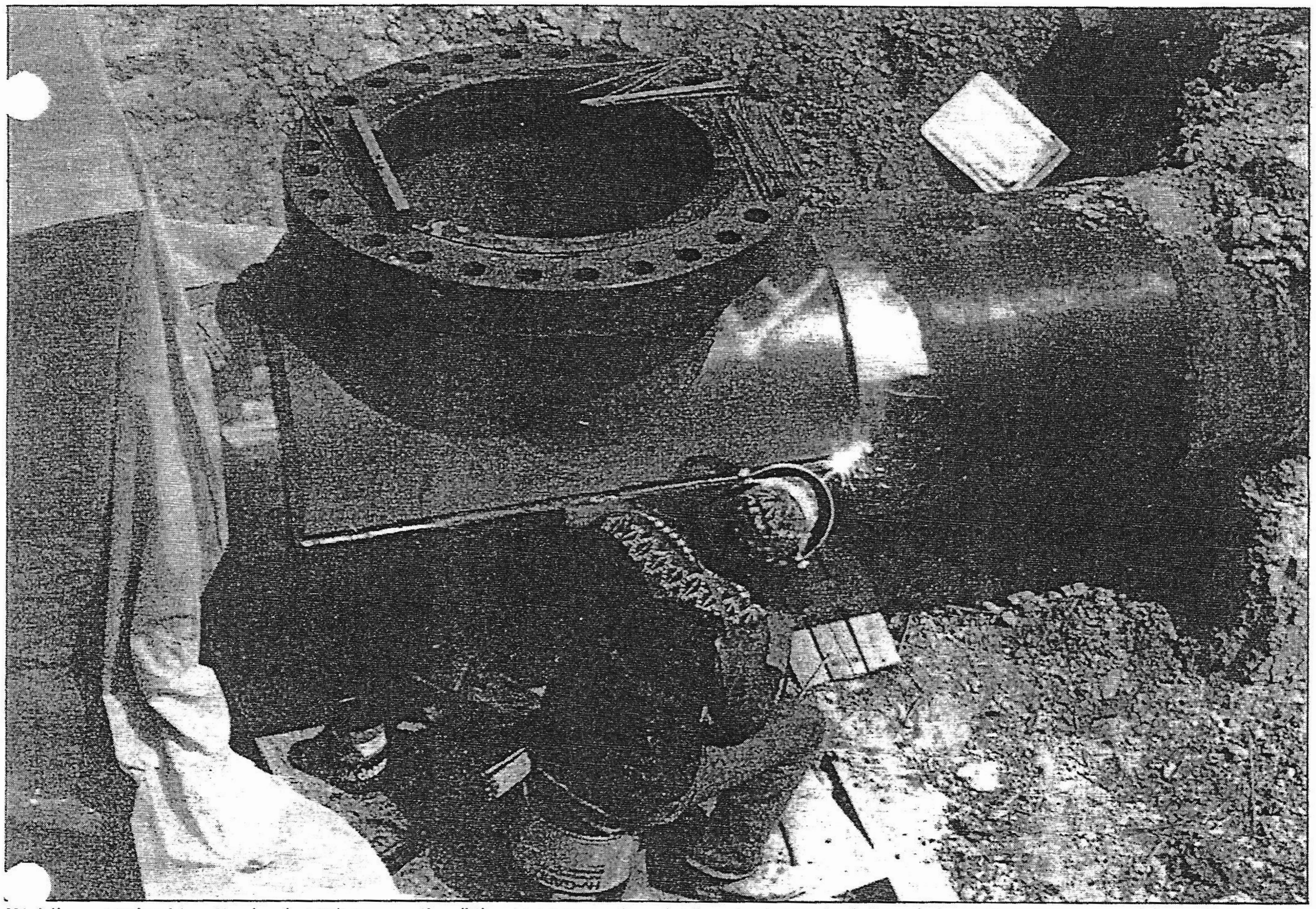


Welding required to attach a branch connection fitting to an operating pipeline, such as this full encirclement tee to be used for a "hot tap," usually involves manual metal arc and is completed under less than ideal conditions.

Guidelines For Welding On Pressurized Pipe

by **Dave J. Hicks,** *P.E., Chief Engineer, T. D. Williamson, Inc., Tulsa, Oklahoma*

Procedure for cutting into an operating pipeline (main, storage tank, or other pressure vessel) and connecting branch piping while the line has product under pressure and/or flowing conditions, is referred to as a "hot tap".

Welding that is required to attach a branch connection fitting (hot tap fitting) to an operating pipeline is called, "hot tap welding". The vast majority of hot tap welding is manual metal arc, and is usually completed under less than ideal conditions.

The practice of "hot tapping" pres-s‥ized pipelines has become wide-‥ad throughout the hydrocarbon and chemical pipeline business.

Hot tapping on pipelines containing water, crude oil, natural gas, petroleum products, and other materials has been a common practice for many years.

Problem Areas

Generally, in almost all hot tapping jobs, the main problem areas to be dealt with or avoided are associated with welding the fitting on the pipeline. If the fitting can be welded to the pipe safely, then the hot tapping procedure can be done safely.

There are three main areas that need to be taken into account during the fitting installation stage. They are:

1. Weld cracking, heat affected zone (HAZ) cracking, or other common weld defects.
2. Blow-through where the weakened pipe material under the weld and the molten pool is blown out by the internal pipe pressure.
3. Unstable pipe contents.

Common Weld Cracking is caused by the following factors; joint restraint, bead shape, weldability of the material, hydrogen pickup, and high cooling rate.

Heat Affected Zone Cracking is usually caused by absorption of atomic hydrogen from the weld metal into the HAZ of the base metal. A rapid cooling rate traps this hydrogen between the crystal lattice and builds up pressure. This pressure, combined with the shrinkage and hardening effect of the steel's chemistry, causes cracking.

Other Common Weld Defects such as lack of fusion, undercut, and porosity are caused by the correctable welding variables such as improper weld gap, welding speed, low current, electrode size, faulty electrode manipulation, high current, short arc, insufficient puddling time, and wrong electrode.

Blow Through is a term describing a condition where the weakened pipe material under the weld, and the molten pool, is blown out by the internal pipe pressure. On non-full encirclement fittings, tests have shown that flow through would most likely occur on the weld running longitudinal to the pipeline. On a full encirclement fitting, the only welds made directly to the pipeline are the end circumferential weld.

From previous tests, it has been shown that the possible causes of blow through are as follows:

1. Type of electrode (deeper penetration vs shallow penetration electrode).
2. Electrode manipulation (electrode being left in one spot too long).
3. Direction of welding in relation to hoop stress on the pipeline. Welding perpendicular to pipe hoop stress has been found to be more likely to produce a blow through condition.
4. Pipe wall thickness – tests have shown blow through possible with 0.156-in. wall pipe.
5. Pipe internal pressure or stress level in pipe. Tests have shown blow through possible on 0.188-in. pipe wall with a 72% stress level.
6. High heat input.

Work done thus far, in several important areas of study on preventing blow through, allow some guidelines to be drawn. Additional technical work is being completed on this important subject at the present time.

Unstable Pipe Contents

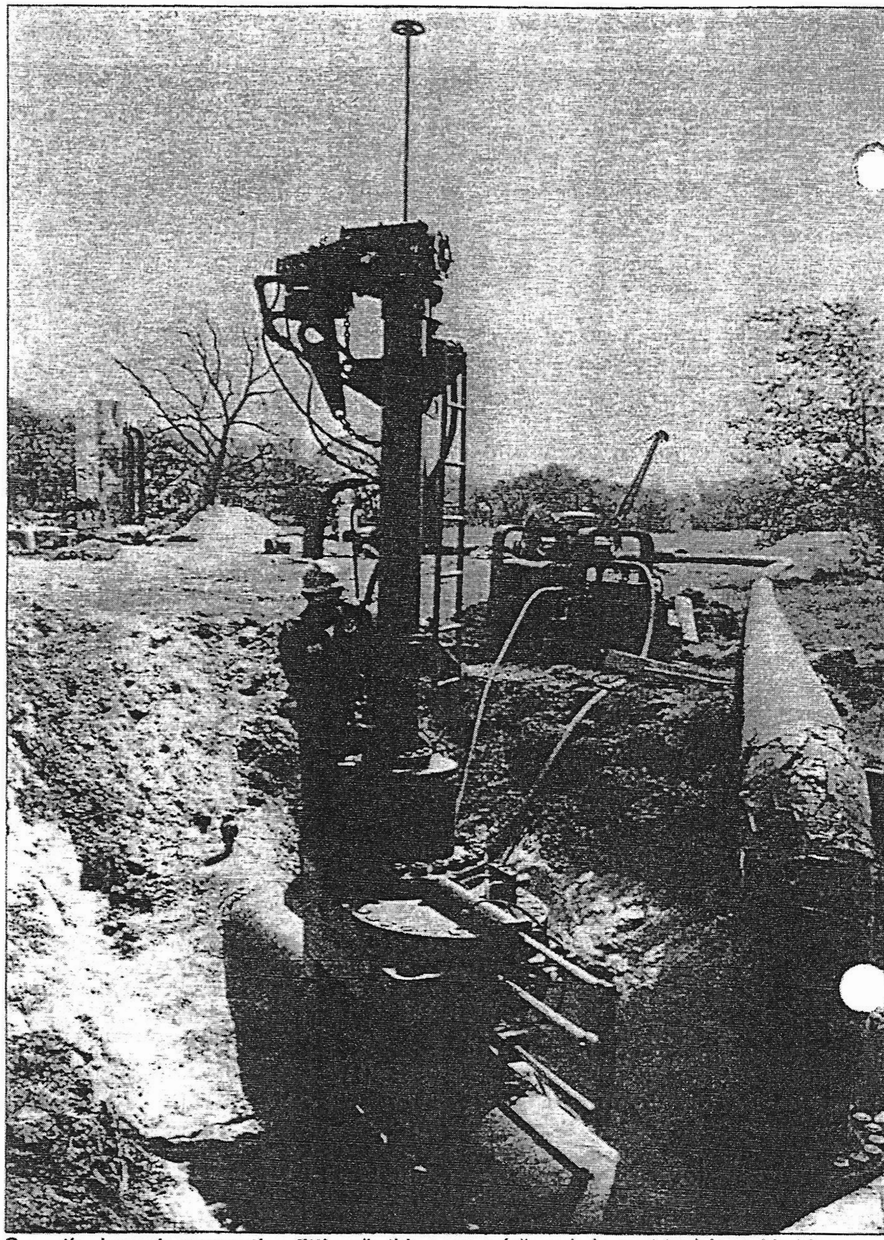
Factors to be considered concerning *unstable pipe contents* are normally related to pipe contents that become unstable with the addition of heat and/or nonflowing conditions. Some examples of these types of problems are as follows:

Combustible mixtures such as air and fuel or oxygen and fuel of the mixture percentages that could allow ignition and propagation of an oxidation reaction (sustained combustion) with the addition of heat, should not be welded upon or hot tapped.

Oxygen, oxygen-enriched air or compressed air could allow ignition and propagation of oxidation with the addition of heat and fuel. These should not be welded upon if there is any possibility of fuel being present.

Chlorine can present similar problems.

Ethylene (C_2H_4), an unsaturated hydrocarbon which under certain conditions, can be decomposed explosively in the absence of oxygen. Ethylene pipelines normally can be hot tap welded if pressure is 1100 psi or less, temperature is 250 F or less, and the concentration of oxygen is 1000 ppm or less.



Once the branch connection fitting (in this case a full encirclement tee) is welded into place, the procedure known as "hot tapping" can begin.

Hydrogen, hydrogen mixture, and caustic present a different type problem. The main problem with welding on these materials is the possible cracking that can occur in the weld metal or heat affected zone. Welding and hot tapping on lines containing these materials should be avoided if there is any possibility that the hydrogen could get into the molten weld metal, or the caustic could cause stress corrosion cracking in the pipe wall.

No flow conditions can allow the contents of a pipe to reach a higher temperature than with flow conditions. Pipe contents with impurities (oxygen) at higher temperatures are more likely to ignite. Flow conditions help to dissipate heat but serve to speed up the quench rate which is a factor in weld cracking problems.

In gases, no-flow conditions are potentially hazardous. Conversely, high flow rates have rarely been found to present problems. A minimum velocity of 1.3 ft/sec on a gas line should be maintained to carry the welding heat away. A maximum flow rate does not appear critical within the limits of practicability.

In liquids, a no-flow rate condition can also be potentially hazardous. Unlike gases, high flow rates in liquids do present problems:

1. More heat input is required to ensure full weld fusions.
2. High flow rates tend to result in too rapid quenching, which contributes to cracking problems.

To avoid these two problems, it is recommended that a minimum velocity of 1.3 ft/sec and a maximum of 4 ft/sec be maintained on liquid lines.

It should be noted here that preheat

and post weld treatment can sometimes be used to allow welding outside these recommendations.

Hot Tap Welding

. latest work being done on this subject is by Battelle Memorial Institute, sponsored by several companies. It is called the "Hot Tap Welding" Project, with its objective being to develop calculated and tested parameter limits so that the hot tap welding can be done safely. Results of the study will be available for use by the sponsoring companies immediately, and will be made public in two years. Preliminary reports indicate that the work has increased the current "state of art" of hot tap welding.

Basically, this project has developed computer programs that take input job parameters (pipe size, working fluid, pipe thickness, velocity of flow, type of welding electrode, speed of electrode, volts, amps, etc.), and output temperatures achieved and cooling rates.

The temperature output indicates and predicts the likelihood of blow through.

The cooling rates output used with carbon equivalent vs hardness curves indicates and predicts likelihood of heat affected zone cracking.

The above information is presented in the form of curves.

C lusions

..ot tap welding, which has become necessary from a functional and economical standpoint, can be done safely. On each job, the parameters need to be identified and evaluated relative to the current techology available. The level of hot tap welding technology is growing due to the general welding technology increase and the current hot tap welding project by Battelle. Care must be taken to follow the available guidelines.

Recommendations

Recommended **Guidelines** to prevent hot tap welding problems include:

1. Qualify weldors and weld procedures to applicable codes and make sure procedures are followed.
2. A shallow penetration or low process hydrogen electrode should be used.
3. Control the heat input.
4. Unstable working fluids, such as air and fuel, oxygen and fuel, oxygen, chlorine, ethylene, hydrogen, and caustic should be considered very carefully, and special precautions should be taken, some of which are ..ted in this paper under Unstable .pe Contents.
5. The contents of the line should be flowing. A minimum velocity of 1.3 ft/sec on a gas line should be maintained to carry the welding heat away. A maximum flow rate does not appear critical within the limits of practicability. It is recommended that a minimum velocity of 1.3 ft/sec and a maximum of 4 ft/sec be maintained on liquid lines.
6. Heat area on the pipe where fitting is to be installed to remove moisture from the line.
7. Control the carbon and alloy content of the base metals. The carbon equivalent should be low. A carbon equivalent less than or equal to 0.43 is suggested on pipe over X-42; one formula for C.E. would be:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

8. Use the proper sequence of welds (longitudinal welds first, then one end circumferential weld, then the other).
9. The electrode should be manipulated so that there is a heat balance between the fitting and the pipe.
10. The weld attaching the fitting to the pipe should be circumferential to the pipe. It should not be perendicular to the hoop stress of the pipeline.
11. Minimum pipe wall should be 0.156-in. or greater. If the weld must be longitudinal to the pipe, then the minimum wall should be 0.188-in. with a 72% stress level or less.
12. The pressure in the pipeline should be reduced according to the ASME Gas Piping Standards Committee's recommended formula for welding split repair sleeves on gas pipelines. (Other industry or company pressure reduction formulas could be used.) ASME Formula:

$$P = \frac{2S\,(t\text{-}c)\,0.72}{D}$$

S = specified minimum yield strength, psi
t = nominal pipe wall thickness, inch
D = nominal pipe diameter, inch
c = correction factor, inch – for which present committee thinking reflects a value of 3/32 inch (allowance for heated metal loss of strength)

(Note: The ASME formula is thought to be conservative.)

and/or

Use should be made of new hot tap welding technology recently developed in Battelle Hot Tap Welding Project.

13. Inspection and testing of the field weld is an important procedure after the welding is complete. It is a good idea to pressure test the hot tap fitting before the hot tap, and to nondestructively examine the welding. It is recommended that the maximum test pressure not exceed the internal pipe pressure. **P&GJ**