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OIL WELL CASING

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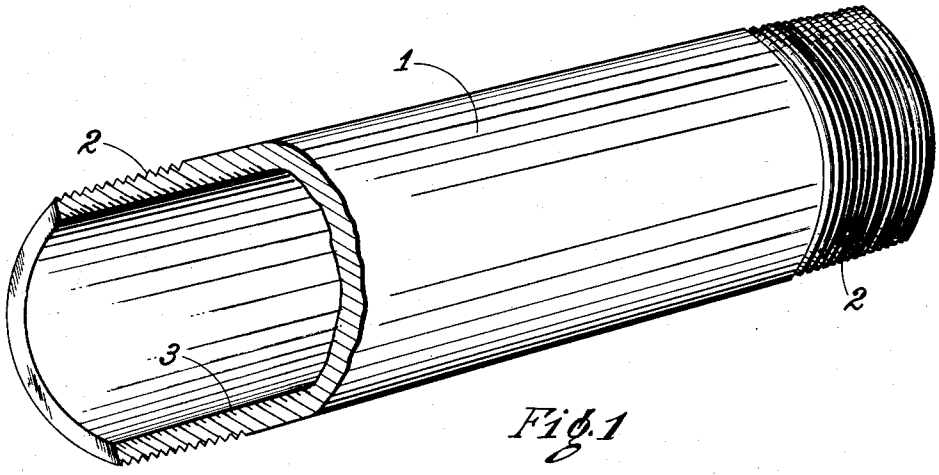


Fig. 1

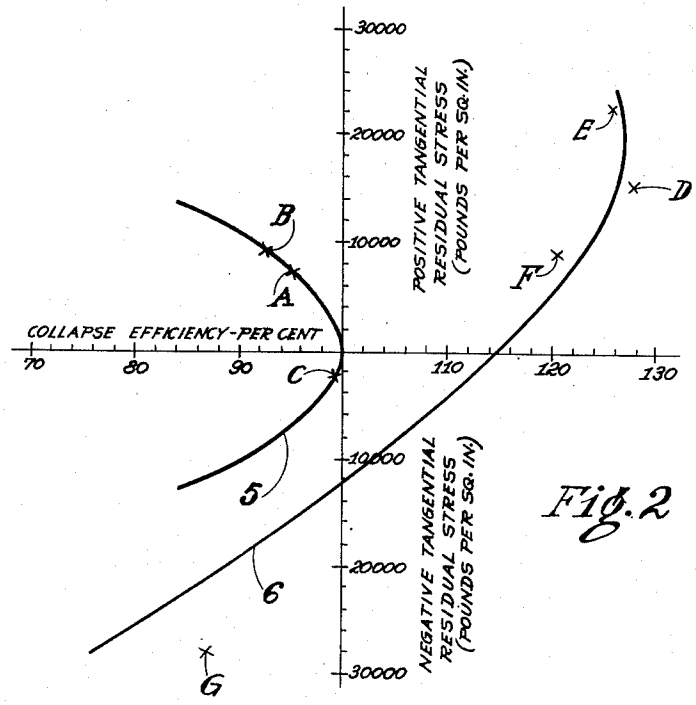


Fig. 2

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OIL WELL CASING

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3 Claims. (Cl. 285—146)

This invention relates to the art of steel pipe and its manufacture and is particularly concerned with steel casing for use in deep oil wells, and to a new and improved method for making oil well casing which will have improved resistance to collapse and improved joint strength.

Steel casing for oil wells is subjected to external forces which increase with the depth of the well and which must be resisted to avoid failure of the casing. Such casing is made in pipe lengths which are about 40 feet long and are connected together by couplings threaded to the ends of adjacent lengths of pipe. Since the weight of the string of casing is carried by these threads and couplings, the threaded portions of the pipes must have a high joint strength to prevent parting of the string and to permit removal of the string from the well should the occasion demand. Joints having standard threads usually part because of the radial compression of the threaded ends of the pipe which takes place under tension, such distortion allowing the threads to disengage. Joints having acme or square threads usually fail by breaking off the pipe at the thread root beyond the last engaged thread. Furthermore, oil well casing must be sufficiently ductile to resist breakage in instances where the drilled hole is not perfectly straight.

One important specification for oil well casing has been that of relatively high ductility. Such high ductility has been accompanied by collapse strengths and joint strengths which were not as high as were desirable. Various expedients have been tried to increase the collapse efficiency and joint strengths of casing without materially decreasing the ductility of the casing, but so far as I know these efforts have not been entirely satisfactory.

The American Petroleum Institute, appreciating the need in the industry for a joint of higher strength, yet using standard thread dimensions and couplings, has recently appointed an engineering committee to work on the problem of designing such joints on American Petroleum Institute standard 5½" and 7" casing where rotary drill pipe is not used inside the casing except in emergencies. One proposal is to upset the threaded ends of the pipe internally to provide sufficient metal under the threads to give the desired strength.

By the present invention I am able to increase joint strengths of casing not only of those sizes but also of larger sizes within which drill pipe is used for drilling and accomplish these results without the extra cost, reduced clearances and localized wear which are inherent factors in upset pipe ends.

By the present invention I am able to increase the collapse strength of casing as much as 25% or more and to increase the joint strength as much as 50% or more, without materially decreasing the ductility of the casing. Briefly stated, I increase the collapse strength and efficiency of the casing in any one of several ways. I may quickly heat a thin interior layer of the casing to a temperature between about 500° F. and about 1000° F. and allow the pipe to cool; or I may quickly heat a thin interior layer to above the Ac_3 temperature of the steel and quench it and, if and when necessary to improve ductility, I may temper or draw the resulting hardened layer by quickly reheating it to a temperature between about 500° F. and about 1000° F. and allowing the pipe to cool. Where it is desired to preserve the effects of previous cold working of the pipe in the portions thereof which have not been hardened by heat treatment, the drawing operation should be carried out rapidly and locally so that the heating effect is confined to the hardened material. When the drawing operation undesirably changes stresses in the pipe and it is desirable to improve the stresses, I may quickly and locally heat the exterior of the pipe to a temperature between about 500° F. and about 1000° F. and allow it to cool.

I increase the joint strength by quickly heating a thin interior layer of the casing at and adjacent to the pipe ends to a temperature above the Ac_3 temperature of the steel and then quenching and hardening this heated layer.

In the drawing accompanying and forming a part of this specification,

Figure 1 is a perspective view, partly in section, of a length of oil well casing embodying the present invention; and

Figure 2 shows curves illustrating collapse efficiencies of casing and the effects thereon of the present invention.

In Fig. 1, 1 designates a length of oil well casing, 2 designates the exterior threads at each end thereof which are to engage with couplings (not shown), and 3 indicates the thin hardened layer of metal on the inside of the casing within the threaded portions. In general, the ratio of the diameter of the casing to the wall thickness, i. e., D/t, ranges from about 12 upwardly, and the present invention insofar as improving collapse strength is concerned is directed to steel casing having a D/t ratio of more than about 14.

One convenient and satisfactory method of treating casing such as is shown at 1 in Fig. 1 to improve its collapse efficiency, is as follows: An electric induction heating element in the form of a short cylindrical member slightly less in diameter than the casing to be treated is inserted in the casing and is connected to a source of electrical power which is sufficient to heat the inner surface of the pipe by induction to a temperature between about 500° F. and about 1000° F., within a very short time, for example within a few sec-

onds. Relative axial movement of the heater and pipe is created, and preferably the heater alone is moved. The rate of this relative movement may range from about 1¼" upwardly to 15" or more per second, depending upon the power input available. It will be understood that the speed of such relative movement may be varied depending on the power input, but the speed and power input should be so regulated that only the inner surface or a very thin inner surface layer is heated to the desired temperature, and that this heating is done very rapidly and, in effect, locally for it is important that the casing should not be heated thruout its wall thickness to the peak temperature but that the heat supplied to the thin inner layer should dissipate itself by spreading to the remainder of the casing wall. Preferably the pipe is rotated during relative axial movement of the pipe and heater to overcome the effects of variations in clearance therebetween.

When a plurality of lengths of steel casing having a D/*t* ratio of more than 14 is so treated, the average collapse efficiency will be improved and the statistical minimum values on which design factors of safety are based will be raised still more in proportion.

I have found that collapse strength in steel casing having a D/*t* ratio of 14 or more is affected by the presence of stresses which, for lack of a better description, have been called "tangential residual stresses." If a short length or ring of casing having such stresses is cut longitudinally, i. e., axially, the casing tends to spring open, thereby opening the cut, when the tangential residual stresses are positive, and tends to spring inwardly, thereby closing the cut, when these stresses are negative. I have also found that when a length of casing of homogeneous structure possesses substantially no tangential radial stresses its collapse strength and efficiency is at the maximum, and that as these stresses increase in magnitude, whether they are positive or negative, the collapse strength and efficiency decreases.

Steel casing having a D/*t* ratio above 14 as ordinarily made heretofore, usually—as a result of cold rotary straightening—possessed tangential residual stresses which were positive and which varied in amounts from a few thousand pounds per square inch to 20,000 pounds per square inch or more. These stresses can be diminished and in some cases reversed from positive to negative values by the treatment above described. As these stresses approach a minimum, the collapse strength and efficiency increase.

Curve **5** of Fig. 2 illustrates not only the relationship existing between collapse efficiency and transverse residual stresses in steel casing having a D/*t* ratio of 14 or above, but also the improvements in collapse efficiency which I have obtained by means of the above described treatment. Lengths of casing which have been straightened while cold by the rotary method have positive tangential residual stresses of various amounts usually greater than about 5000 lbs. per square inch and are illustrated by the upper part of curve **5**. When a plurality of such casing lengths is treated as above described, those stresses are decreased and may be reversed with the result that the group of points representing the stresses in the various casings is moved closer to the node of the curve and the average and the minimum collapse efficiencies are increased. As curve **5** indicates, the collapse efficiency of a length of such casing is about 100% when substantially no transverse residual stresses are present.

The point A on curve **5** indicates a similar length of casing which, before being treated as above described, had a positive transverse residual stress of about 7000 pounds per square inch and a collapse efficiency of about 95%. Point B illustrates a length of casing which had a positive tangential residual stress of about 9400 pounds per square inch and a collapse efficiency of about 92%. Point C on curve **5** illustrates another length of similar casing after it had been treated, as described above. It had a negative tangential residual stress of about 3000 lbs. per sq. in. and a collapse efficiency of about 99%. It is believed that the specimen indicated by point C had a low positive transverse residual stress before treatment and that the treatment reduced that stress thru zero and on to the indicated negative stress. These specimens show how it is possible, by this invention, to improve the collapse strength and efficiency of cold-rotary-straightened casing.

The illustrative figures were obtained on homogenous casing, i. e., a pipe which is substantially uniform in structure thruout its wall section. These results were obtained with steel containing between about .20% and about .24% of carbon and between about .61% and about .65% of manganese.

Instead of using the low temperature treatment described above, I may use a higher temperature and harden an inner thin layer of the casing. As briefly described above, this treatment consists of quickly heating a thin inner layer of the casing to above the Ac_3 temperature of the steel and then quenching and hardening that layer.

Curve **6** of Fig. 2 illustrates improvements in collapse strength and efficiency which have been obtained by such a high temperature treatment. The specimen illustrated by E on curve **6** had a positive tangential residual stress of about 22,000 pounds per square inch with an accompanying collapse efficiency of about 125%. Similarly, another specimen illustrated by D had a positive transverse residual stress of about 15,000 pounds per square inch and a collapse efficiency of about 127%. F represents another specimen whose positive transverse residual stress was about 9400 pounds per square inch and whose collapse efficiency was about 120%.

When casing is provided with such a hardened inner layer its ductility is decreased somewhat. The ductility may be improved by reheating the hardened layer quickly and, in effect, locally as previously described, i. e., by heating it rapidly to between about 500° F. and about 1,000° F. and allowing it to cool. Point G on curve **6** illustrates casing similar to the casing of points D and E but drawn as just described. This specimen had a collapse efficiency of about 88%, a negative tangential stress of about 28,320 lbs. per square inch and increased ductility (not shown by the curve) as compared with its ductility before this drawing treatment.

The collapse efficiency of casing such as is illustrated by the hardened and drawn specimen of point G on curve **6** may be increased by subjecting the exterior surface to a low temperature treatment, for example, by quickly heating the outer surface to a temperature between about 500° F. and about 1000° F. and allowing it to cool. Such a treatment will decrease the

negative transverse residual stress and increase the collapse efficiency.

The joint strength may be increased in the following manner: A heating element as above described is inserted within the end of the pipe to be threaded and sufficient electrical power is employed to heat the inner surface layer of the casing to a depth of, for example, .075" to a temperature above the Ac_3 point of the steel, for example, to between about 1600° F. and about 1800° F. for steel of the foregoing composition, and to do this heating within a very short period of time, for example only a few seconds. The heater may remain stationary if it is of sufficient length to heat the desired length of the casing at and adjacent to the part to be threaded, or, if the heater is not that long the heater and casing may be moved relatively at a speed which may range upwardly to about 15" per second or more, depending upon the power input. Immediately after the surface of the casing has been heated to the desired temperature it is quenched, as by spraying water on it. This quenching may be accomplished by first removing the heater or by moving the heater in the pipe and following it with a quenching spray.

The effect of this treatment is to increase the hardness of the highly heated and quenched inner layer. For example, I have obtained inner hardened layers having hardnesses of from about 30 to about 46 on the Rockwell C scale, while the hardness of the remainder of the pipe wall was about 90 on the Rockwell B scale. The untreated pipes failed in pullout tests under loads of about 175,000 pounds, while corresponding pipes treated as just described failed at pullout loads averaging about 315,000 pounds. Thus pipes so treated had strengths which were increased by about 80%.

The heating and quenching treatment somewhat reduced the ductility of the pipes at their ends but this decrease was not serious because of the support afforded by the coupling. However, the ductility of pipes thus heat treated and quenched at their ends may be increased by a drawing treatment, i. e., by rapidly heating the thin hardened layers to between about 500° F. and about 1000° F. In other words, the first collapse improving treatment described above may be carried out on the heat treated and hardened pipe ends with the result that the ductility will be considerably increased without much decrease in joint strength. For example, pipes having heat treated and quenched ends as above noted failed in a pullout test at about 315,000 pounds, which was about 180% of the strength of untreated pipes. After being treated by this drawing operation the pullout failure strength dropped to about 287,000 pounds, which was still about 155% of the corresponding strength in untreated pipes.

When a length of casing is subjected to the high temperature and hardening treatment the improvement in joint strength will be obtained simultaneously with the improved collapse efficiency. When the hardened layer is to be drawn to improve ductility, the drawing treatment is preferably not applied to the end portions which are to be threaded.

From what has been said hereinabove, it will be understood that either the collapse improving treatment or the joint strength improving treatment may be carried out together or independently of one another. For example, if it is desired to increase both the collapse and joint strengths of a length of casing, the heater may be passed axially thru the length of pipe and the heat may be so adjusted as to raise the temperature at one end to be threaded to above the Ac_3 point and then decreased to heat the portion of the pipe between the ends to be threaded to a temperature in between about 500° F. and about 1000° F. and then the heat may be increased when the heater comes to the other end to be threaded so that it will be heated to the temperature used at the first end. When this method is employed, the highly heated inner surface of each end is quenched immediately after the heating. This may conveniently be done by embodying in the heater a water-carrying tube thru which water may be sprayed onto the heated walls immediately back of the moving heater. When this procedure is followed and it is desirable to increase the ductility of the hardened end portions of the pipe, the heater may be reemployed to reheat the quenched portions of the pipe to a drawing temperature, i. e., from about 500° F. to about 1000° F.

It will be understood that it is not essential to use an electric induction heater as described above but that any other heating means may be employed which is suitable for carrying out the present invention.

The subject-matter described but not claimed in this application is being claimed in copending application Ser. No. 407,350 filed August 18, 1941.

Having thus described my invention so that others skilled in the art may be able to practice the same, I state that what I desire to secure by Letters Patent is defined in what is claimed.

What is claimed is:

1. In a thin walled steel pipe which is exteriorly threaded at its ends and which is to be subjected to heavy tensile stresses in use, means for increasing, in the region of the threaded ends, the normal resistance of the pipe to tensile failure and to radial deformation resulting in failure by thread disengagement of the threaded joint, said means comprising a thin integral layer of steel at the inner surface of each threaded end, said layers being harder than the thread carrying portions of the pipe and being substantially coextensive with said threads longitudinally of the pipe.

2. In a thin walled steel pipe which is exteriorly threaded at its ends and which is to be subjected to heavy tensile stresses in use, means for increasing, in the region of the threaded ends, the normal resistance of the pipe to tensile failure and to radial deformation resulting in failure by thread disengagement of the threaded joint, said means comprising a thin integral layer of steel at the inner surface of each threaded end, said layers being harder than the thread carrying metal, being spaced apart radially from the roots of the threads and being substantially coextensive with the threads longitudinally of the pipe.

3. In steel pipe having a D/t ratio of above about 14 and having exteriorly threaded ends, for use as casing in oil wells, means for increasing the normal joint strength of said pipe comprising thin integral inner surface layers within and substantially coextensive with said threaded ends longitudinally of the pipe, said inner layers having a hardness of above about 30 on the Rockwell C scale and being harder than the remainder of the steel in said threaded ends.

THOMAS J. CRAWFORD.

DISCLAIMER

2,256,455.—*Thomas J. Crawford*, Youngstown, Ohio. OIL WELL CASING. Patent dated September 16, 1941. Disclaimer filed March 1, 1943, by the assignee, *Republic Steel Corporation.*

Hereby enters this disclaimer, to wit: that the term "substantially co-extensive" which appears in claims 1, 2, and 3 shall mean that the hardened layers and the threaded portions are substantially equal in length and that the hardened layers are not substantially longer than the threaded portions.

[*Official Gazette March 30, 1943.*]