The Selection Of Tubing Strings

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INTRODUCTION

The purpose of this paper is to select a normal deep well and to design combinations of tubing strings. In many wells today, the design of tubing strings is not based simply on the function of tension, collapse and burst of available API tubes.

Corrosion has been an oilfield problem almost from the beginning of the industry. High field pressures and deeper wells have added a whole new list of words to the oilfield vocabulary, particularly when referring to tubing; words such as stress corrosion cracking, hydrogen embrittlement and so on.

STEEL CHARACTERISTICS

Before we get into the design of the tubing strings let us review what we can expect from the steel tubes which will make up our string of tubing. First, as yields increase the ductility decreases. The harder the steel, and the more brittle the steel, the more the steel is affected by notches, or is said to be more notch sensitive. The likelihood of failures, because of cold shuts in the upset area, plug scores on the I. D. (which are manufactured notches), and slip and tong marks (which are running or handling notches), are also increased.

Notches which are in P-105 material, whether they be handling notches or manufacturing notches, are the cause of some 32 per cent of all P-105 failures. It should also be pointed out that, in most cases, as we increase yield so do we increase the difficulties of manufacturing.

For example, high strength steels reach their physicals through either heat treatment or chemistry, or a combination of both. These steels, for the most part, resist heat; therefore, they resist flow and it is necessary for the steel to flow in order to form the upset. Without uniform heat and without uniform flow in the upsetting operation cold shuts may develop in the upsets. These cold shuts have been known to be so tight that it is extremely difficult to detect these flaws even with a magnetic particle end area inspection.

Plug scores, which may not appear to be harmful, may have a stress or quench "V" crack at the base. Plug scores are the result of the pipe being passed longitudinally without rotating over a plug and between rolls which act as an elongator. Some mills refer to this particular piece of equipment as an elongator or a high mill or a plug mill. These scores do not follow the conventional outside or inside seam pattern, which is spiral, and produced as a result of the initial piercing operation; rather, these scores are straight and usually go from one end of the tube to the other.

Our inspection company maintains accurate records on rejects by grades and sizes and we find the percentage of rejects on P-105, for example, is much less than that in J-55. This is due to closer mill controls and inspection procedures and because the oil industry has demanded a better product from the steel industry. It is, of course, obvious in most cases that a well requiring P-105 is far more costly than one using J-55.

Susceptibility of Corrosion

Second, as we increase yield we increase the susceptibility of corrosion, erosion, stress corrosion cracking and hydrogen embrittlement. From the steel makers' point of view, the control of general corrosion can be accomplished by enriching the steels with alloying additives or by the use of high alloys. Along with the alloying additives, the oil industry demanded additional strength which was accomplished by either warm working, cold working or by normalizing and tempering.

Depending upon the alloy involved, the wall thickness and the diameter of the tube, it is possible to build in a set of internal or external stresses, which, when coupled with a notch, are the prime target for stress corrosion cracking to develop. Stress corrosion cracking can possibly be described as the product of internal stresses or external stresses coupled with a notch in the presence of hydrogen. It is believed that hydrogen is effective in extending a crack to critical size in the first stages of failure. The stresses in the metal present favorable conditions for forming the triaxial stresses needed in the second stage of failure. The diffused hydrogen in the steel can contribute to failure by lowering the brittle strength.

TUBING REQUIREMENTS

Let us assume our producing zone is 17,500 ft. with a bottom hole pressure of 12,000 psi using 14#/gal. mud. There are many ideas about what is required of a tubing string; each has merit. For example, one company when faced with a well with normal or slightly higher than normal pressure conditions, but which is corrosive, will run 2-7/8 in. O. D. by .440 wall 11.65 pd. N-80 tubing with little consideration given to corrosion protection. This particular tubing has an inside diameter of 1.995 in. which allows the operator to use standard 2-3/8 in. wire line tools.

On the other hand, there are the advocates of standard wall high yield, such as the 2-7/8 in. O. D. by .217 wall 6.50 pd. P-105 tubing utilizing any number of corrosion protection means. Heavy .440 wall tubing, of course, is less susceptible to running or handling damage and the bare steel will corrode at a slower rate than the P-105 bare steel. The safety factor in burst is very high, whereas the standard wall P-105 has a considerably high safety factor in tension and a comparable safety factor in collapse.

The standard weight of P-105 with the same given volume of gas will have a slower velocity which should retard the combined action of corrosion and erosion. Some companies feel that the tension safety factor is most important while burst and collapse are only to be contended with. Others feel that a high safety factor in burst is all important — still others want protection against collapse.

SPECIAL ALLOYS

During the past fifteen years there have been many special alloys used by the oil industry in an attempt to cope with the extreme situations encountered in the deep, high pressure, high temperature walls. The corrosion in well equipment and high pressure condensate wells was a problem of such magnitude that in 1944 Committee TP-1 of the National Association of Corrosion Engineers undertook its study and discovered CO_2 to be the major contributing factor.

This marked the introduction of nine per cent nickel tubing, tempered to N-80 physicals, and five per cent nickel tempered to J-55 physicals. These two nickel alloy mixes were used very extensively and in some areas did an exceptionally good job — while in other areas they failed miserably. About 1954, nine per cent chrome, 0.50 or 1.0 per cent molybdenum, AISI 4340, AISI 4145 and AISI 4140 tempered to from 80,000 psi to 110,000 psi minimum yield was used and is still being used in many areas.

Custom Specifications

It is the opinion of many operators that if a well requires a premium grade of tubing they should obtain their tubing from mills which manufacture, literally, to custom specifications the type of steel in a controlled range of yield, hardness and elongation to fit their almost exact requirements. For example, AISI 4340 steel can be tempered to J-55 specifications or could be tempered to produce 100,000 psi yield with the physical properties held to a rather narrow range, which usually does not exceed 15,000 psi. The only difference in the manufacturing process would be in the heat treatment of the tubes after they had been pierced, sized and upset.

Not only have many operators gone to special alloys but they have also gone to any number of special wall thicknesses in their tubing strings. Of these, some have become more-or-less standards and are presently being produced by several of the major oil country pipe mills. Figs. 1 and 2 demonstrate what safety factors can be obtained with 2-3/8 in. and 2-7/8 in. O. D. tubing of various wall thicknesses and grades. Fig. 3 demonstrates the use of some possible combination strings.

COMBINATION STRINGS

The use of combination tapered strings is relatively

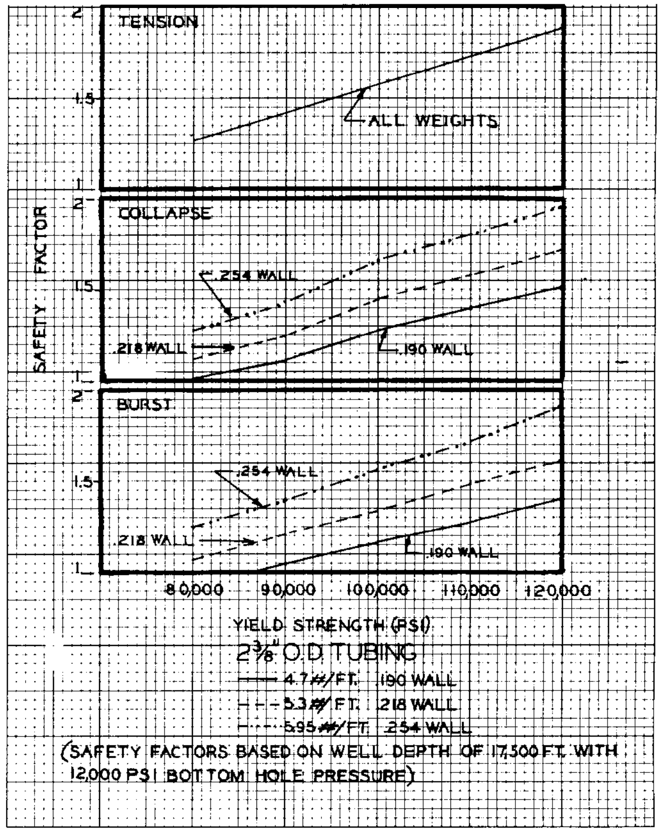

Fig. 2

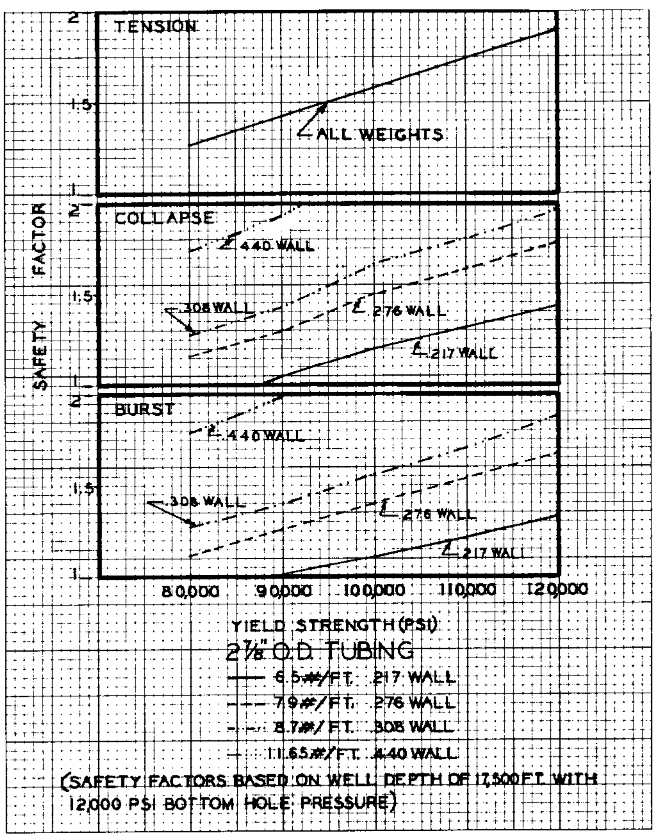

Fig. 1

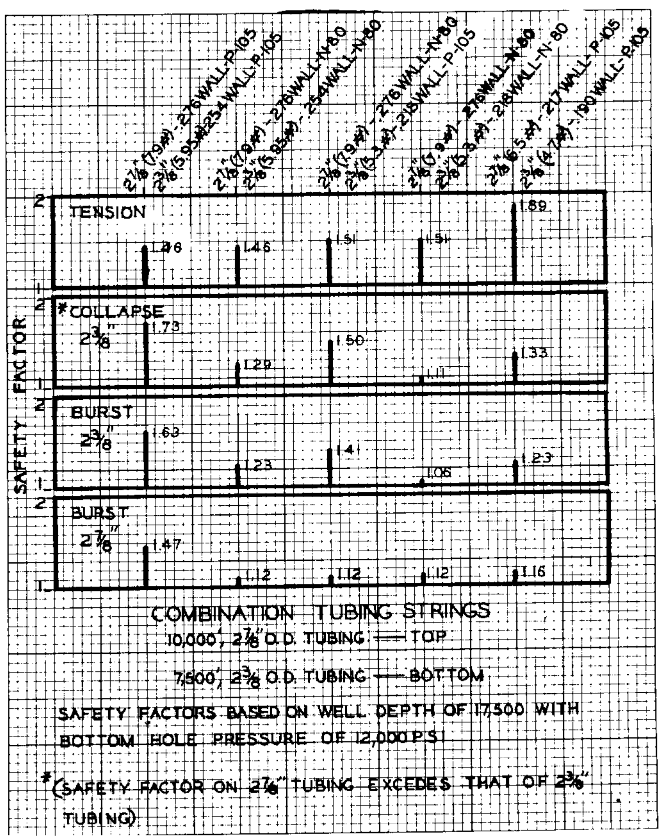

Fig. 3

commonplace along the Texas-Louisiana Gulf Coast. Some operators go one step further and run what is called a "kill" string inside their 2-7/8 in. O. D. tubing to a depth below the calculated condensate point in gas condensate wells. Chemical inhibitors are then pumped into the 2-7/8 in. annulus and returned through the 1-1/4 in. kill or producing string. There are questions, however, about the effect of velocity in gas wells upon the tubing. There are any number of cases existing where the velocity exceeds 200 miles per hour.

Naturally, those of us involved in the sale and manufacture of high strength tubing and tubing connections feel that it is not our responsibility to recommend the actual type of tubing and safety factors that operators should use in various installations. It is our opinion that we can only offer information about how various steels at various yields and wall thicknesses will perform under certain known conditions.

CONCLUSIONS

Our findings can be summarized as follows:

1. The life of a string of tubing can be extended by using material in a controlled hardness or yield range.

2. More caution should be given to running and handling of high strength steels. It seems unrealistic to score frequently beyond API tolerances every joint of tubing with running equipment and still pay a premium price for near perfect tubing.

3. A balance can be obtained between yield strength and wall thicknesses to obtain the desired safety factors and keep failures to a minimum.