

[54] **DRILLING APPARATUS**

[72] Inventors: **Roy H. Cullen; Jimmie R. Aker; William E. Burke**, all of Houston, Tex.

[73] Assignee: **Youngstown Sheet and Tube Company**, Youngstown, Ohio

[22] Filed: **March 19, 1970**

[21] Appl. No.: **21,120**

[52] U.S. Cl. **175/106, 74/801**

[51] Int. Cl. **E21b 3/08**

[58] Field of Search **175/104, 106, 101; 415/503; 74/801**

[56] **References Cited**

UNITED STATES PATENTS

2,654,572 10/1953 Aruntunoff 175/106 X
3,209,275 8/1965 Hoover 74/801 X

1,790,460 1/1931 Capeliuschnicoff 175/106
2,743,084 4/1956 Aruntunoff 175/104 X

Primary Examiner—Marvin A. Champion

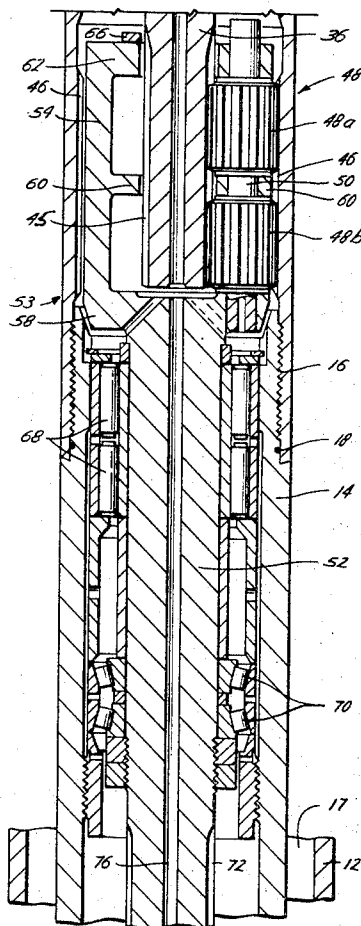
Assistant Examiner—Richard E. Favreau

Attorney—J. Vincent Martin, Joe E. Edwards, M. H. Gay, Alfred H. Evans and Jack R. Springgate

[57] **ABSTRACT**

This invention relates to drilling apparatus having a flexible drill string, a motor supported by the drill string, two-stage planetary gear-reduction means driven by the motor, and a drill bit driven by the gear-reduction means. In the gear-reduction means the second stage sun, planet and ring gears have increased longitudinal dimension for carrying the increased torque loading, and the second stage planet gears are split into sections and supported at each end of each section to prevent excessive outward deflection of their bearing shafts.

3 Claims, 5 Drawing Figures



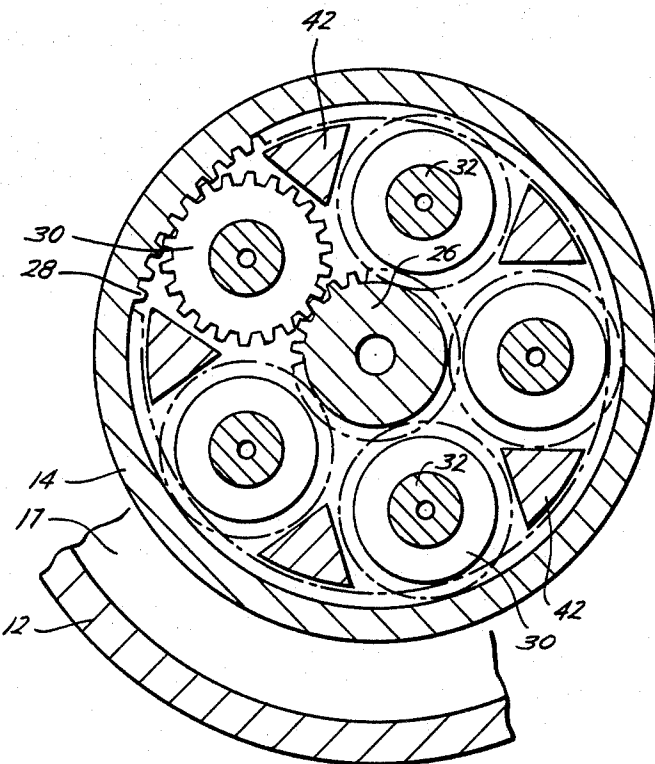
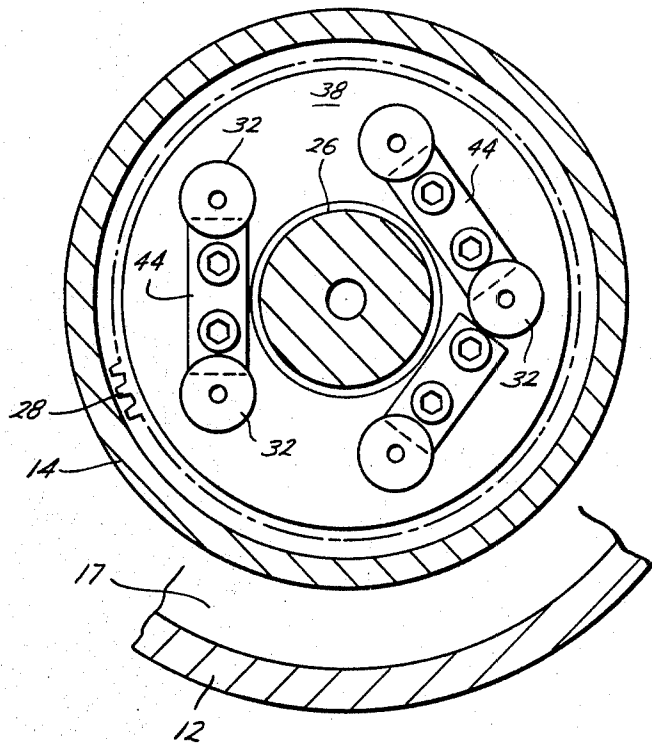
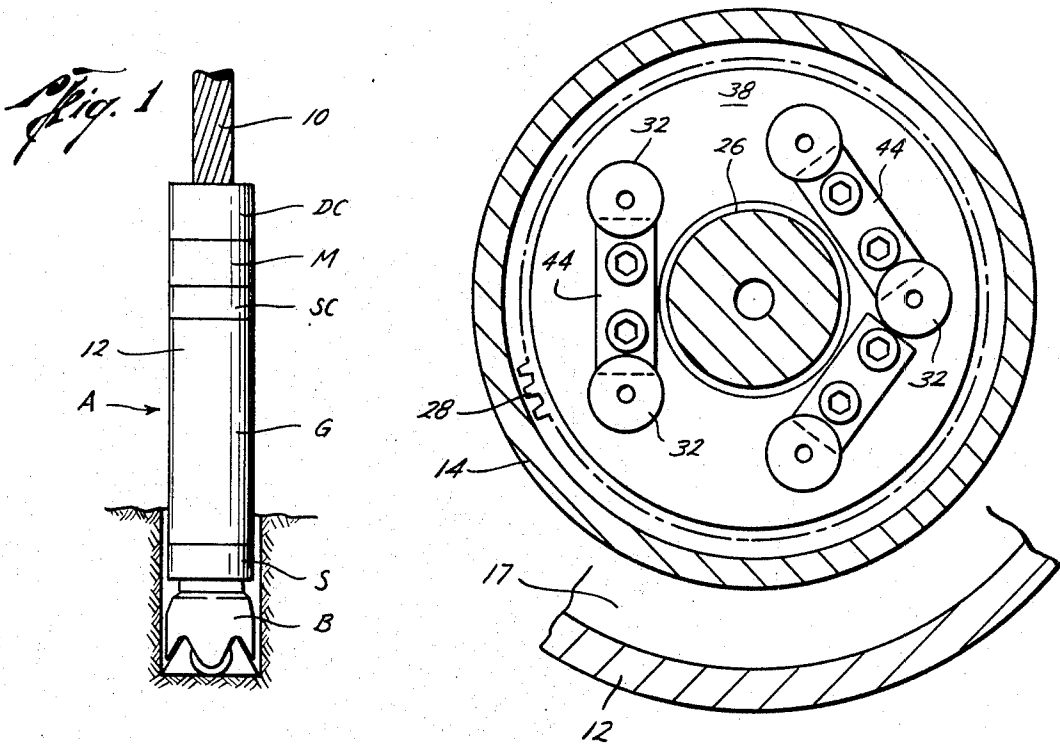
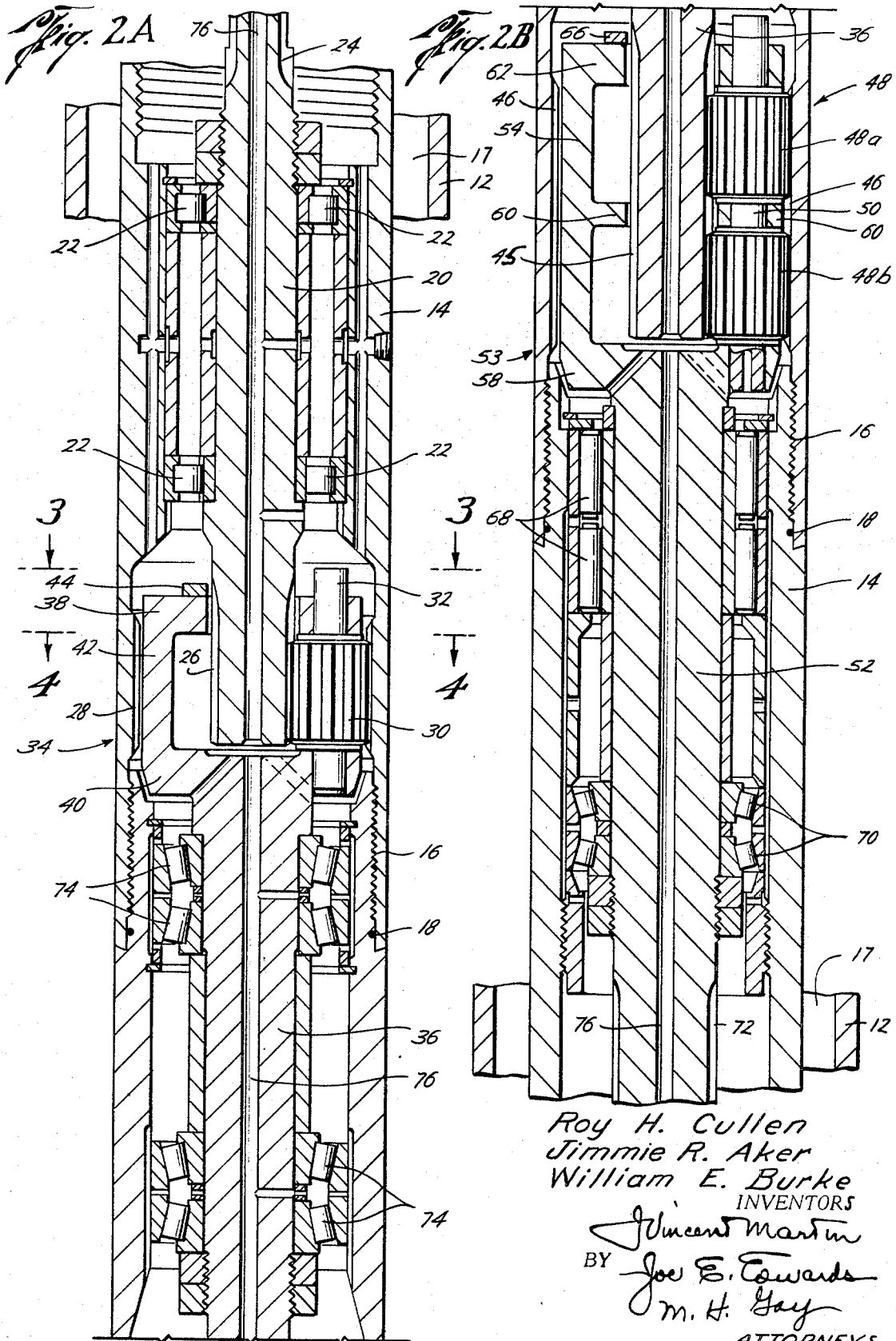


Fig. 3

Fig. 4

Roy H. Cullen
 Jimmie R. Aker
 William E. Burke
 INVENTORS
 BY *Vincent Martin*
Joe E. Edwards
M. H. Gay
 ATTORNEYS



Roy H. Cullen
Jimmie R. Aker
William E. Burke
INVENTORS

Vincent Martin
BY Joe E. Edwards
M. H. Gay
ATTORNEYS

DRILLING APPARATUS

This invention relates to drilling apparatus, and particularly to drilling apparatus wherein the drill bit is powered by a downhole motor through a novel two-stage planetary gear reduction.

Normally, wells are drilled using steel drill pipe for supporting and rotating a drill bit, power for rotation being obtained at the ground level through a rotary table and kelly. However, as illustrated in U.S. Patents No. 2,892,535; No. 2,915,323; No. 2,989,980; No. 3,004,779; No. 3,232,362; No. 3,285,629 and No. 3,291,230, it is now possible to construct a flexible drilling hose and apparatus for handling same so that the flexible hose takes the place of the former steel drill pipe. When such flexible hose is used, the drill bit is rotated by a motor, or other power source, located in the well bore in proximity to the drill bit. In such a drilling apparatus it may be desirable to provide gear-reduction means between the motor and the drill bit so that the motor may operate at a speed substantially greater than the bit to economically provide the torque necessary for operating the drill bit.

It is, therefore, an object of the present invention to provide such a drilling apparatus including novel gear-reduction means capable of transferring large torques within a relatively small diameter with minimal deflection.

Another object is to provide such an apparatus which is capable of transferring the substantial torque generated by the motor to a drill bit operating at a speed substantially less than that of the motor.

A further object is to provide a two-stage planetary gear-reduction which includes means for preventing outward deflection of the planet gear shafts and excessive planet gear bearing loads under heavy torque loading.

These and other objects and advantages of the invention will become apparent from the drawings, the specification and the claims.

In the accompanying drawings which illustrate the preferred embodiment of the present invention, and wherein like numerals indicate like parts:

FIG. 1 is a view in elevation schematically illustrating the drilling apparatus of the present invention;

FIG. 2A and FIG. 2B together form a view in section of the two-stage gear-reduction means of the drilling apparatus of the present invention;

FIG. 3 is a cross-sectional view taken on line 3—3 of FIG. 2A; and

FIG. 4 is a cross-sectional view taken on line 4—4 of FIG. 2A.

In the drawings, the letter "A" designates generally the well drilling apparatus of this invention which is adapted to be disposed in a hole for the drilling of an oilwell or the like. As schematically illustrated in FIG. 1, the apparatus A includes a flexible drill string 10 extending upward to the surface and supporting near its lower end suitable drill collars DC and a motor M for driving the drill bit B to drill the well. The motor M, which is preferably an AC electric motor, is interconnected with the drill bit for imparting rotation thereto and for accomplishing such drive a slip clutch SC, a gear-reduction G, and a shock absorber S are included in the connection between the motor and the bit. By reason of the present invention, the gear-reduction G permits the torque developed by the motor M to be multiplied and transferred to the drill bit B operating at a substantially slower speed. The preferred form of the gear-reduction G is illustrated in FIGS. 2A through 4.

The gear reduction has an outer housing 12 and an inner housing 14 which may be in multiple sections threadedly connected as at 16. The annular space 17 between the two housings permits the flow of drilling fluid past the gear-reduction mechanism to the drill bit below. O-ring seals 18 prevent the entry of fluid through the threaded connections 16 into the gear mechanism.

Within the inner housing 14 is disposed a first sun shaft 20, which is radially aligned within the housing by roller bearings 22 and has on its upper portion splines 24 to facilitate driving of the sun shaft 20 by the motor M through slip clutch SC.

A first sun gear 26 is provided on the first sun shaft 20, preferably by forming the lower end of the sun shaft into the desired sun gear configuration. A first ring gear 28 is integrally formed into housing 14 opposite sun gear 26.

A plurality of first planet gears 30 are disposed between the first sun gear 26 and first ring gear 28. As shown in FIG. 4, five such planet gears are provided rotatably mounted on first planet shafts 32.

Support means for supporting the first planet shafts 32 are provided in the form of a first planet carrier assembly indicated generally at 34, integrally formed onto a second sun shaft 36. The planet carrier assembly 34 comprises two annular discs 38 and 40 joined by five ribs 42. As shown most clearly in FIG. 4, the ribs 42 are of approximately triangular cross-sectional configuration so that they can be accommodated between the planet gears 30. The first planet shafts 32 have their ends journaled in the discs 38 and 40. As shown in FIG. 3, planet shafts 32 are locked against rotation relative to the discs by keepers 44 which are bolted onto the annular disc 38, and which engage notches in the shafts 32. The annular disc 40 is integrally formed onto second sun shaft 36 which is co-axial with the first sun shaft 20 and is adapted to rotate at a speed less than that of the first sun shaft. Thrust and radial alignment roller bearings 74 keep the second sun shaft properly aligned within housing 14.

A second sun gear 45 is formed on the lower end of sun shaft 36, and a second ring gear 46 is integrally formed into housing 14 opposite sun gear 45. A plurality of second planet gears 48 are disposed between the second sun gear 45 and second ring gear 46. Again, five such planet gears 46 are rotatably mounted on second planet shafts 50.

In the preferred embodiment, the first gear-reduction stage is 4 to 1 so that second sun shaft 36 rotates at $\frac{1}{4}$ the speed of first sun shaft 20. This 4 to 1 speed reduction results concomitantly in the torque loading on sun shaft 36 being four times as great as that on sun shaft 20.

The second gear-reduction stage is also 4 to 1 so that there is a 4 to 1 decrease in speed of rotation and a 1 to 4 increase in torque between second sun shaft 36 and the output shaft 52. This results in an overall speed reduction of 16 to 1 between the first sun shaft 20 and the output shaft 52, and a corresponding 1 to 16 increase in torque between the same two shafts. It is preferable to provide additional gear contact surface for transferring the greatly increased torque through the second reduction stage to the output shaft 52. Since the gear-reduction G, like any downhole tool, is severely limited in diameter, this additional gear contact surface is preferably provided by increasing the length of the various gears in the second reduction stage. Thus, as shown in FIG. 2B, the sun, ring and planet gears comprising the second reduction stage are of substantially greater length than those of the first reduction stage.

If the second planet gears 48 were merely longer than the first planet gears 30 and their planet shafts 50 were supported only at each end, there would be substantial danger of the planet shafts 50 undergoing excessive and undesirable outward deflection. This deflection problem is solved in the gear-reduction of the present invention by having each second planet gear 48 divided into two or more coaxial sections mounted on the second planet shafts and supporting the second planet shafts at each end of each coaxial section. This results in the second planet shafts having an unsupported span which is no longer than that of the first planet shafts. Consequently, the second planet shafts will have less outward deflection than if they were supported only at their ends.

With the combined length of the coaxial sections comprising the second planet gears being substantially greater than the length of the first planet gears, the second planet gears can transmit a substantially greater amount of torque than the first planet gears, while the provision of support means for supporting the second planet shafts at each end of each coaxial section prevents excessive outward deflection. Sectioning the second planet gears also provides an additional advantage in

that if the increased torque causes the longer sun gear 45 to twist slightly about its axis, the distortion will be divided among the several coaxial sections and will consequently be of less effect than it would on a single long planet gear.

Thus, as shown in FIG. 2B, each of the second planet gears 48 is composed of two coaxial sections 48a and 48b rotatably mounted on the second planet shafts 50. Each of the sections 48a and 48b is approximately as long as the first planet gears 30, so that each second planet gear 48 has a total effective length approximately twice that of each first planet gear. Second support means for supporting the second planet shafts 50 at each end of each coaxial section are provided by a second planet carrier assembly 53. The second planet carrier assembly comprises three annular discs 58, 60 and 62 joined by five triangular ribs 54. The second planet shafts 50 are journaled in all three discs with the two end discs 58 and 62 supporting the ends of shafts 50, and the middle disc 60 supporting the shafts 50 intermediate the two sections 48a and 48b of each second planet gear 48. The middle disc 60 thus provides additional support to prevent outward deflection of the second planet shafts 50 and more evenly distributes the load on the planet gear bearings. Keepers 66 on disc 62 lock the planet shafts against rotation relative to the discs. The first disc 58 is formed integrally with and rotates with the output shaft 52 which is coaxial with the second sun shaft 36 and rotates at a speed less than that of sun shaft 36. Roller bearings 68 and axial alignment and thrust bearings 70 keep the output shaft properly aligned within housing 14. Splines 72 are provided on the lower ends of output shaft 52 to facilitate the driving of the drill bit below through the intermediate shock absorber S. Oil conduits 76 are provided for circulating lubricating oil throughout the gear mechanism.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A drilling apparatus comprising:
 - a flexible drill string;
 - a motor supported by said drill string;
 - two-stage gear-reduction means driven by said motor;
 - and
 - a drill bit driven by said gear-reduction means;

said two-stage gear-reduction means comprising:
a housing;

first and second ring gears in said housing,

a first sun shaft driven by said motor,

a first sun gear on said first sun shaft,

a plurality of first planet gears disposed between said first sun gear and said first ring gear,

said first planet gears rotatably mounted on first planet shaft means,

first support means for supporting said first planet shaft means,

said first support means carried by a second sun shaft coaxial with said first sun shaft and adapted to rotate at a speed less than that of said first sun shaft,

a second sun gear on said second sun shaft,

a plurality of second planet gears disposed between said second sun gear and said second ring gear,

each second planet gear being composed of two or more coaxial sections,

said second planet gears rotatably mounted on second planet shaft means,

second support means for supporting said second planet shaft means at each end of each coaxial section,

said second support means carried by an output shaft coaxial with said second sun shaft and adapted to rotate at a speed less than that of said second sun shaft,

the combined length of said coaxial sections comprising said second planet gears being substantially greater than the length of said first planet gears,

thus permitting said second planet gears to transmit a substantially greater amount of torque than said first planet gears, while the second support means supporting the second planet shaft means at each end of each coaxial section prevents excessive outward deflection of said second planet shaft means.

2. A drilling apparatus according to claim 1, wherein the ratio of speed reduction through said first reduction stage is approximately equal to the ratio of speed reduction through said second reduction stage, and the total longitudinal dimension of each said second planet gear is approximately twice the longitudinal dimension of each said first planet gear.

3. A drilling apparatus according to claim 1 wherein each said second planet gear comprises at least two coaxial sections.

* * * * *

50

55

60

65

70

75