April 27, 1965 J. T. DEWAN 3,180,409

ORIENTING SYSTEMS

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Fig. 1

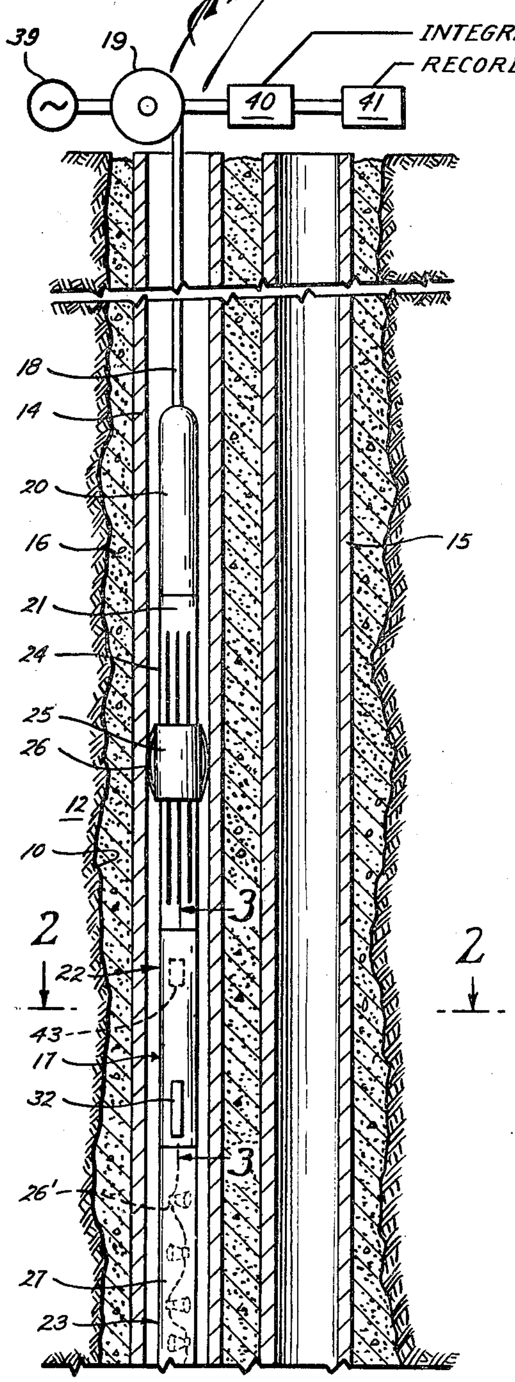

Fig. 3

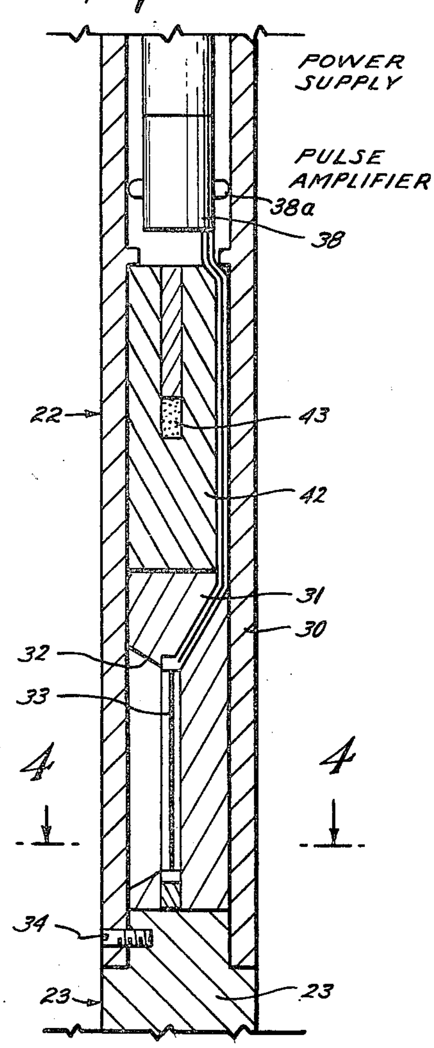

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Fig. 5

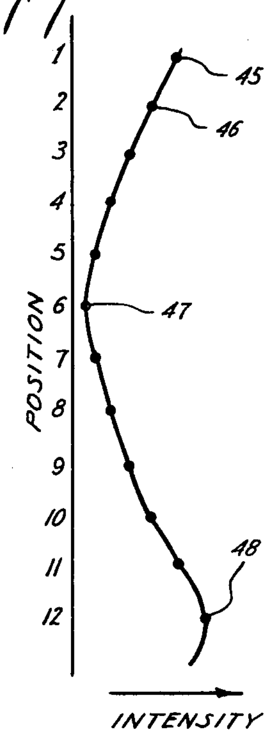
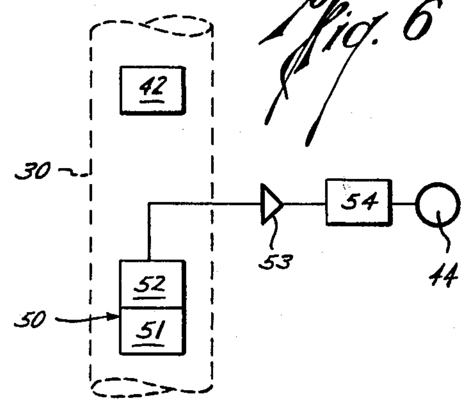


Fig. 6



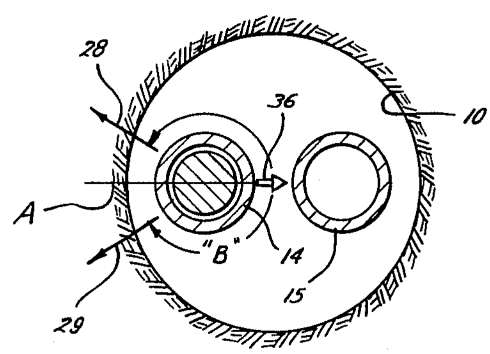
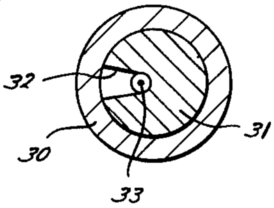


Fig. 2

Fig. 4



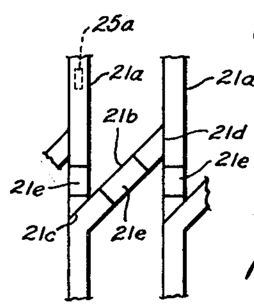


Fig. 7

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ORIENTING SYSTEMS

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Filed Sept. 29, 1959, Ser. No. 843,244
6 Claims. (Cl. 166—4)

This invention relates to methods of orienting and, more particularly, to methods for orienting the direction of firing of a perforating apparatus in one of a plurality of tubing strings in a borehole.

Multiple well completion techniques are concerned with the problem of obtaining independent production from a plurality of producing zones from a single borehole where the zones are spaced vertically from one another.

In one technique of multiple well completion, after the borehole has been drilled, the tubing strings are positioned with their respective lower ends at each of the production zones involved and the entire borehole filled with cement so that each tubing string effectively serves as a casing. Selective perforation of the various production zones may then be accomplished by apparatus disclosed in a copending application of M. P. Lebourg, Serial No. 760,138, filed September 10, 1958, and now abandoned in favor of application Serial No. 816,993 filed May 29, 1959, now Patent No. 3,168,141. Briefly described, a perforating apparatus in the aforesaid application is provided with an orienting means arranged to cooperate and align with a special locating collar inserted in a preselected position in a tubing string. The perforating or firing axis (or axes) of the perforating apparatus is located with respect to the orienting means and collar so as to avoid perforation of adjacent coextending tubing strings. While this apparatus is highly successful and satisfactory, it does require that the locating collar be positioned in a tubing string at the time the string of tubing goes into the well.

Another type of selective perforation for dual tubing strings in a well bore is disclosed in copending application Serial No. 795,099, filed February 24, 1959. In this application there is disclosed an apparatus which employs a directional radioactivity source associated in a predetermined relationship to the perforating axis (or axes) of a gun which is disposed in one tubing, while at the same level in another tubing, a radioactivity detector is disposed. The directional radioactivity source is adapted to be indexed relative to the tubing string in a predetermined manner so that the detector responds to radioactivity as the directional source is rotated relative to the string to obtain indications of the variations by radioactivity. Thus, the orientation of the radioactivity source relative to the detector may be determined and the source together with the perforating axis may then be directed so as to avoid interference with any adjacent tubing string. While this apparatus is commercially satisfactory, it is readily apparent that at least two winches and cables are required to lower the individual apparatus into the individual tubing strings. Therefore, it will be appreciated that a system for orienting the perforating apparatus which requires only one cable has definite advantages.

It is accordingly an object of the present invention to provide new and improved methods of orienting the firing axis of a perforating apparatus used in a multiple well completion.

Another object of the present invention is to provide new and improved methods of orienting perforating apparatus for multiple well completion using a single cable.

These and other objects of the present invention are achieved, in a borehole containing two or more strings of pipe, by emitting radioactivity-inducing radiation into the media surrounding the tubing at a given level. Thereafter, a perforating means having at least one laterally-

extending zone in which perforations are not produced is aligned in a preselected manner with a directional energy detecting device and attached thereto. The energy-detecting device is then disposed at the given radio-activated level. The detecting device and perforating means are then positioned at various rotative positions in the one tubing so that the induced activity in the adjacent string or strings of tubing may be selectively detected, thereby permitting location of any adjacent tubing strings by radioactivity measurements so that the perforator may be oriented to perforate in a selected direction.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention both as to its organization and manner of operation together with further objects and advantages thereof may best be understood by way of illustration and example of certain embodiments which taken in conjunction with the accompanying drawings in which:

FIG. 1 is an elevational view of an apparatus by which the present invention may be practiced as disposed in a tubing cemented in a borehole;

FIG. 2 is a cross-sectional view taken along line **2—2** of FIG. 1;

FIG. 3 is a view taken in longitudinal cross section along line **3—3** of FIG. 1;

FIG. 4 is a horizontal cross-sectional view taken along line **4—4** of FIG. 3;

FIG. 5 is a typical representation of indications obtained by a recording apparatus indicating various rotative positions of the tool in a string of tubing; and

FIG. 6 is a schematic representation of another embodiment of the present invention.

FIG. 7 is a partial plan view of a portion of the indexing system.

Referring now to the drawings, in FIG. 1, a borehole **10** extends transversely through earth formations **12** and contains strings of pipe **14**, **15** which extend coextensively of one another and may be cemented in place by a body of cement **16**. The pipe strings, for example, may extend to production zones at different levels. As will be described hereinafter, it is desired to perforate a pipe string disposed adjacent to another pipe string. It will be understood, however, that while the present invention will be described with respect to two strings of pipe, it is also applicable to bore holes containing three or more strings of pipe.

An elongated tool **17** by which the present invention may be practiced is adapted to be lowered and suspended in tubing string **14** at the level to be perforated by means of an armored electrical cable **18**. Cable **18** is spooled on a winch **19** which, in a customary manner, serves to raise and lower the tool through the tubing. The tool **17** includes a conventional cable head attachment and collar locator **20**, an indexing mandrel **21**, a radiation orienting device **22** and a perforating apparatus **23** which are interconnected endwise to one another to form a unitary assembly.

The indexing mandrel **21** is slidably received inside of a centralizer collar **25** which has centralizing springs **26** to frictionally engage with the inner wall of the tubing **14** in a conventional manner. The indexing mandrel **21** and collar **25** are arranged so that upon longitudinal or reciprocal movement of the cable **18**, the indexing mandrel **21** will rotate relative to the centralizer collar **25** and thus rotate the entire assembly relative to the tubing string. In this rotation device, the mandrel **21** is provided with circumferentially spaced vertical slots **21*a*** and inclined interconnecting slots **21*b***. Collar **25** has an indexing pin **25*a*** received in the slots system which is resiliently urged into contact with the bottom of the slots and cooperates with the inclined slots **21*b*** to cause the rotation of the mandrel **21** as the indexing pin is transferred between adjacent vertical slots **21***a*. Shoulders **21***c*, **21***d* in the slot system effect an irreversible transfer of the indexing pin from a vertical slot to an inclined slot and from an inclined slot to a vertical slot. Ramp portions **21***e* are provided in the slots **21***a*, **21***b* to effect the transfer of the pin **25***a* from the bottom of a slot to an elevation where the pin passes over a shoulder and again contacts the bottom of a slot. For further details of the indexing mandrel and collar, reference may be made to the aforesaid Lebourg application Serial No. 795,099 or to a copending application of C. P. Lanmon, filed February 24, 1959, Serial No. 794,877, now Patent No. 3,154,147.

The perforating apparatus **23** may be any one of the presently known commercial devices which is adapted to pass through tubing. For example, shaped charge perforating means **26′** may be disposed in a tubular housing **27** and be suitably interconnected in a well-known manner either for successive or simultaneous detonation. The firing axes (indicated by the arrows **28**, **29** in FIG. 2) of the perforating apparatus, that is, the axes along which the perforating jets travel are preferably phased at an angle of 30° on opposite sides of a longitudinal plane "A" which intersects the central axis of the tool assembly. With this arrangement, there will be a blind zone "B" of approximately 300° extending about the periphery of the perforating apparatus in which perforations are not produced, the zone "B" also extending longitudinally of the perforator. Obviously, the perforating axes **28**, **29** may be arranged to be coincident so as to fire only in one direction or can be aligned relative to one another in any preselected manner in harmony with the principles of the invention which hereinafter will be made more apparent.

The radiation orienting device **22** shown in more detail in FIG. 3 includes a tubular housing **30** constructed of a material such as steel relatively transparent to radiant energy such as gamma rays. Disposed within the lower end of housing **30** is a cylindrical shield **31** constructed of lead, for example, to block gamma radiation. Shield **31** has a vertically-elongated and narrow width opening or aperture **32** adjacent to a radiant energy detector **33**, for example, a Geiger-Mueller tube, which responds to gamma radiation in a well-known manner. The opening **32** thus permits gamma radiation to be detected in an essentially vertical directional pattern. The shield **31** is oriented relative to the perforator **23** so that detector **33** detects in a directional radiation pattern (indicated by the arrow **36**—FIG. 2) in a plane through a vertical axis of the housing which pattern essentially lies in plane "A" and is directed opposite to the direction to which the perforating jets will extend. A threaded connector **34** serves to secure the housing **30** to the perforator **23**.

Electrical conductors are connected between the detector **33** and an electrical device **38** in the upper end of the housing **30**, which electrical device includes a battery power supply and pulse amplifier (FIG. 3). Shock absorbers **38***a* can be used to mount the pulse amplifier **38** relative to the housing **30**. At the surface of the earth, an integrator **40** is coupled to a recorder **41**. The recorder **41** has a recording medium which is driven each time the tool is indexed. The integrator **40** is coupled via cable **18** to the pulse amplifier in device **38** to derive electrical indications of the intensity of the radiation. The details and operation of the electrical device **38** may follow conventional practice as shown in the Johnson Patent No. 2,852,-696 and thus a further description is deemed unnecessary.

Intermediate of the electrical device **38** and the shield **31** is a cylindrical member **42** which receives a neutron source **43** such as conventional radium-beryllium, polonium-beryllium, actinium-beryllium or like sources. The member **42** is also coated with a boron layer to provide a thermal neutron sink in the immediate vicinity of the tubing containing the tool thereby minimizing background activity of the tubing in which the tool is positioned. Also the neutron source **43** should be spaced a sufficient distance from the detector to prevent direct detection of the

gamma rays emitted by the neutron source or neutron captured gamma rays produced in the adjacent media, a distance of five or six feet being suitable.

In practicing the present invention the opening **32** for the detector **33** is aligned relative to the direction of the perforating axes **28**, **29**, for example, in the plane "A" as shown in FIG. 2. Thereafter the tool is passed through a tubing until the neutron source **43** is positioned just above or at the level to be perforated. The tool is allowed to remain stationary for, say, 15 minutes to an hour in this position during which time the neutron bombardment induces gamma ray activity in the surrounding media. The main activities induced are Al^{28}, having a half-life of 2.3 minutes, caused by bombardment of Al^{27} and Si^{28} in the surrounding cement and formation, and Mn^{56} having a half-life of 2.6 hours caused by bombardment of Mn^{55} in adjacent steel tubings. When the Mn^{56} activity has built up sufficiently, the tool is raised so that the directional gamma detector **33** is positioned at the point of activation, and about 10 minutes is allowed to elapse thereby permitting the Al^{28} activity to decay.

In a first position of the radiation detecting device **33**, some of the gamma radiation from the Mn^{56} activity passes through the aperture **32** and impinges on detector **33**. The detector **33** produces pulse responses which occur at a rate dependent upon the intensity or flux of the incident gamma radiation and such pulses are amplified in device **38** and supplied to integrator **40** which derives a potential representing the pulse rate. That potential is applied to recorder **41** so that a record of pulse rate is obtained. If the tool is, for example, initially positioned as shown in FIG. 2, a pulse rate indicated on a record such as by typical point **45** as shown in FIG. 5 may be obtained.

Since the centralizing springs **26** have sufficient frictional force to prevent the centralizer collar **25** from rotating, limited up and down movement of the cable **18** permits the radiation orienting device **22** and perforating means **23** to be rotated relative to the tubing **14** by the indexing mandrel **21** between successive rotative positions. As illustrated by points **46**, **47** in FIG. 5, as the aperture **32** rotates away from the adjacent tubing, the indications obtained will decrease; and when the aperture **32** rotates towards the adjacent tubing, the indication will increase to the point **48** where the tool has been rotated through 360°. At the proper location of perforating jets **28**, **29** relative to the adjacent tubing (FIG. 2) the gun **23** may be fired and the perforating jets **28**, **29** will avoid the tubing **15**.

It should be appreciated from the foregoing that the locations of the detecting device **33** and source **43** may be inverted, if desired, for convenience of construction and assembly.

In another aspect of the present invention, the orientation of a perforating apparatus may be achieved by use of a source **42** of radioactivity as described previously suitably spaced from an energy-selective detection system **50** (FIG. 6) such as a scintillation element **51** optically coupled to a photomultiplier **52**. The source **42** and detection system **50** are disposed in a housing **30** in a similar manner to the arrangement described with respect to FIG. 3. The output of the photomultiplier **52** is conducted via a cable in a manner similar to that described with respect to FIG. 1 to an amplifier **53** located at the earth's surface. The amplifier **53** is coupled to a pulse-height analyzer **54**, the analyzer **54** being coupled to a recorder **44**. In this system, by detecting the energy level of incident radiant energy on the scintillation element **51**, the effect of Mn^{56} and Al^{28} activities may be discriminated from one another so that the oriented indications in the Mn^{56} activities may be directly obtained without the necessity of moving the source and waiting for the decay of Al^{23} activities. This is possible because the energy level of the gamma rays emitted by the Al^{28} is 1.8 mev. while the predominant energy level of the gamma rays emitted by Mn^{56} is 0.8 mev. Thus, the pulse height analyzer is arranged to select pulses corresponding to the gamma ray level of 0.8 mev. and transmits a corresponding signal to the recorder **44**. By providing a shielded aperture for the scintillation counter and coupling the counter to a perforating apparatus and an orienting device in a manner similar to that described with respect to FIG. 1 the directional intensities of radiation may be detected. In other respects the structure and operation of the apparatus is as above-described and thus need not be further elaborated upon.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method of orienting a perforating apparatus in a string of well pipe with respect to at least one object disposed in a media in the well bore outside the pipe comprising the steps of: irradiating a media and an object of different compositions characterized by different radioactive half-lives for a period of time wherein the media has a shorter half-life than an object, permitting the delayed radioactivity induced in the media to subside during a succeeding period of time, and subsequently detecting the direction in which a selected value of the remaining delayed radioactivity in an object exists after the radiation induced in the media has substantially decayed, and orienting a perforating apparatus in said pipe string with respect to the selected value.

2. In a method of orienting a zone of a perforating apparatus in which perforations are not produced, in a string of tubing relative to a coextending string of tubing wherein the strings of tubing are disposed in a well bore and surrounded by a media, the steps of: aligning a directional radiation detector relative to the zone of the perforating apparatus in which perforations are not produced, irradiating from one string of tubing the media and at least one adjacent string of tubing which have predominate compositions with different radioactivity half-lives at a level in the borehole through which at least two strings of tubing extend, permitting a period of time to elapse for the short-life radioactivity induced in the media to decay, detecting the remaining delayed radioactivity in the one adjacent string of tubing at a plurality of successive radial positions at the level of induced radiation in the one string of tubing, and obtaining indications of the detected remaining delayed radioactivity in the one adjacent string of tubing for the successive radial positions thereby to permit orientation of the perforating apparatus with respect to the one adjacent string of tubing.

3. In a method of orienting a zone of a perforating apparatus in which perforations are not produced, in a string of tubing relative to another coextending string of tubing wherein the strings of tubing are disposed in a well bore and surrounded by a media, the steps of: aligning a directional radiation detector relative to the zone of a perforating apparatus in which perforations are not produced, irradiating from one string of tubing a media and at least one adjacent string of tubing which have predominant compositions of different radioactivity half-lives for a period of time at a level in the borehole through which at least two strings of tubing extend, permitting another period of time to elapse for the short-life radioactivity induced in the media to decay, detecting delayed radioactivity remaining from the one adjacent string of tubing at a plurality of successive radial positions at the level of induced radiation in the one string of tubing, and obtaining indications of the detected remaining delayed radioactivity for the successive radial positions thereby to permit orientation of the perforating apparatus with respect to the one adjacent tubing, positioning the zone of the perforating apparatus in which perforations are not produced in facing relationship to the one adjacent tubing whereby the perforating apparatus will avoid perforation of the one adjacent string of tubing.

4. In a method of orienting a zone of a perforating apparatus in which perforations are not produced, in a string of tubing relative to another coextending string of tubing wherein the strings of tubing are disposed in a well bore and surrounded by a media, the steps of: aligning a directional gamma radiation detector relative to the zone of a perforating apparatus in which perforations are not produced, irradiating from one string of tubing a media and at least one adjacent string of tubing which have predominant compositions of different radioactive half-lives for a period of time with a source of neutrons at a level in the borehole through which at least two strings of tubing extend, removing the neutron source from the activated level and permitting another period of time to elapse for the short-life radioactivity induced in the media to decay, detecting remaining delayed radioactivity in the one adjacent string of tubing for a plurality of successive radial positions at the bombarded level, and obtaining indications of the detected remaining delayed radioactivity for the successive radial positions thereby to permit orientation of the perforating apparatus with respect to the one adjacent tubing.

5. A method of locating an object disposed in media adjacent to and exterior of a string of well pipe, wherein such object and the media are of different compositions characterized by different radioactive half-lives and wherein the media have a shorter half-life than such object, comprising the steps of: irradiating for a period of time, media exterior to a string of pipe; and subsequently detecting, after a succeeding period of time during which delayed radioactivity induced in the media is permitted to subside, any delayed radioactivity remaining whereby the intensity of radioactivity remaining indicates either the presence or absence of said object at the level of irradiation.

6. In a well bore containing at least two strings of tubing embedded in a media with a characteristic shorter radioactive half-life than such tubing strings, a method of orienting, in one string of tubing relative to another string of tubing, a perforating apparatus having a lengthwise-extending zone in which perforations are not produced including the steps of: aligning a directional radiation detector relative to the zone of the perforating apparatus in which perforations are not produced; irradiating the media and another string of tubing from a position within one string of tubing by means of a source of neutrons for a period of time sufficient for activation of such media and another string of tubing; subsequently, after another period of time adequate for decay of the delayed radiation in the media to subside, detecting, at a succession of radial points relative to the one string of tubing, such delayed radioactivity which emanates primarily from another string of tubing; deriving indications of the intensity of such delayed radioactivity relative to a radial point in the one string of tubing; and orienting the directional radiation detector in accordance with the intensity indications thereby to orient the lengthwise-extending zone of the perforating apparatus relative to another string of tubing.

References Cited by the Examiner

UNITED STATES PATENTS

2,147,544	2/39	Potts	166—66
2,220,509	11/40	Brons	250—83.6
2,228,623	1/41	Ennis	166—4
2,456,233	12/48	Wolf	250—43.5
2,469,461	5/49	Russell	250—83.6
2,667,583	1/54	Herzog	250—43.5
2,998,068	8/61	True	166—55

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