EPICYCLIC GEARS.

Some Theoretical Considerations.

Number of Planet Pinions.

If the Planet Pinions are to be uniformly spaced, the number of teeth on the Annulus (Gear Ring) added to the number of teeth on the Sun must be divisible by the number of Planet Pinions.

1/2 x (number of teeth on Annulus - number of teeth on Sun) must be an integral number, to allow the Planet Pinions to have integral numbers of teeth.

Number of teeth on the Sun + 2 x teeth on the Planet Pinions = number of teeth on the Annulus.

Note. On the FW, FM, FC, ASC and the S5, the Planet Pinions have 14 teeth instead of the theoretically correct 15 teeth. The first models of the AF (later FC) and FM did have 15 teeth Pinions but these were changed in 1940 to 14 teeth. The PCD was retained thus giving a stronger tooth. The ratios were not affected by this change.

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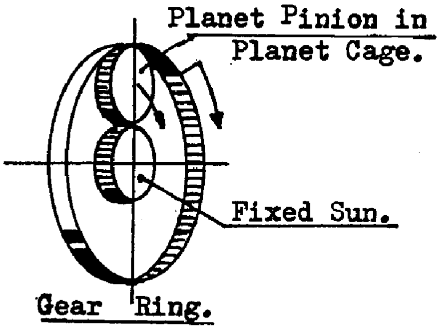
CASE 1. Single Stage, Sun Wheel Fixed.



T. = number of turns.

t. = Number of teeth.

This exercise is to develop a formula to cover the relationship between the number of turns made by the planet and the number of turns made by the annulus, (the gear ring) when the sun wheel is fixed.

a) The Planet is driving.

Assume the planet, sun and gear ring are locked together.
When the planet, which is driving, makes one turn forward, the sun and gear ring also turn one turn. However, the sun wheel should have remained fixed so it must now be turned back one turn to its original position. This has the effect of turning forward the gear ring by an amount corresponding to the number of teeth on the sun wheel.

We can sum up the movements.

The planet. = 1 turn.

The sun. = Fixed.

The gear ring = $1 \text{ turn} + \frac{t.sun}{t.gear}$. turns.

This can be written; $T.\text{gear ring} = 1 + \frac{t.sun}{t.gear}$ .turns.

This assumes one turn of the planet, to cover for T. turns of the planet this formula is re-written:

$$T.\ \text{gear ring} = T.\ \text{planet}\left[1 + \frac{t.sun}{t.gear}\right] \quad (1)$$

b) The Gear Ring is driving.

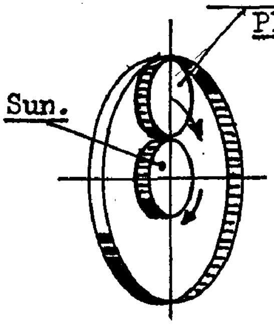
When the gear ring drives, we can find the movement of the planet by transposing the above formula.

$$T.\text{planet} = \frac{T.\text{gear ring}}{1 + \frac{t.sun}{t.gear}} \quad (2$$

CASE 2. Single Stage, Gear Ring Fixed.

T. = number of turns.

t. = number of teeth.



As in case 1, but in this instance the gear ring is fixed.

a) The Planet is driving.

Assume the planet, gear ring and sun are locked together. They all make one turn forward. However, the gear ring should have remained fixed, Therefore, with the planet remaining stationary, the gear ring is turned back to its original position. The sun wheel has already made one turn forward but it is now turned forward still further by an amount corresponding to the number of teeth on the gear ring.

To sum up the movements.

The planet = 1 turn.

The gear ring = fixed.

The sun = 1 turn + $\frac{t.gear}{t.sun}$ turns.

This can be re-written as follows;

$$T.sun = 1 + \frac{t.gear}{t.sun} \text{ turns.}$$

This formula assumes that the planet makes one turn.

To cover for T. turns of the planet this formula is re-written:

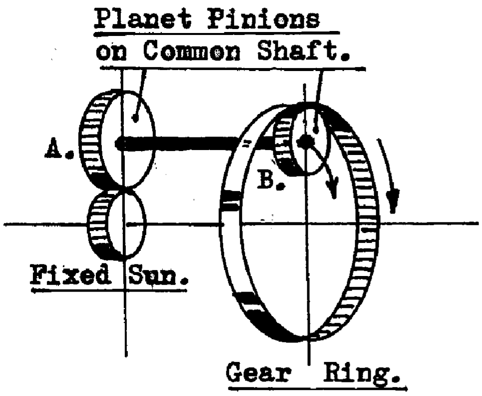
$$T.sun = T.planet \left[1 + \frac{t.gear}{t.sun}\right] \quad (3)$$

b) The Sun Wheel is driving.

When the sun wheel is driving, we can find the movement of the planet by transposing the above formula.

$$T.planet = \frac{T.sun}{1 + \frac{t.gear}{t.sun}} \quad (4)$$

CASE 3. Single Stage, Compound gear. with Sun Wheel fixed.



T. = number of Turns.

t. = number of teeth.

A & B are planet pinions on common shaft.

In the two previous cases it will have been noted that the number of teeth on the planet pinions did not enter into the calculations. They merely acted as idlers between the sun and the gear ring.

However, with the compound train now being considered, the number of teeth on the pinions A and B are taken into account.

Formula (1) is thus modified to take these pinions into account.

i.e. $\frac{t.sun}{t.gear}$ becomes, $\frac{t.sun}{t.A} \times \frac{t.B}{t.gear}$

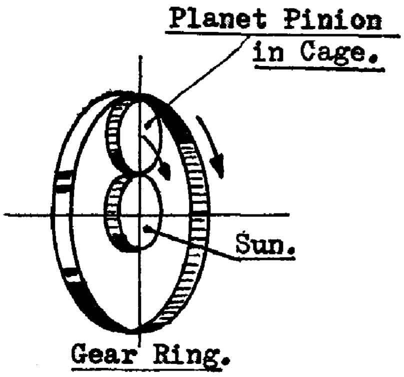
and the full formula is now,

$$T.gear\ ring = T.planet. \left[1 + \left[\frac{t.sun}{t.A} \times \frac{t.B}{t.gear} \right] \right] \qquad (5)$$

When the Gear Ring drives the formula 2 becomes,

$$T.planet = \frac{T.gear}{1 + \left[\frac{t.sun}{t.A} \times \frac{t.B}{t.gear} \right]} \qquad (6)$$

EXAMPLES OF SINGLE STAGE HUBS.



These hubs all use a single stage epicyclic gear train in which the sun wheel in fixed to the axle.

The ratios are above and below the normal direct gear.

Formula 1 is used for high gear.

" 2 is used for low gear.

HUBS AW & K.

Gear ring 60 teeth.
Sun wheel 20 "

High Gear.

$$\text{T.gear ring (hub)} = \text{T.planet}\left[1 + \frac{\text{t.sun}}{\text{t.gear}}\right]$$

$$= 1\left[1 + \frac{20}{60}\right] = 1.333$$

∴ 1 turn of planet = 1.333 turns of hub.

= 33.3% increase.

Low Gear.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear}}}$$

$$= \frac{1}{1 + \frac{20}{60}} = \frac{1}{1.333} = 0.75$$

∴ 1 turn of gear ring = .75 turns of hub.

= 25% decrease.

HUB SW.

Gear ring 52 teeth.
Sun wheel 20 "

High Gear.

$$\text{T.gear ring (hub)} = \text{T.planet}\left[1 + \frac{\text{t.sun}}{\text{t.gear}}\right]$$

$$= 1\left[1 + \frac{20}{52}\right] = 1.384$$

= 38.4% increase

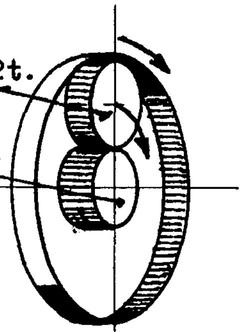
Low Gear.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear}}}$$

$$= \frac{1}{1 + \frac{20}{52}} = \frac{1}{1.384} = 0.723$$

= 27.7% decrease.

MODELS X. & BSA.



These hubs use a single stage epicyclic gear train in which the Sun wheel is part of the axle. The Planet Cage moves axially on this Sun and is in mesh for the three gears.

Slack wire	= Low Gear.	- 23.8%
Mid position	= Direct Gear.	0
Fully drawn out	= High Gear.	+ 31.25%

High Gear.

$$\text{T.gear ring (hub)} = \text{T.planet}\left[1 + \frac{\text{t.sun}}{\text{t.gear ring}}\right]$$

(Follow formula 1.)

$$= 1\left[1 + \frac{20}{64}\right] = 1.3125$$

$\therefore$ 1 turn of planet (driver) = 1.3125 turns of hub.

= 31.25% increase.

Low Gear.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear ring}}}$$

(Follow formula 2.)

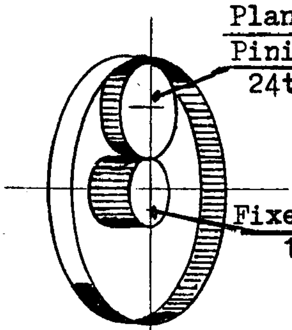
$$= \frac{1}{1 + \frac{20}{64}} = \frac{1}{1.3125} = 0.762$$

$\therefore$ 1 turn of gear ring (driver) = 0.762 turns of hub.

= 23.8% decrease.

Direct Gear. Driver connects via two sets of pawls to the hub.

MODEL OF 1902.



This hub uses a single stage epicyclic gear train in which the 16t Sun Pinion is part of the axle.
The Planet Cage moves axially on this Sun and is in mesh for the three gears.
Control wire is at the left hand side.

Slack wire,	High Gear,	+ 25%
Midway,	Normal,	0
Fully withdrawn,	Low Gear,	- 20%

High Gear. Gear Ring dogged to the Hub, Driver dogged to Planet Cage.

(Use formula 1.)

$$\underset{\text{(hub)}}{\text{T.gear ring.}} = \text{T.planet}\left[1 + \frac{\text{t.sun.}}{\text{t.gear ring.}}\right]$$

$$= 1\left[1 + \frac{16}{64}\right] = 1.25$$

∴ 1 turn of planet Cage. (driver) = 1.25 turns of hub.

= 25% increase.

Low Gear. Driver dogged to Gear Ring, Planet Cage dogged to Hub.

(Use formula 2.)

$$\underset{\text{(hub)}}{\text{T.Planet Cage.}} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun.}}{\text{t.gear ring.}}}$$

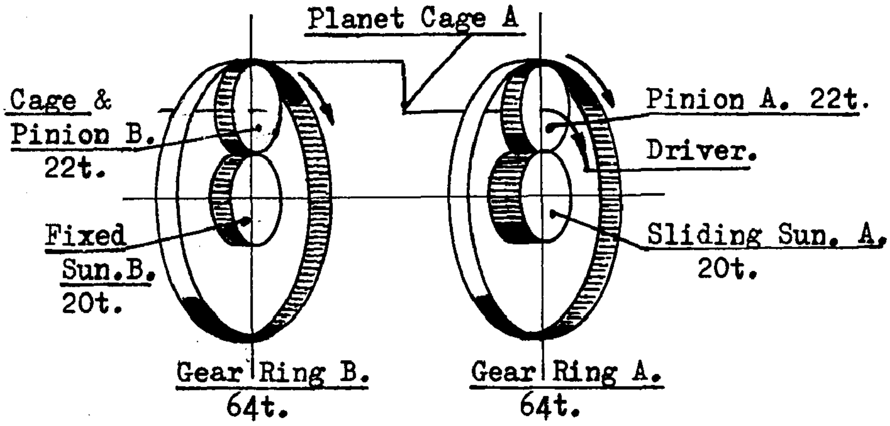
$$= \frac{1}{1 + \frac{16}{64}} = \frac{1}{1.25} = 0.80$$

∴ 1 turn of gear ring (driver) = 0.80 turns of hub.

= 20% decrease.

Direct Gear. Driver is dogged to Planet Cage,
Planet Cage dogged to Hub.

MODELS A. N. FN. & V.



+ 31.25%

Direct.

- 23.8%

These hubs have two gear trains A and B.

Gear Ring B, Planet Cage A and the Driver are in one piece. (see note.)

Planets A and Gear Ring A are used for high and direct gears.

Planets B and Gear Ring B are used for Low Gear.

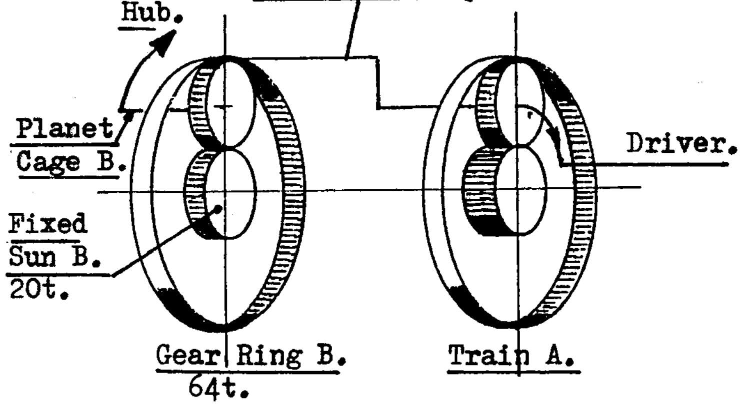
The Sun A can slide along the axle and is locked to the Planet Cage A for normal gear, and is locked to the axle for high gear.

For low gear the Sun A is in the middle position and is free.

Sun B is part of the axle.

Note. After c1918 the Driver was separated from the Planet Cage A and the Gear Ring B. Operation of the gear was exactly the same.

MODELS A, N, FN & V.



Low Gear. - 23.8%

Mid position of control wire. Sun of train A is free on axle.

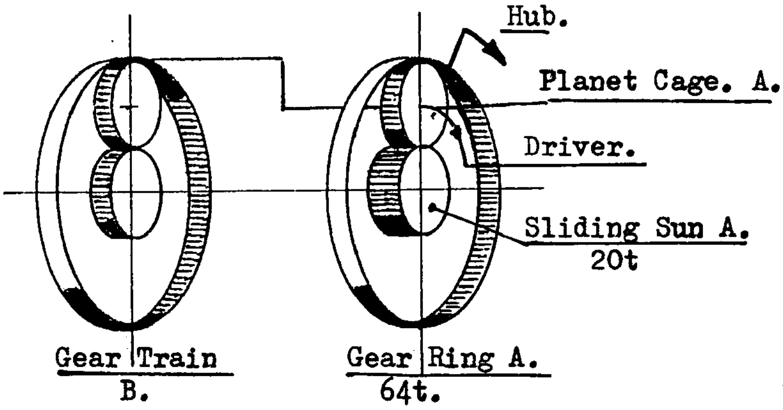
Drive is via Planet Cage A to Gear Ring B, thence at reduced speed to hub through Planet Cage B.

Single stage as formula 2.

$$\text{T. Planet B. (hub)} = \frac{\text{T.Gear Ring B. (driver.)}}{1 + \frac{\text{t.sun B.}}{\text{t.gear ring B}}}$$

$$= \frac{1}{1 + \frac{20}{64}} = \frac{1}{1.3125} = 0.762$$

∴ 1 turn of the Driver (Gear Ring B.) = 0.762 turns of the hub, = 23.8% decrease.



High Gear. + 31.25%

Control wire fully drawn out, this locks Sun A to axle.

Drive now passes from Planet Cage A to Gear Ring and thus to Hub via its own pawls.

Gear train B idles and pawls in gear ring B are overridden.

Single stage as formula 1.

$$\text{T. Gear ring A.} = \text{T. Planet A.} \left[1 + \frac{\text{t.sun A.}}{\text{t.gear ring A.}}\right]$$

$$= 1 \left[1 + \frac{20}{64}\right] = 1.3125$$

∴ 1 turn of Driver (planet) = 1.3125 turns of hub. = 31.25% increase.

Direct Gear.

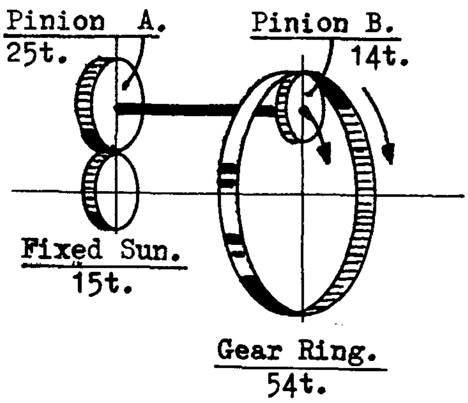
The control wire is slack for direct gear.

The sliding sun now locks with the planet cage A so that the gear train A rotates as a fixed unit.

Drive is via pawls in gear ring A to hub.

+ 15.55 %
Direct.
- 13.46 %

MODEL AM



This is a single stage compound gear with the sun wheel fixed.

The ratios are above and below the normal direct gear.

High gear follows formula 5.
Low " " " 6.

The planet pinions 14t and 25t are on the same shaft.

High Gear.

$$T.\text{gear ring (hub)} = T.\text{planet}\left[1 + \left[\frac{t.\text{sun}}{t.A} \times \frac{t.B}{t.\text{gear}}\right]\right]$$

$$= 1\left[1 + \left[\frac{15}{25} \times \frac{14}{54}\right]\right] = 1.1555$$

$$= \underline{15.55\%\ \text{increase.}}$$

Normal Gear. Direct.

Low Gear.

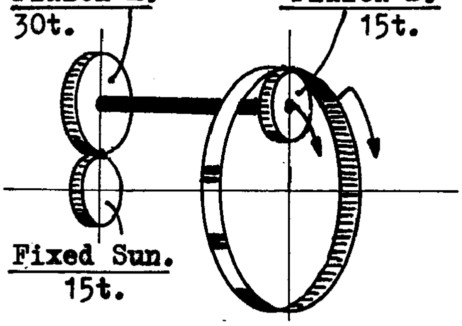
$$T.\text{planet (hub)} = \frac{T.\text{gear}}{1 + \left[\frac{t.\text{sun}}{t.A} \times \frac{t.B}{t.\text{gear}}\right]}$$

$$= \frac{1}{1 + \left[\frac{15}{25} \times \frac{14}{54}\right]} = 0.8654$$

$$= \underline{13.46\%\ \text{decrease.}}$$

MODEL KS.

+ 12.5%
Direct.
- 11.1%



This is a single stage compound gear with the sun wheel fixed.

The ratios are above and below the normal direct gear.

High gear follows formula 5.
Low " " " 6.

The planet pinions 15t and 30t are on the same shaft.

High Gear.

$$\text{T. gear ring (hub)} = \text{T.planet}\left[1 + \left[\frac{\text{t.sun}}{\text{t.A}} \times \frac{\text{t.B}}{\text{t.gear}}\right]\right]$$

$$= 1\left[1 + \left[\frac{15}{30} \times \frac{15}{60}\right]\right] = 1.125$$

= 12.5% Increase.

Normal Gear. Direct.

Low Gear.

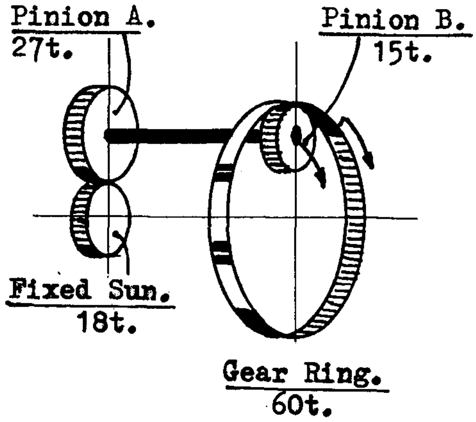
$$\text{T.planet (hub)} = \frac{\text{T.gear}}{1 + \left[\frac{\text{t.sun}}{\text{t.A}} \times \frac{\text{t.B}}{\text{t.gear}}\right]}$$

$$= \frac{1}{1 + \left[\frac{15}{30} \times \frac{15}{60}\right]} = 0.889$$

= 11.1% Decrease.

+ 16.66%
Direct.
- 14.29%

MODEL KSW.



This is a single stage compound gear with the sun wheel fixed.

The ratios are above and below the normal direct gear.

High gear follows formula 5.
Low " " " 6.

The planet pinions 15t and 27t are on the same shaft.

High Gear.

$$\text{T.gear ring (hub)} = \text{T.planet}\left[1 + \left(\frac{\text{t.sun}}{\text{t.A}} \times \frac{\text{t.B}}{\text{t.gear}}\right)\right]$$

$$= 1\left[1 + \left(\frac{18}{27} \times \frac{15}{60}\right)\right] = 1.1666$$

= 16.66% Increase.

Normal Gear.

Direct.

Low Gear.

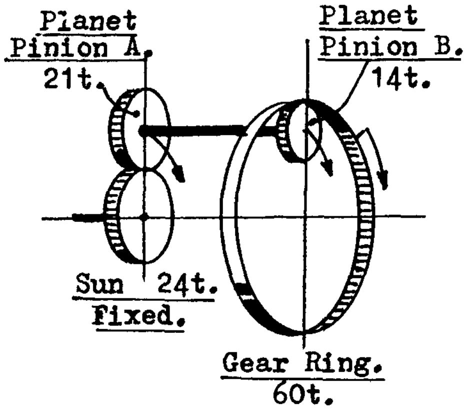
$$\text{T.planet (hub)} = \frac{\text{T.gear}}{1 + \left[\frac{\text{t.sun}}{\text{t.A}} \times \frac{\text{t.B}}{\text{t.gear}}\right]}$$

$$= \frac{1}{1 + \left[\frac{18}{27} \times \frac{15}{60}\right]} = 0.8571$$

= 14.29% Decrease.

MODEL FW.

+ 26.6%
Direct
- 21.1%
- 33.3%



For high and low gears, this hub utilises a single stage compound gear train.
The 24t. sun wheel is fixed.

For extra low gear the 24t. sun is free and the 30t. sun wheel is now fixed.
This is now a simple single stage gear train.

High Gear. (Formula 5.) The planet is driving, 1 turn.

$$\text{T.gear ring. (hub)} = \text{T.planet}\left[1 + \left(\frac{\text{t.sun}}{\text{t.A.}} \times \frac{\text{t.B.}}{\text{t.gear}}\right)\right]$$

$$= 1\left[1 + \left(\frac{24}{21} \times \frac{14}{60}\right)\right] = 1.2666 \text{ turns.}$$

= 26.6% increase.

Normal Gear Direct.

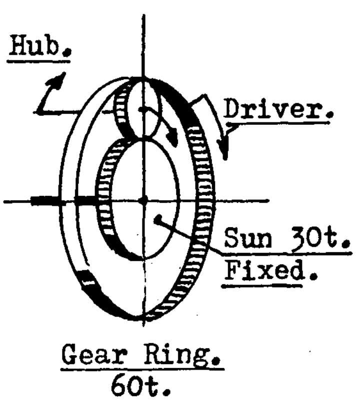
Low Gear. (Formula 6.) The gear ring is driving, 1 turn.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \left(\frac{\text{t.sun}}{\text{t.A}} \times \frac{\text{t.B}}{\text{t.gear}}\right)}$$

$$= \frac{1}{1 + \left(\frac{24}{21} \times \frac{14}{60}\right)} = \frac{1}{1.2666} = 0.789 \text{ turns.}$$

= 21.1% decrease.

Extra Low Gear. (Formula 2.) Gear ring drives, 1 turn.



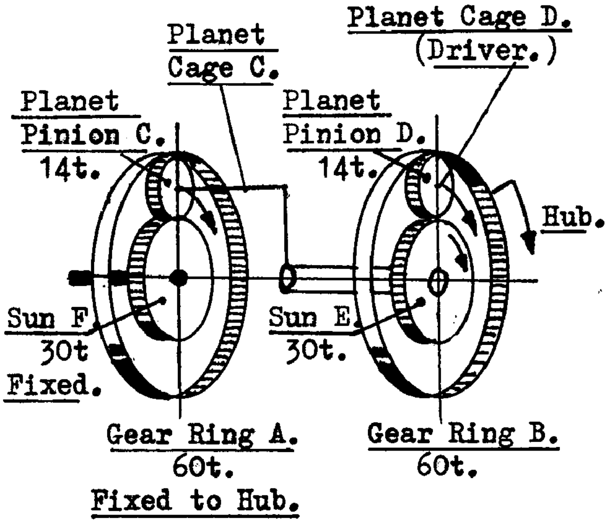
$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear}}}$$

$$= \frac{1}{1 + \frac{30}{60}} = \frac{1}{1.5} = 0.6666 \text{ turns.}$$

= 33.3% decrease.

<u>MODEL FM.</u>

<u>High Gear. + 12.5%</u>



This is a two stage gear in which the gear ring A is part of the hub.

In high gear the sun wheel F is fixed to the axle.

Sun wheel E is connected to planet C and turns with it.

Planet D is the driver and gear ring B is the driven member, being connected to the hub via its own pawls.

The low gear pawls in the planet C are overridden by the hub.

The hub, and hence gear ring A moves forward 1 turn.

From formula 2 we find that the planet C moves forward

$$\frac{1}{1 + \frac{30}{60}} = 0.6666 \text{ turns.}$$

∴ Sun wheel E also moves forward 0.6666 turns.

Now assume E is stopped and gear ring B moves 1 turn.

As calculated above, planet D turns forward 0.6666 turns.

But sun wheel E actually turned forward by 0.6666 turns. and this has the effect of turning planet D by an additional amount : as covered by formula 4.

$$\text{T.planet D} = \frac{\text{t.sun}}{1 + \frac{\text{t.gear}}{\text{t.sun}}} = \frac{0.6666}{1 + \frac{60}{30}} = \frac{0.6666}{3} = 0.2222 \text{ turns}$$

∴ The total movement of planet D = 0.6666 + 0.2222 = 0.8888.

Thus for 1 turn of the hub, the driver, planet D turns forward 0.8888 turns.

Therefore for 1 turn of the driver, the hub turns

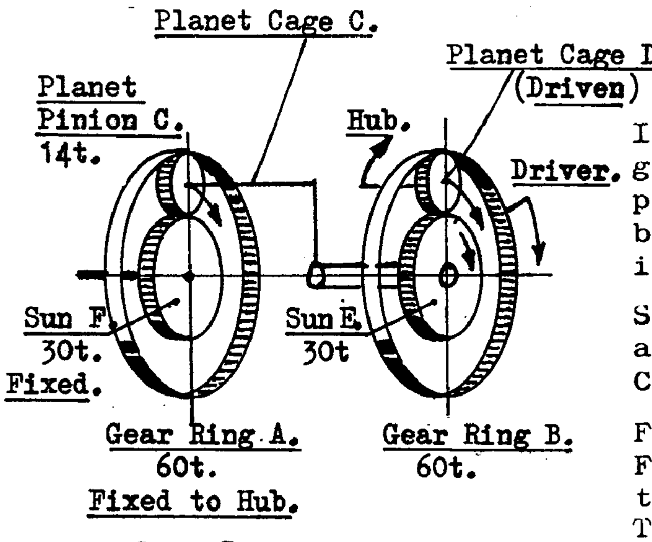
$$\frac{1}{0.8888} = 1.125 \text{ turns.}$$

= <u>12.5% increase.</u>

MODEL FM.

Low Gear - 14.31%

Extra Low. - 33.3%



Low Gear.

In the low gear position the gear ring B is the driver and planet D is the driven member being connected to the hub via its own pawls.

Sun wheel F is fixed to the axle and sun E is connected to planet C and turns with it.

For extra low gear, sun wheel F is free and sun E is fixed to the axle.
This is now a simple single stage gear train.

The hub, and hence gear ring A moves forward 1 turn.

As shown for the high gear, planet C and sun E move forward 0.666 turns.

Now assume E is stopped. from formula 1 we find that the gear ring B turns: $1 + \frac{30}{60} = 1.5$ turns.

But E actually turned 0.666 turns forward.

This has the effect of turning the gear ring B backwards by $0.666 \times \frac{30}{60} = 0.333$ turns.

$\therefore$ the driver, gear ring B actually moves $1.5 - 0.333 = 1.167$ turns.

Thus for 1 turn forward of the hub, the driver moves forward 1.167 turns.

Therefore for 1 turn of the driver, the hub turns

$$\frac{1}{1.167} = 0.8569 \text{ turns.}$$

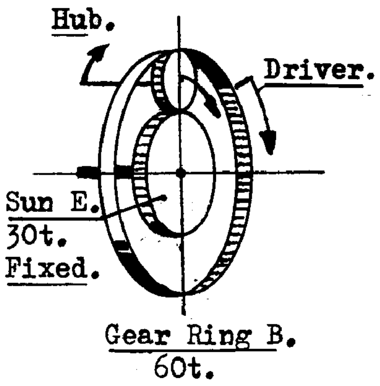
= **14.31% decrease.**

Extra Low Gear.

Using formula 2, the gear ring drives and makes 1 turn.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear}}}$$

$$= \frac{1}{1 + \frac{30}{60}} = \frac{1}{1.5} = 0.6666 \text{ turns.}$$

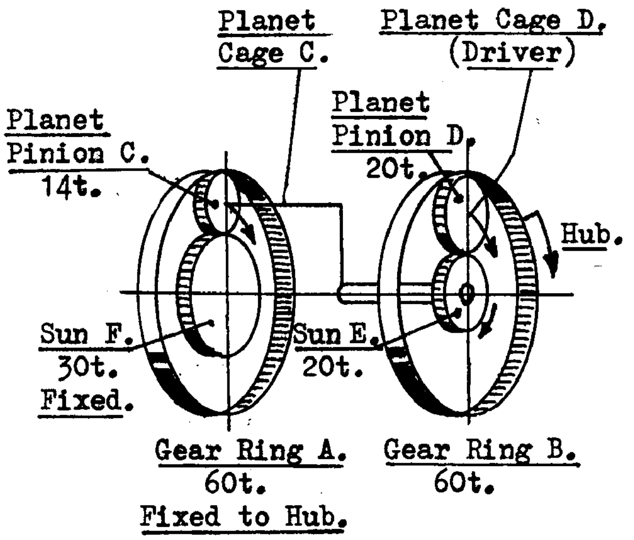


Therefore one turn of the gear ring (the driver) turns the hub 0.6666 turns.

= **33.3% decrease.**

MODEL FC.

High Gear. + 9.1%



This is a two stage gear in which the gear ring A is part of the hub.

In high gear the sun wheel F is fixed to the axle.

Sun wheel E is connected to planet C and turns with it.

Planet D is the driver and gear ring B is the driven member, being connected to the hub via its own pawls.

The low gear pawls in the planet C are overridden by the hub.

The hub, and hence the gear ring A moves forward 1 turn.

From formula 2 we find that the planet C moves forward

$$\frac{1}{1 + \frac{30}{60}} = 0.666 \text{ turns.}$$

∴ Sun wheel E also moves forward 0.666 turns.

Now assume E is stopped and gear ring B moves 1 turn.

Planet D, (from formula 2) moves forward

$$\frac{1}{1 + \frac{20}{60}} = 0.75 \text{ turns.}$$

But sun wheel E actually turned forward by 0.666 turns, and this has the effect of turning planet D by an additional amount: as covered by formula 4.

$$\text{T.planet D} = \frac{\text{t.sun}}{1 + \frac{\text{t.gear}}{\text{t.sun}}} = \frac{0.666}{1 + \frac{60}{20}} = \frac{0.666}{4} = 0.1665 \text{ turns}$$

∴ the total movement of planet D = 0.75 + 0.1665 = 0.9165 turns.

Thus for one turn of the hub; the driver, planet D turns forward 0.9165 turns.

Therefore for 1 turn of the driver, the hub turns

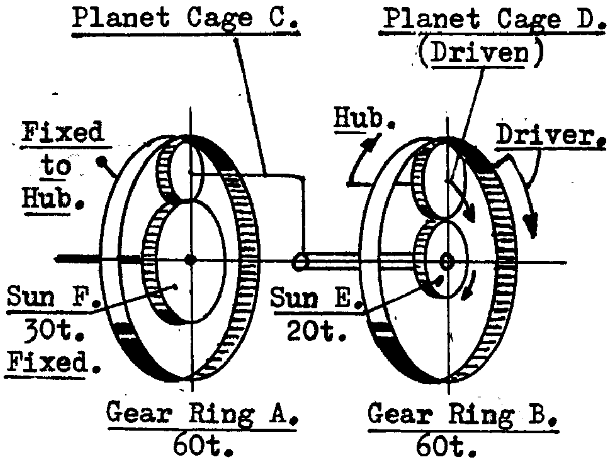
$$\frac{1}{0.9165} = 1.091 \text{ turns.}$$

= **9.1% increase.**

MODEL FC.

Low Gear. - 10%

Extra Low. - 25%



In the low gear position the gear ring B is the driver and planet D is the driven member being connected to the hub via its own pawls.

Sun wheel F is fixed to the axle and sun E is connected to planet C and turns with it.

For extra low gear, sun wheel F is free and sun E is fixed to the axle.

This is now a simple single stage gear train.

Low Gear.

The hub, and hence gear ring A moves forward 1 turn.

As shown for high gear, planet C and sun E move forward 0.666 turns.

Now assume E is stopped. Planet D moves forward 1 turn with the hub and thus turns the gear ring B, (form.1)

$$1 + \frac{20}{60} = 1.333 \text{ turns forward.}$$

However, E actually turned forward 0.666 turns, and this has the effect of turning the gear ring B backwards

$$\text{by } 0.666 \times \frac{20}{60} = 0.222 \text{ turns.}$$

$\therefore$ the driver, gear ring B actually moves 1.333 - 0.222

= 1.111 turns.

Thus for 1 turn forward of the hub, the driver moves forward 1.111 turns.

Therefore for 1 turn of the driver, the hub turns

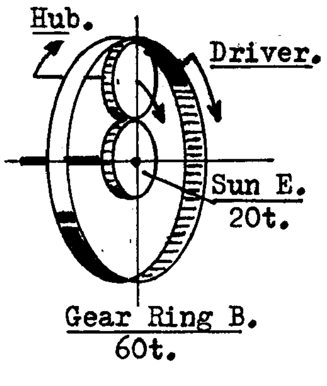
$$\frac{1}{1.111} = 0.90 \text{ turns.}$$

= **10% decrease.**

Extra Low Gear.

Using formula 2, the gear ring drives and makes 1 turn.

$$\text{T.planet (hub)} = \frac{\text{T.gear ring}}{1 + \frac{\text{t.sun}}{\text{t.gear}}}$$

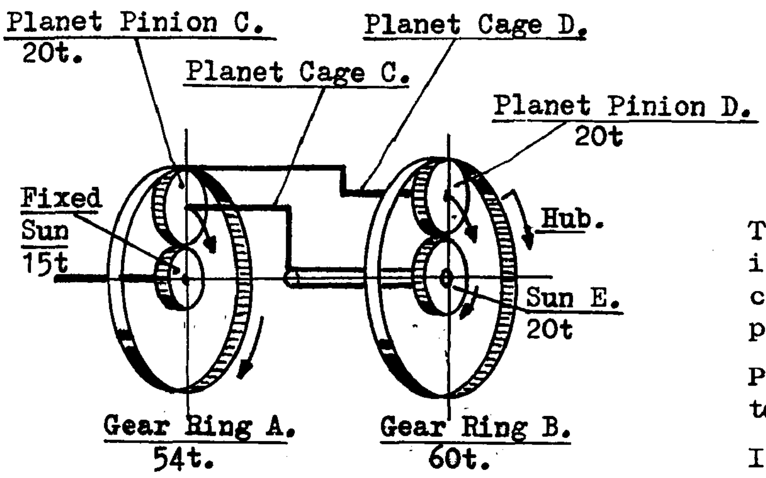


$$= \frac{1}{1 + \frac{20}{60}} = \frac{1}{1.33} = 0.75 \text{ turns.}$$

$\therefore$ One turn of the driver turns the hub 0.75 turns.

= **25% decrease.**

MODEL AR.



High Gear. + 7.24%

This is a two stage gear, in which gear ring A is connected directly to planet cage D.

Planet cage C is connected to sun wheel E.

In high gear the planet cage D drives, and gear ring B is the driven member, being connected to the hub via its own pawls. The low gear pawls in planet cage D are overridden by the hub.

The 15t. sun wheel is fixed to the axle. The sun wheel E of 20t. is part of planet cage C and rotates with it.

Assume sun E is stopped, and hub (gear ring B) turns forward 1 turn.

Planet cage D moves forward $\dfrac{1}{1 + \frac{20}{60}}$ = 0.75 turns. (from formula 2)

∴ Gear ring A also turns forward 0.75 turns.

Planet C turns forward $\dfrac{0.75}{1 + \frac{15}{54}}$ = 0.5870 turns. (formula 2)

The sun E is fixed to planet C, so it too turns forward by this amount which has the effect of winding back the gear ring B (and thus the hub) by:

$$0.5870 \times \frac{20}{60} = 0.1957 \text{ turns.}$$

Therefore the hub, (gear ring B) did not make a complete turn but actually turned 1 - 0.1957 = 0.8043 turns.

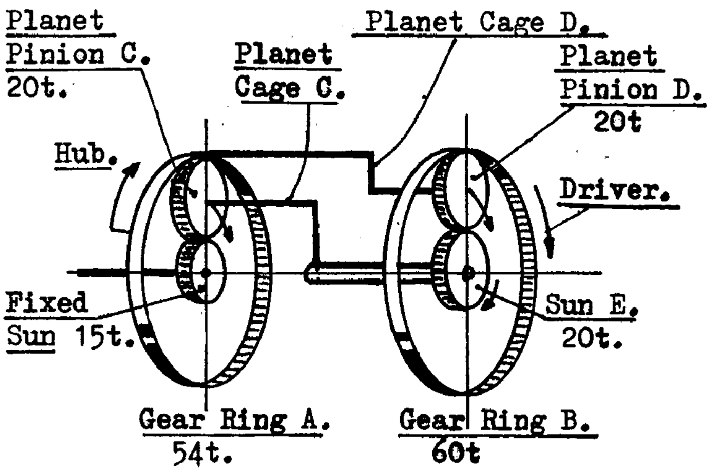
To sum up; the driver, planet D, turns 0.75 turns.
the driven, the hub, turns 0.8043 turns.

∴ for one turn of the driver, the hub turns:

$$\frac{0.8043}{0.75} = 1.0724 \text{ turns.}$$

= 7.24% increase.

MODEL AR.



Low Gear. - 6.75%

In the low gear position the gear ring B is the driver.

Planet cage D is the driven member and this is connected to the hub by the low gear pawls.

The 15t. sun wheel is fixed to the axle. The sun wheel E of 20t. is part of planet cage C and rotates with it.

Let the hub (and gear ring A,) move forward 1 turn.

The planet cage C, and with it the sun wheel E move forward by: $\dfrac{1}{1 + \frac{15}{54}} = 0.7827$ turns.
(from formula 2)

Assume sun wheel E is stopped, and the planet cage D turns forward 1 turn (together with gear ring A to which it is fixed); the gear ring B now turns forward:

$$1\left[1 + \frac{20}{60}\right] = 1.3333 \text{ turns.}$$

(from formula 1)

However, from above we know that the sun wheel E actually turned forward by 0.7827 turns.

This has the effect of winding gear ring B back by:

$$0.7827 \times \frac{20}{60} = 0.2609 \text{ turns.}$$

Therefore driver B actually turns 1.3333 - 0.2609
= 1.0724 turns.

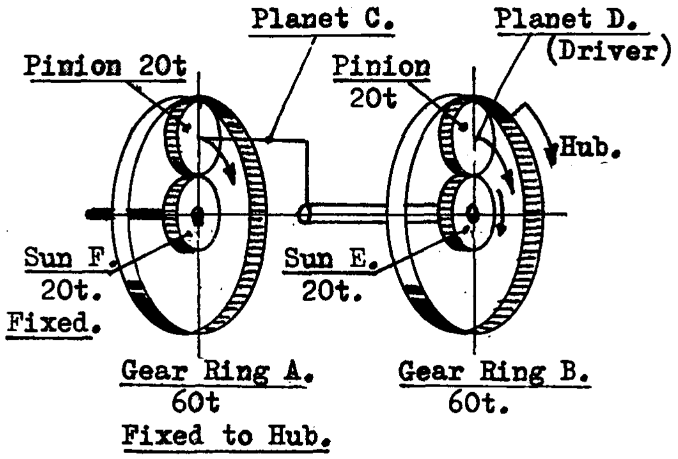
To sum up; 1.0724 turns of the driver, turns the hub by 1 turn.

∴ 1 turn of the driver turns the hub $\frac{1}{1.0724} = 0.9325$ turns.

= <u>6.75% decrease.</u>

MODEL AC.

High Gear. + 6.66%



This is a two stage gear. Gear ring A is part of the hub. Planet C is part of sun wheel E and they turn together.

In high gear the planet D drives, and gear ring B is the driven member, being connected to the hub via its own pawls.

The low gear pawls in the planet D are overridden by the hub.

The hub, and hence gear ring A moves forward 1 turn.

From formula 2 we find the planet C moves forward

$$\frac{1}{1 + \frac{20}{60}} = 0.75 \text{ turns.}$$

∴ Sun wheel E also moves forward 0.75 turns.

Now assume E is stopped and gear ring B moves 1 turn.

Similarly from formula 2 we fing the planet D moves forward by 0.75 turns.

But E actually moves forward by 0.75 turns, this has the effect of moving the planet D forward by an additional amount.

$$\text{T.planet D} = \frac{\text{t.sun}}{1 + \frac{\text{t.gear}}{\text{t.sun}}} = \frac{0.75}{1 + \frac{60}{20}} = \frac{0.75}{4} = 0.1875 \text{ turns}$$

(formula 4)

∴ The total movement of planet D is 0.75 + 0.1875

= 0.9375 turns.

Thus for 1 turn forward of the hub, the driver, planet D moves forward 0.9375 turns.

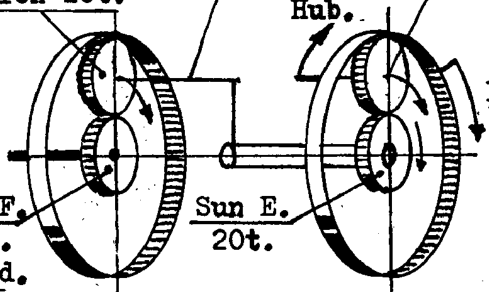
Therefore for 1 turn of the driver, the hub turns

$$\frac{1}{0.9375} = 1.0666 \text{ turns.}$$

= 6.66% increase.

MODEL AC.

Low Gear. -7.7%



In the low gear position the gear ring B is the driver and the planet D is the driven member, being connected to the hub via the low gear pawls.

Sun wheel E is part of the planet C and turns with it.

Gear ring A is part of the hub.

Hub and gear ring A make 1 turn forward.

Sun wheel E turns forward 0.75 turns. (see previous)

Now assume sun E stopped, from formula 1 we find that the gear ring B turns; $1\left(1 + \frac{20}{60}\right) = 1.333$ turns.

But sun E actually turned forward 0.75 turns.

This has the effect of turning the gear ring B backwards

$$\text{by } 0.75 \times \frac{20}{60} = 0.25 \text{ turns.}$$

$\therefore$ the driver, gear ring B actually turns $1.333 - 0.25$

$$= 1.083 \text{ turns.}$$

Thus for one turn forward of the hub; the driver, gear ring B turns 1.083 turns.

Therefore for 1 turn of the driver, the hub turns

$$\frac{1}{1.083} = 0.923 \text{ turns.}$$

$$= \underline{\underline{7.7\% \text{ decrease.}}}$$