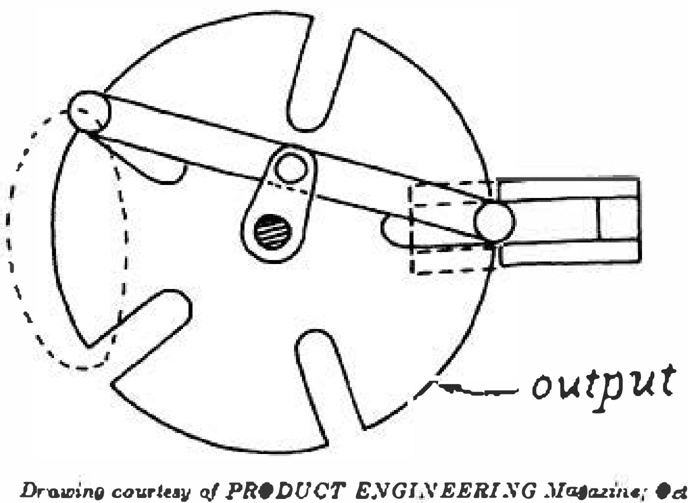


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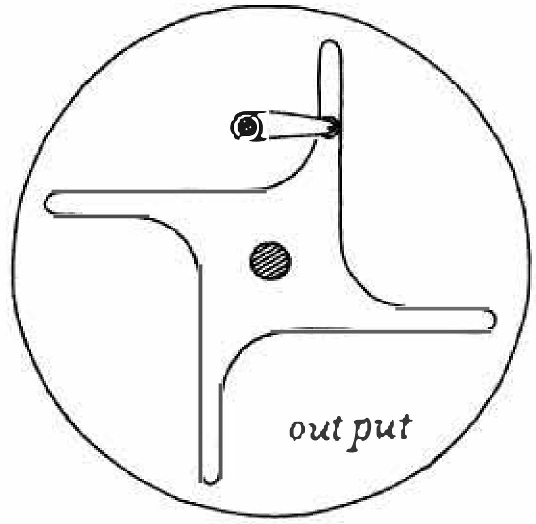
Fig. 9–24. Locking slide Geneva.



Drawing courtesy of PRODUCT ENGINEERING Magazine; Dec. 20, 1965: pp. 86–88

Fig. 9–25. Internal groove Geneva.

Figure 9–26 is a drawing of an external Geneva driven by elliptical gears. The drive pins do not enter the Geneva wheel slots tangent to the centerline, but pin velocity is at a minimum when they enter. And again, in the sketch to the right, the Geneva's motion curves can be seen to be modified drastically by this drive means.

In Fig. 9–27, a four-step sequence in the operation of a Geneva driven by an elliptical gear combination can be seen. It should be noted that the Geneva rotates 180 degrees in two steps for every revolution of the input.

Anatomy of the Geneva Mechanism

The designer should be completely familiar with the anatomy of a conventional Geneva and the

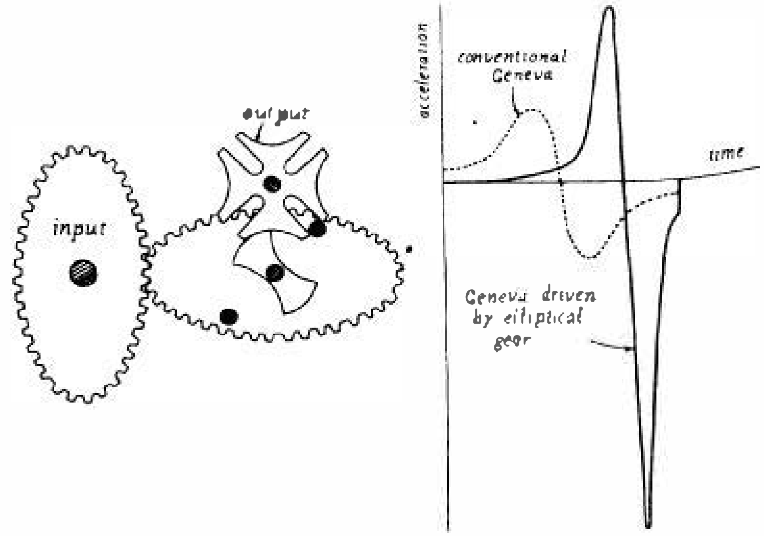


Fig. 9–26. (*Left*) External Geneva driven by elliptical gears. (*Right*) Comparative acceleration curves.

functions of its parts (Fig. 9–28)

A. Driver—rotates continuously; *B*. Geneva wheel (output)—rotates 90 degrees for every 360-degree motion of the input driver It [illegible] a maximum accelera[illegible] of approximately 5 radians/sec² for each revo[illegible] per minute [illegible] input. *C*. Drive [illegible] hardened steel or [illegible]valent and good fit in the drive slots of the Geneva wheel. Enters slot, moving parallel to the centerline of the slots fo[illegible] [illegible] "jerk." Cantilevered [illegible] most designs, yoke-mounted in some (supported at both ends) for maximum speed and load; *D*. Slot entrance—square, not chamfered, in best designs, where misalignment between drive pin and slot is eliminated by proper matching of *E* and *F*. Centerline of pin should be aligned with ends of slot when "contact" is first made; *E*. Locking ring on driver—hard, polished, smooth; used to hold driver during dwell periods. Must be good fit with *F* to guarantee proper location of drive slot-versus-drive pin at start of motion. *F*. One of four locking surfaces on Geneva wheel—the comments given for *E* apply here also; *G*. Bearings—should be sufficiently

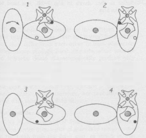


Fig. 9–27. Sequence of Geneva operation with elliptical gear combination drive.

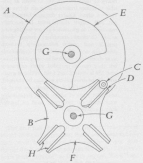
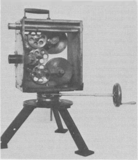


Fig. 9–28. [illegible]



British Crown copyright, Science Museum, London

Fig. 9–29. Antique cine-camera on a revolving stand, built in 1896 and used at Queen Victoria's Diamond Jubilee celebration. An early form of Geneva is used to index the film.

heavy to handle loads, yet as small as possible to reduce frictional drag on driver and Geneva wheel. Center distance between input and output shafts must be carefully maintained to guarantee proper locking-ring action (without cramping) during dwell periods and proper relationship between drive pin and drive slots. *H.* Replaceable wear shoes—not required in many situations, but they can be provided where extremely long life is desired and field service is available. If the drive rollers can also be changed, the system can be made nearly as good as new after years of active duty. Replaceable wear shoes are frequently used on heavy-duty machine tools.

Historical Note

Intermittent motion mechanisms are used to index film in cameras, projectors, film-processing equipment, etc. A wide variety of mechanisms has been used in photographic equipment right from the beginning. Such things as epicyclic gears, mutilated gears, and Genevas can be found in cameras and projectors built in the late 1800's. The photograph in Fig. 9-29 (British Crown copyright, Science Museum, London), is of Paul's Cine-camera on a revolving stand, which was built in 1896. A note on this print points out that this camera was used for the Diamond Jubilee; the celebration of the 60th year of Queen Victoria's reign. A Geneva mechanism, similar to that shown in Fig. 7–2B, was used to index the film.