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OIL WELL CASING PIPE AND METHOD OF PRODUCING SAME

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This invention relates to oil well casing pipe suitable for use in deep wells.

An object of the invention is to provide a new casing which can be set at a greater depth than the casings which are now generally used.

The trend of the development of the petroleum industry has been in the direction of increasing the depth of oil wells in order to tap deep lying sources of oil. In the drilling of oil wells the well is lined with casing to support the walls of the well and to prevent the entrance of water or other undesired substances into the well. The bore of the well is decreased in steps as the depth is increased and is lined with casings of decreasing diameter, the casing of smallest diameter being the one which extends the farthest distance into the earth.

As oil wells now extend from one to two miles into the earth and as it is desirable to extend them even farther in order to reach deeper lying deposits of oil, the inner casing which extends the full depth of the well is subjected to tremendous external pressures which tend to cause its collapse, and to large forces acting in the longitudinal direction of the casing which tend to cause a permanent increase in its length or rupture of the casing. The forces acting in the direction of the casing are its weight, and the pull that is sometimes applied to the upper end of the casing in order to draw it from the well.

One of the factors which now limits the depth to which oil wells can be sunk is the lack of a casing pipe which is not prohibitive in cost and is at the same time of such characteristics as to be suitable for use in an oil well casing which can be set a great distance in the ground. In its more specific aspects, the object of this invention is to provide such a casing.

The relatively large diameter surface casings used near the top of the well are exposed to relatively low external pressures and are relatively thin. The external pressures which these large diameter and thin casing pipes can withstand without collapse, depend upon the diameter and thickness of the pipe and the modulus of elasticity of the material of which it is made. The collapsing pressures for such pipes are substantially independent of the strength of the material of which they are made, or of the yield point of the material in compression; at least so long as this yield point is above a minimum value which is low when the pipes are of large diameter as compared to the thickness. Steel of almost any kind has a compression yield point well above this minimum value, and a large diameter thin pipe of high strength steel with a high yield point in compression will fail by collapsing under external pressure at substantially the same pressure as another pipe which is of the same dimensions but which is made of a lower strength steel with a lower yield point in compression.

Conditions are different in a casing pipe in which the diameter is decreased or the thickness increased, or both, so that the ratio of diameter to thickness is smaller than for the larger pipes which have just been considered. For tubes or pipes with the lower ratios of diameter to thickness, the external pressure required to collapse the pipe depends upon the stress at which the material of the pipe begins to yield in compression, in addition to the other factor enumerated above. A pipe of this kind made of a steel with a high yield point in compression will require a much greater external pressure to collapse it than a pipe of the same dimensions made of a steel with a lower yield point in compression. The smaller diameter casings used in oil wells have a ratio of diameter to thickness such that the collapsing pressure depends upon the yield point of the material in compression to a very large extent.

This invention provides an oil well casing pipe of this kind which can be made of plain carbon or alloy steel and mechanically treated to raise its yield point in compression, and the external pressure which it can withstand without collapsing. Because of the increased pressure which this casing can withstand without collapse, it can be set at a greater depth in the ground. Furthermore, the same mechanical treatment which increases the compression yield point of the material used for the pipe and gives the casing pipe increased resistance to collapse under the action of an external pressure, also increases the tensile yield point of the material in the longitudinal direction of the casing and enables the casing to be subjected to heavier tensile stresses in this direction without permanent elongation.

The casing pipe of this invention is made of steel and is mechanically treated after the pipe is fabricated. In general a plain carbon steel of 0.10 to 0.50 carbon is used but any other suitable steel can be used if desired. The pipe may be fabricated from the steel in different ways. Electric flash welding or electric arc welding may be used to advantage but other methods of fabrication may be employed. After the pipe has been formed it is compressed radially to a smaller diameter by the application of force to the outside of the pipe. A suitable method which is also very simple and easy to apply, and which is

therefore preferred, is to place the casing pipe between two semi-cylindrical dies, which, when forced together, form a cylinder of lesser diameter than the external diameter of the pipe placed within the dies. The dies are then forced together, compressing the pipe radially and decreasing its diameter. The compression is effected while the casing is cold, that is, at ordinary room temperature. The casing is then ready for use.

The dies may advantageously extend the full length of the casing pipe, but this is not essential since the pipe of this invention can be made by compressing the pipe in sections by the use of a die which is shorter than the pipe. The full reduction in diameter can also be made in one step, or in a series of steps. While any suitable steel can be used and alloy steels may be preferable for the constructions of casings to reach extreme depth, plane 0.10 to 0.50 carbon steel permits casings to be made which will reach depths greatly in excess of those attainable with seamless casings now in use, and is consequently often preferable to other steels because of its lower cost.

For annealed 0.10 to 0.50 carbon steel the yield points in compression and tension are approximately the same, both being equal to about 45,000 pounds per square inch for 0.35–.45 carbon steel and somewhat lower as the carbon is decreased. By cold compression of casing pipe made from such steel, the yield point in compression in the circumferential direction can be raised to well beyond 60,000 pounds per square inch. When casing pipe of 0.35 to 0.45 carbon steel was compressed to produce a decrease in circumference of about 4.75%, it was found that the yield point in compression, as measured in the circumferential direction of the casing, was increased to about 80,000 pounds per square inch; while the yield point in tension, as measured in the longitudinal direction of the pipe, was increased to about 60,000 pounds per square inch. The increase in tensile yield point is of advantage in that it permits an increased force to be applied in the longitudinal direction of a string of casing, as when pulling the casing out of the well, without producing a permanent extension. The increase in compression yield point in the direction of the circumference of the casing makes the casing capable of standing higher external pressures without collapse than if it had not been compressed. The difference between the yield point in compression in a circumferential direction and the yield point in tension in the longitudinal direction may vary to some extent with the relative flow of metal radially and longitudinally in the pipe.

A reduction in diameter of the casing pipe of the order of about 2% will ordinarily suffice to raise the compression yield points to about 60,000 pounds per square inch, as above referred to, and greater reductions in diameter will give higher yield points. For values under about 2% reduction in diameter it has been found that no appreciable raise in yield point can be relied upon since the manufacturing tolerance as to dimension of the pipe introduce factors which make the results inconsistent and unreliable. Such compression amounts to no more than a sizing or trueing of the pipe in dimension. While for values above about 2% reduction in diameter and of the order of 4.75% or more consistent results are obtained and there is a substantially uniform distribution of the new properties throughout the circumference and length of the pipe.

While the compression which is used in making the casing pipe of this invention may be varied, it is desirable that the diameter or the circumference of the casing be decreased by an amount sufficient to produce a substantial increase in the compression yield point as measured in the circumferential direction of the casing. It it further desirable in making the casing of this invention, that the compression of the casing between dies or otherwise, be such as to produce a compression yield point which is correlated to the diameter and wall thickness of the casing. Thus, when the ratio of the outside diameter of the casing to the wall thickness is less than about 30, it is advantageous to have a compression yield point which is not less than 60,000 pounds per square inch, but no corresponding advantage in respect to the external pressure which the casing can withstand without collapse or the depth to which it can be set is obtained with a yield point of 60,000 pounds per square inch or higher if the ratio of the diameter to wall thickness is greater than 30. The yield points in compression which correspond in a similar way to ratios of diameter to wall thickness of about 26 and about 24 are respectively 70,000 and 80,000 pounds per square inch.

It is characteristic of the casing pipe of this invention that the material of the casing preferably possesses different physical properties in different directions. Instead of possessing a yield point in compression which is substanially the same as that in tension and which is substantially the same in all directions, as would be the case for annealed or for heat treated steel, the steel in this casing possesses a high yield point in compression as measured in the direction of the circumference of the pipe, and a yield point in tension measured in the longitudinal direction, which is likewise higher than the yield point of the annealed steel though lower than the compression yield point as measured in the circumferential direction.

As compared to the annealed steel of which the pipe is made, the steel in the pipe that has been fabricated and subjected to mechanical treatment, is of enhanced physical properties, and these enhanced physical properties are in precisely the directions which increase the utility of the casing pipe for service at great depths. Furthermore, the enhanced properties are roughly in proportion to what are desired for making a casing pipe of economical proportions, that is, one which is no stronger with respect to one kind of service than with respect to another. It is found, in general, that for a casing pipe which has a high yield point in compression in the circumferential direction, a lower yield point in tension in the longitudinal direction of the pipe will suffice to provide an ample factor of safety in this direction to permit the pipe to be used at any setting depth which it can reach without danger of failure due to compression by the action of external pressure.

This casing pipe possesses important advantages as compared with the seamless casings which are now generally in use in deep wells and which are made of a relatively high manganese steel which is more costly than ordinary carbon steel. When the casing pipe of this invention is made of plain carbon steel with the same thickness as the seamless casing made of the high manganese steel, it can be set at depths which are

some thirty per cent greater than can be reached with the seamless casing. The following table shows a comparison between the setting depths for a casing of this invention and for Class D seamless casing, the highest class of seamless casing and the one with which the greatest setting depths are reached.

The Class D seamless casing for which the figures are given has carbon about 0.4%, manganese about 1.4%, and silicon about 0.16%, a compression yield point of about 55,000 pounds per square inch, and elongation in 2 inches of over 30.0%, while the casing of this invention with which it is compared has carbon about 0.35–0.45%, manganese about 0.35–0.70%, a compression yield point of about 80,000 pounds per square inch, and elongation in 2 inches of about 30%.

Table

Outside diameter of casing in inches	Thickness of casing in inches	Setting depth in feet for Class D seamless casing	Setting depth in feet for the casing of this invention	Percent increase in setting depth
6⅝	.288	4156	5100	23
	.352	5617	7250	29
	.385	6370	8250	29
	.394	6576	8500	29
	.417	7101	9150	29
	.432	7443	9500	29
8⅝	.352	3754	4500	20
	.400	4595	5900	29
	.425	5034	6500	29
	.487	6121	7950	30
	.500	6349	8250	30

The setting depths for both types of casings are figured on the basis of an external pressure on the casing of one half pound per square inch for each foot of depth and a factor of safety of two. The figures in the third column for the setting depths of Class D seamless casings are taken from American Petroleum Institute Supplement No. 1 to A. P. I. Standards No. 5A on the care and use of oil country tubular goods, the supplement being dated January, 1934.

It will be noticed that the new casing when made of carbon steel provides for setting depths which are, for most of the thicknesses tabulated, about thirty per cent greater than for the Class D seamless casing which is made of a high manganese steel. If the casing of this invention is made of the same kind of steel as is used for the seamless casing, or of other special alloy steel instead of from plain carbon steel, a still greater increase in setting depth will be obtained. The importance of the increased depth which can be reached with the new casing is obvious for it means that deep lying oil deposits can now be tapped and made available for use. The benefits of the invention are not confined solely to increasing the possible depths of oil wells, however, since this casing can be used to advantage at moderate depths. Reference to the table shows that a setting depth of 7101 feet for a 6⅝ inch casing requires a seamless casing of the high manganese steel with a thickness of 0.417 inch while a depth of 7250 feet can be reached with the new casing of plain carbon steel if the thickness is 0.352 inch, 16% less than the thickness of the seamless casing. This represents a saving in weight of material used, and a further saving in that the new casing for which the figures are given, is made of plain carbon steel which is cheaper than the high manganese steel used for the seamless casing.

It is phenomenal, that considering the great changes effected in the physical properties of the metal in the making of the casing pipe of this invention, there is no appreciable change in either the metallurgical structure as evidenced by microscopic examination, or in the density of the metal. It is also significant that the ductility of the metal, as expressed in percent elongation in 2 inches is not appreciably affected with ordinary carbon steel. The loss in ductility is sufficiently small as to permit the new casing to come within the requirements generally specified in the trade for casing pipe. Thus, when low carbon steel is employed as given in the illustrations above to provide a casing, the metal of which has a yield point in compression in the circumferential direction of about 80,000 pounds per square inch, the metal is shown to have an elongation in 2 inches of about 30%. This shows a much greater ductility than can be obtained by heat treatment of the same metal under the most favorable conditions providing a comparable yield point.

I claim:

1. A well casing of steel having a ratio of outside diameter to wall thickness not greater than about 30, and the metal thereof having a yield point in compression in a circumferential direction not less than about 60,000 pounds per square inch and a yield point in tension in a longitudinal direction less than the yield point in compression in the circumferential direction and substantially greater than the yield point in tension of the same metal in completely annealed state.

2. A well casing of steel, the casing having a ratio of outside diameter to wall thickness such that the strength of the casing to resist a collapse is chiefly dependent upon the yield point of the metal in compression in a circumferential direction, and the metal having a yield point in compression in a circumferential direction not less than about 80,000 pounds per square inch and a yield point in tension in a longitudinal direction less than the yield point in compression in the circumferential direction and substantially greater than the yield point in tension of the same metal in annealed state.

3. A well casing of low carbon steel having less than 0.50% carbon, the casing pipe having a ratio of outside diameter to wall thickness not greater than about 30, and the metal thereof being cold compressed substantially beyond its natural yield point when in completely annealed condition to raise the yield point in compression in a circumferential direction, and having a yield point in compression in the circumferential direction in excess of 60,000 pounds per square inch and a yield point in tension in a longitudinal direction less than the yield point in compression in the circumferential direction but substantially greater than the yield point in tension of the same metal in completely annealed state, said yield point in compression and said yield point in tension being substantially higher than the corresponding yield points for the metal of the casing prior to being cold compressed.

4. A well casing of steel having less than 0.50% carbon, the casing pipe having a ratio of outside diameter to wall thickness not greater than about 24, and the metal thereof being cold compressed substantially beyond its natural yield point when in completely annealed condition to raise the yield point in compression in a circumferential direction, and having a yield point in compression in the circumferential direction in

excess of 80,000 pounds per square inch and a yield point in tension in a longitudinal direction less than the yield point in compression in the circumferential direction but substantially greater than the yield point in tension of the same metal in completely annealed state, said yield point in compression and said yield point in tension being substantially higher than the corresponding yield points for the metal of the casing prior to being cold compressed.

5. A cylindrical low carbon steel casing for lining wells at depths of the order of one mile and greater, the casing being of a size that the ratio of its outside diameter to its wall thickness is less than about 30, the casing being cold compressed radially to effect a substantial increase in the yield point of its metal in compression in a circumferential direction, which increase is substantially uniformly distributed throughout the casing, the yield point in compression of the metal of the casing in a circumferential direction being in excess of 60,000 pounds per square inch, and the micro-structure and density of the steel of the casing being substantially the same as that of the same steel prior to compression of the casing.

6. A cylindrical low carbon steel casing for lining wells at depths of the order of one mile and greater, the casing being of a size that the ratio of its outside diameter to its wall thickness is less than about 26, the casing being cold compressed radially to effect a substantial increase in the yield point of its metal in compression in a circumferential direction, which increase is substantially uniformly distributed throughout the casing, the yield point in compression of the metal of the casing in a circumferential direction being in excess of 70,000 pounds per square inch, and the micro-structure and density of the steel of the casing being substantially the same as that of the same steel prior to compression of the casing.

7. A cylindrical low carbon steel casing for lining wells at depths of the order of one mile and greater, the casing being of a size that the ratio of its outside diameter to its wall thickness is less than about 24, the casing being cold compressed radially to effect a substantial increase in the yield point of its metal in compression in a circumferential direction, which increase is substantially uniformly distributed throughout the casing, the yield point in compression of the metal of the casing in a circumferential direction being in excess of 80,000 pounds per square inch, and the micro-structure and density of the steel of the casing being substantially the same as that of the same steel prior to compression of the casing.

8. In a deep well, a steel casing pipe lining the walls thereof and positioned therein to resist the compression forces of the earth tending to collapse the casing, said casing having a ratio of outside diameter to wall thickness such that the strength of the casing to resist collapse is chiefly dependent upon the yield point of the metal in compression in a circumferential direction, the casing being cold compressed radially to effect a substantial increase in the yield point of its metal in compression in a circumferential direction, the said increase in yield point being substantially equally distributed throughout the casing, the metal of the casing having a yield point in compression in a circumferential direction in excess of 60,000 pounds per square inch, and the micro-structure and density of the steel of the casing being substantially the same as that of the same steel prior to compression of the casing.

9. In a deep well, a steel casing pipe lining the walls thereof and positioned therein to resist the compression forces of the earth tending to collapse the casing, said casing having a ratio of outside diameter to wall thickness such that the strength of the casing to resist collapse is chiefly dependent upon the yield point of the metal in compression in a circumferential direction, the metal thereof being treated to substantially raise its yield point in compression in a circumferential direction and having a substantially greater yield point in compression in a circumferential direction than the yield point in tension in the longitudinal direction.

10. In a deep well, a steel casing pipe lining the walls thereof and positioned therein to resist the compression forces of the earth tending to collapse the casing, said casing having a ratio of outside diameter to wall thickness such that the strength of the casing to resist collapse is chiefly dependent upon the yield point of the metal in compression in a circumferential direction, the metal of which has a yield point in compression in a circumferential direction in excess of 80,000 pounds per square inch and a ductility, as measured by the percent elongation in 2 inches in standard pulled tension test specimens of not less than 30% elongation.

11. A well casing of steel having less than .50% carbon, the metal of which has a yield point in compression in a circumferential direction in excess of 75,000 pounds per square inch and a ductility, as measured by the percent elongation in 2 inches in standard pulled tension test specimens, of not less than 30% elongation.

12. In the manufacture of well casing pipe, the steps of making a steel casing pipe having a ratio of outside diameter to wall thickness such that the strength of the pipe to resist collapse is chiefly dependent upon the yield point of the metal of the pipe, and compressing said casing pipe radially an amount sufficient to reduce its outside diameter in excess of 2%, to substantially increase the yield point of the metal in compression in a circumferential direction, and to obtain a substantially uniform distribution of such increase in yield point throughout the pipe.

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