Various Methods of Pressure Testing Oilfield Tubular Goods

By C. W. CROWL
Hydro-Test of West Texas

NEED FOR NON-DESTRUCTIVE TESTS

The conditions that casing and tubing are subjected to have become increasingly more severe. Therefore, the manufacturer and user have had to find ways to perform non-destructive tests to measure the performance properties of these tubes.

Wells are not only being drilled deeper but more areas of high pressure are being encountered. Secondary recovery projects quite often increase the working pressure under which the tubes operate. The stimulating processes for oil and gas wells, such as fracturing and acidizing, have brought about new demands on tubular goods.

Until several years ago the performance properties were based on the ability of the product to meet certain API specifications. The requirements covered grade of steel to be used, method of manufacture, physical properties of strips cut from the rolled tubes, dimensional limits, thread elements, etc. All of these were important, but did not assure the user that the completed product would adequately resist failure in a well. For one thing, most of the tests were not applied to each individual length but only to representative samples or tubes selected at random. Even the mill inspection hydrostatic test, which was purported to be a test of the resistance to bursting and was applied to each individual length, was quite inadequate because the pressure was limited to 3000 psi maximum internal water pressure.

The API has now adopted an alternative internal pressure test based on 80% of the minimum yield strength, which is a big step toward a real measure of performance value. The mill test on N-80 and grades above this is 80% of minimum internal yield. Grades J-55 and below are pressure tested to 3000 psi or lower, depending on the size of the pipe, unless the purchaser orders the pipe tested to 80% of minimum internal yield.

Actually, the full step would be to test each length of casing in a collapse chamber to some 80% of its minimum collapse value, and in a tension pulling machine to 80% of its joint strength. This should be done in addition to the 80% burst test. The cost of the collapse and tension tests, however, would be prohibitive as far as large pipe is concerned, particularly in the field. Therefore, the most economical and truly worthwhile performance test would be the high internal pressure test.

Internal Pressure Test

Mr. H. G. Texter, formerly chief field engineer (now retired) for Spang-Chalfant Division of National Supply, in a paper presented at the Third World Petroleum Congress, presented arguments to show that ability to withstand high internal pressure is very great assurance that a pipe will likewise withstand tension and collapse forces of equal degree of intensity. At the same time, the above author presented examples of failure that could have been caught had the pipe been tested at a high pressure. Cases were also discussed in which perfectly good tubes, that had been rejected because of doubtful surface blemishes, were proved to be perfectly capable of serving their purpose. It is wasteful to discard casing and tubing on appearance and then accept lengths inherently, but not visibly, faulty.

To argue that some method of pressure testing of casing and tubing is not justified would be extremely difficult. Therefore, it should be interesting to consider the various methods of performing this test.

As the size goes down and the wall thickness increases and the grade of steel improves, the test pressures increase to some fairly high figures. For example, to test 5 1/2 inch O. D. 23# P-110 casing to 80% of the minimum yield, requires a pressure of 13,300# psi. Handling such a pressure, safely and properly, presents some interesting and involved mechanical and mathematical problems. The discussion of these problems is the principal purpose of this paper.

MILL TEST PROCEDURE

While there are several types of mill testers, the most common type consists of two large heads supported by suitable beams for carrying the tension loads. In the centers of the heads are rings containing gaskets which serve as fluid seals and against which the ends of the pipe are pressed.

One of the heads is stationary and the other hydraulically movable, the latter being moved towards the stationary one after the tube has been dropped into position. The movable head not only accomodates itself to variable pipe lengths and to compression of the packing, but also to the slight shortening of the tube as pressure is applied. Suitable connections through the heads serve for water input and air release, as in the portable method.

This type of equipment is not overly expensive, but it is far too heavy and cumbersome to be portable and can only be used in the pipe mill. As it is used for pressures up to about 5000 psi, no particular safety precautions need be taken except that men should not stand directly beside a pipe under test. There is no danger of end connections ever blowing out.

Speed Of Operation

The great advantage of this method is its speed of operation. For example, 7 inch OD casing can be tested at the rate of 70 to 75 joints per hour. This is compared to 10 to 15 joints per hour by the portable method.

Normally in high pressure testing, the pipe is subjected to longitudinal tension; however, in this arrangement, it is subjected to some compression. The higher the pressure, the greater the compression because the hydraulically movable head, as well as the stationary one, must continue to force the packing gaskets against the ends of the tubes to prevent leakage. Thus, to test 7 inch OD 20 pound J-55 casing to 3000 psi, there must be an end loading at something greater than the internal cross-sectional area, 32.7 square inches times 3000 psi, or 98,000 pounds.

In order to keep the gaskets from leaking, it is necessary to keep the pressure differential at approximately 10%. Therefore, the net column loading on the pipe will be about 10,000 pounds. The 98,000 plus 10% equals hydraulic head 108,000 minus 98,200 equals 9800 pounds equals net column loading applied to the pipe under test.

This compression loading tends to buckle the pipe and clamps or fingers are provided to close down, especially over small size material, to prevent them from springing out of the bench. This is one of the reasons this method is not applicable to the new, alternative, pressure testing in which high end loading would be required. The real reason is the inability of the gaskets to hold against pressures much over 5000 psi.

Another very important limiting factor is that the ends of couplings may be too light, because of their recess, as compared with the wall thickness of the body of the pipe. This would make them unable to resist the stresses imposed by the internal pressure and they would expand to elastic limit. This, in itself, is not serious; but a partial deformation of the adjacent threads and a resulting steepening of their taper beyond API allowable occurs.

NEW HIGH PRESSURE MILL TESTING

There are now in service new type test benches capable of upwards of 10,000 psi.

Instead of gaskets sealing at the ends, there are external rubber flanges around each end of the pipe, one, of course, being over the coupling (if testing is required after the coupling is screwed on). The rubber flanges are so designed that the greater the applied pressure, the tighter the rubber will be pressed against the OD of the pipe, or the coupling. In this respect the design is ideal.

Although this method avoids the mechanical end thrust of the heavy gasketed ends of the older mill benches, there is introduced the end thrust of the water pressure itself against the cross sectional area of the metal of the tube. This becomes a surprisingly high longitudinal compression when high test pressures are involved.

Consider the case of testing a plain end (no couplings) 7 inch OD 32 pound N-80 tube to 80% of the minimum yield or 8,300 psi. The cross sectional area of the metal of such a tube is 9.3 square inches. Then this figure, times 8300 gives a longitudinal compression load of approximately 77,000 pounds, which is fairly high. Obviously, except for a very short tube, buckling could take place, and like older benches, finger clamps must be employed to hold the tube straight.

As in the case of testing by the field method, there are again biaxial stresses involved. This time, however, the longitudinal stress is one of compression, just the reverse of the field method. As might be guessed, compression tends to decrease resistance to internal pressure.

Going back again to 7 inch OD 32 pound N-80 casing, consider testing not the plain end material but a finished piece, with coupling screwed on. The cross sectional area of the metal on the field end (threads only) is the same as before, but on the coupled end the area of metal of the coupling must also be taken into consideration. This amounts to 7.5 square inches (effectively the area of a tube whose OD is 7.65 inches and ID of 7 inches). This area plus the tube wall is equal to 9.31 square inches plus 7.55 equals 16.86 square inches.

Advantages & Disadvantages

Then 16.86 square inches times 8300 psi equals 140,000 pounds, which is very high. As the end loading is unequal, due to the added area of the coupling on one end, the pipe must be restrained from moving towards the uncoupled end. This requires a very heavy ring, the presence of which makes it difficult, but not impossible, to see a small leak through the threads.

The cost of the new type high pressure test benches is approximately $250,000 (total about $600,000 with attendant skids, coupling screw on machine, handling equipment, etc.). The old style test bench cost about $35,000 or $250,000 total.

These new high pressure test units have many novel and interesting refinements, such as handling the tubes in and out of the test bench, methods of speeding up operations, safeguards against accidents, etc.

One particular feature worth noting concerns freedom of movement of the movable head.

When a tube is subjected to internal pressure it expands, thus shortening its length. Thus, as the tube becomes shorter, the head and the rubber flange move with it. Without this ingenious arrangement, the test bench would be out of service a considerable amount of the time for replacing the rubber seals of the movable head.

An alternate method of sealing is to employ internal seals. This will avoid longitudinal loading due to the end thrust of the water pressure on the ends of the tubes.

It might seem, then, that there would be no buckling tendency, finger clamps would be unnecessary, and the test unit could be simplified considerably. This, however, is not true. The longitudinal end thrust of the water on the cross sectional area of the tube wall would be eliminated, of course, but there still remains another serious buckling force, the existence of which will seem quite surprising to most of us.

The explanation of the force is contained in a letter by Arthur Lubinski, a Pan-American Petroleum Company research engineer. In this letter the following conclusions were drawn:

"Using internal seals and applying an internal pressure to a length of pipe open at both ends has the same effect on buckling as compressing the length of two forces applied at its end and equal to the product of the internal pressure in psi and the cross sectional area in square inches corresponding to its ID."

If the internal pressure is large enough, the pipe buckles without being under compression.

FIELD PRESSURE TEST

In the past few years several methods have been devised for pressure testing tubular goods in the field. The oldest method of testing is normally called rack testing. This is a mobile unit and could be used at the mill if other equipment is temporarily unavailable, or is of insufficient pressure capacity. This method consists of screwing a plug into the coupling and a cap on the field end threads with connections for admitting water and releasing air. Pumps then apply pressure as required. The bleed end plug (the one which bleeds the air out of the pipe) must be elevated higher than the fill plug. This is to get the maximum amount of air out of the pipe. This is a safety precaution as well as a means of speeding the job up by requiring less time to pressure the joint. There is no need to support the pipe against buckling as is true of the usual mill method of testing. In fact, only skids or a pipe rack are needed.

At this time, it might be well to disabuse the layman's mind of the common conception that longitudinal tension increases the tendency of API threaded joints to leak. This is not so. Several comprehensive research problems have proved conclusively that there is no more tendency towards leakage at tension loads up to the yield point of the metal under the last engaged thread, than at zero tension.

A Point Of Controversy

A point of controversy that arises is the degree of make up of the test plugs being screwed into the joints to test the coupling and threaded end. The common procedure is to screw the plug on with handles approximately 2 feet long and bump the plug up as tight as possible. The joint of pipe is then filled with water and pressured to the desired pressure. Approximately 90% of the connections on new casing and tubing hold up to 80% of minimum internal yield with this amount of make up. However, if the connections leak, the pressure is released and pipe tongs applied to further tighten the connections, and again the joint is pressured to the desired pressure. If the joint leaks with this additional make up it is marked as a "leaker". Field testing experience indicates that a good thread should show a positive test at this point, which is quite often short of the ft/lb torque used when running the pipe in the hole.

Arguments to support the above practice are that if the last thread must be covered, or if you must use the full make up of the pipe, then you are operating at the leak proof limit of the connection rather than 80% of its ability to resist leakage. Also this is an instantaneous test; the pressure is held on the joint for five seconds. If the pressure were held for thirty minutes to one hour it would be considerably different. The threads are the important part that need testing on new pipe in the field. They have never been tested and there is considerable handling at the mill and between the mill and the field that could damage the thread. There is also the possibility that an occasional bad thread might slip through the mass production processes at the mill. High pressure testing of secondhand or rerun casing and tubing is very important for both the body of the pipe and the threaded and coupled ends.

Advantage Of Field Method

A very great advantage of the field method is that any pressure, up to the bursting strength of the tube, can be obtained by using a sufficiently high pressure pump. This is the method commonly used in the mill laboratories for tests to destruction of heavy wall, high strength tubes.

Another advantage of the field method is that leaks through the pipe-coupling threads may be noted very readily. This is more difficult to detect in some of the mill type test benches.

Resistance to leakage is a function of thread accuracy, degree of make up of coupling, type of lubricant, and a time or handling factor. Experience has shown that modern pipe mills have no difficulty whatsoever in conforming to the API thread specifications. Power tight make up of couplings can be controlled accurately, and almost any soap base grease with powdered lead, copper, zinc, or graphite filler will seal effectively for an appreciable amount of time. So, and this is borne out by years of experience, leaks almost never occur at a pipe mill test bench.

Pipe thread lubricants may seal effectively when first applied and the joint is first made up, but may fail to hold after the handling incidental to truck, railroad, or steamship hauling.

One of the disadvantages of rack testing is its slowness of operation. The plugs and caps must be screwed on and off by hand for each test, which consumes considerable time. Depending on the size, only ten to fifteen lengths per hour can be tested.

It is also necessary to take extra safety precautions. The workmen and observers must be careful not to stand directly beside the tube, because of possible shattering, nor directly in front of the cap or plug which may blow off.

RETRIEVABLE PLUG METHOD

As previously stated, the principle of hydrostatic pressure testing is not new, having been used for years in tube mills and in the field on pipe racks. The latter is a simplified method of testing pipe.

The reasons for testing old tubing being rerun in a well are generally to locate deterioration and trouble known to exist. During the past few years, however, this method of field testing has been used more and more for the purpose of testing new tubing direct from the mill. It has been found that some types of defects, although not discernible at the mill, do show up after hauling, and are brought to light by this method of field testing. Also, thread lubricants and proper make up are beyond the control of the manufacturer.

METHOD DESCRIBED

The main advantage of this method of tubing testing is that all collar and pin threads are tested in their make up position while the crew is running the tubing in the well. A retrievable plug, consisting of top and bottom packers joined together by a stand of sucker rods, is lowered into the tubing until the bottom packer is below the make up joint. Then the area between the top and bottom packer is filled with water and pressure is applied by means of a hydraulic ram, located on the service truck. The pressure is held for a few seconds. The loss of any water will register on the sensitive vernier gage and indicate a leak. When a loss of pressure occurs, the stand is pulled above the derrick floor, with the pressure retained. A visual check instantly locates the leak.

If a stand passes the test, the quick change head is removed, the next stand added to the string and lowered to the slips. The testing assembly, which has been lowered with the previous stand, is retrieved by an overshot and placed in the proper position for testing the next stand. The water between the two packers is retained for the next test, except for a few drops lost while the packers are passing over tubing ends in the coupling.

If tubing repairs are necessary at any time, the entire testing assembly may be tripped and lowered to any given depth and reset. The go-devil is dropped to release the wire line, which is pulled out of the hole by the service truck. The stand is then free and unobstructed for repairs.

LEAKS IN NEW TUBING

New tubing and couplings, whose threads are within the API tolerances, will not leak if a minimum amount of caution is used when the stand is made up. It is asserted that pipe thread lubricants will seal effectively for short periods of time when first applied, and fail only after several hours of stress; however, records are available showing a surprising number of leaks in new tubing. The reason for these factory perfect threads leaking when made up was not definitely determined. The equipment used is modern and most crews are experienced. There are two possible conclusions. Faulty handling is considered the principle reason for leaks in new tubing. Another reason is the possibility of imperfectly mated tubing or faulty handling.

COUPLING TESTING

Just recently, tools have been developed for testing casing couplings as they are being lowered into the well. This method of testing is somewhat similar to the retrievable plug method, except the testing is only across the coupling make up. Furthermore, all testing is done above the slips and visibly inspected above the floor. While additional problems had to be worked out in this method of testing, the process is very fast and should prove a good service to the users of oil field tubular good.

REFERENCES

"Various Methods of High Pressure Testing Oil Country Tubular Material" by H. G. Texter. Printed in the Petroleum Engineer, 1953.

"Simplified Method Tests Tubing" by Jerry Stumm. Printed in 1955 issue of the Petroleum Engineer.