UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

2/7/84

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of APPLICATION OF TEXAS UTILITIES GENERATING COMPANY, ET AL. FOR AN OPERATING LICENSE FOR COMANCHE PEAK STEAM ELECTRIC STATION UNITS #1 AND #2 (CPSES)	Docket Nos. 50-445 and 50-446

TESTIMONY OF CASE WITNESSES
DARLENE STINER AND HENRY STINER

Q: Do you have testimony regarding the open welding issues in this proceeding?

A: (Mrs. Stiner): Yes, I do.

A: (Mr. Stiner): Yes. First I'd like to clarify the record regarding some of the things which were stated in Applicants' Summary of the Record Regarding Weave and Downhill Welding, filed July 15, 1983, and then to further clarify some of my previous testimony.

Q: Mrs. Stiner, what do you wish to clarify?

A: (Mrs. Stiner): I was certified to weld to both ASME and AWS D1.1, both of which are used at Comanche Peak. ASME is used for Class 1, 2 and 3 hangers and supports; it's not used for Class 5. AWS D1.1 is used for Classes 4, 5, and 6 -- anything that's not safety-related.

Q: Isn't Class 5 safety-related?

A: (Mrs. Stiner): Procedurally, no. Logically, Class 5 should be considered safety-related, because the Class 5 hangers and supports are all in safety-related areas, to the best of my knowledge.

Q: Mr. Stiner, what codes did you work to at Comanche Peak?

A: (Mr. Stiner): I was also certified to weld to both ASME and AWS D1.1 Codes. As Darlene Stated, both of these Codes are used at Comanche Peak.

Q: And is it also your understanding that ASME is used for Classes 1, 2, and 3 hangers and supports, but not for Class 5, and that AWS D1.1 is used for Classes 4, 5, and 6?

A: (Mr. Stiner): Yes.

Q: What specific codes and procedures did you use at Comanche Peak?

A: (Mrs. Stiner): WPS 11032, 10046, and 11065, and CPM 6.9 plus quality control procedures (it's been a while, but I believe the numbers of the ones I used primarily as far as QC control procedures were QI-QAP-11.16-1 and ANSI Code B31.1).

A: (Mr. Stiner): As stated in my testimony (Tr. 4210/16-24), the welding procedures for the C-10 and A-10 welding process codes are 11032, 11065, and 10046.

Q: What else would you like to clarify?

A: (Mr. Stiner): The first time we testified, we didn't have time to put every detail in our testimony and (although I'm not putting CASE down in any way -- I think they've done a fantastic job) CASE didn't know enough about what we were talking about to be able to help us put into the right words what we wanted to say. And we didn't know about things like rebuttal testimony then. We thought everybody understood what we meant, but from some of the Board's Orders which I have read, it is very plain to see that we were not fully understood. Therefore, I will now attempt to clarify my testimony.

I previously stated in my testimony that inexperienced welders were doing some poor and/or illegal welding practices at Comanche Peak. I know now that a skillful welder is one who possesses a considerable amount of technical information. Merely being able to run a pass or make a good bead is not enough, because in the process of making a weld he may, from lack of understanding, jeopardize the strength of the welded structure. Consequently, such factors as properties of metals, expansion and contraction grain growth, effects of heat, and others should definitely be considered essential knowledge for any welder. I was not trained by Brown & Root to know these things. I was not even given a written test; the only requirement at Comanche Peak is to pass a three-position plate test, which only requires the ability to make a good bead. All of the welders at Comanche Peak are trained in the same manner and, according to the ASME Code, it is up to the Applicants to assure that each welder is qualified to do the job, not just make a good bead but to understand all of the process.

Q: Mrs. Stiner, do you agree with Mr. Stiner's statements?

A: (Mrs. Stiner): Most definitely. I was trained the same way, and the test was the same. Most of what I learned, I learned for myself by reading and trying to improve my skills. I have recently found a welding manual that George Baird had me buy while I was in training for welding (SMAW). I was having some problems with my welds, so Mr. Baird ordered me to buy a copy of WELDING SKILLS AND PRACTICES, published by the American Technical Society, to help me with my training. (I believe it cost $9.00.) Mr. Baird said he thought it was about the best welding book he had seen and that I should use it at CPSES. It did help me at that time, and I hope it will also help the Board members to better understand some of Henry's and my testimony. We have attached as Attachment B to our testimony some of the pages from it, and we will be referring to them in our testimony later. Also, we hope to be able to bring to the hearings some actual welding tests to show the Board just what we're talking about.

As I received additional certifications, and especially after I became a QC inspector, I learned more and more by reading and trying to understand the importance of what I was doing.

A: (Mr. Stiner): It helped me a lot to understand why welding was supposed to be done a certain way and the importance of doing it right when I started reading some of Darlene's QC books and procedures. That was when I really began to become concerned about the welding practices at Comanche Peak. And I'm still reading and trying to understand more. At the time I worked at Comanche Peak, I knew that some of the things I was ordered to do weren't right, but it wasn't until I started reading and talking with Darlene after she became a QC inspector that I really began to understand how bad some of those things were. That's why I decided to come forward and testify. It was an especially difficult decision because Darlene was still working at Comanche Peak, but when I realized the importance of doing the welding right and saw the manner in which the NRC investigators had handled the problems Darlene and I brought up, I knew something had to be done.

A: (Mrs. Stiner): And even though I was afraid I might lost my job, I agreed with Henry that he should testify because I knew that we had to try to do something about the way the plant was being built.

Weave Beading (Weave Welding) -- HEAT INPUT

Q: In their 1/30/84 Reply to CASE's Identification of Issues (page 10), Applicants state that they: "intend to present testimony to address the relationship between the AWS and ASME Codes and the several open welding issues, viz., weave beading, welding of misdrilled holes, downhill welding and weld rod control."

Do you have any further clarifying testimony regarding weave beading (or weave welding)?

A: (Mr. Stiner): It's obvious that we didn't make ourselves clear in our previous testimony. There are several aspects of weave welding which need to be clarified.

A: (Mrs. Stiner): That's right. During my testimony, I tried to indicate that one of the things we were concerned with is the excessive heat input when you weave weld.

Q: Is it still your understanding that weave welding is not allowed at Comanche Peak?

A: (Mr. Stiner): That's what I always understood. The procedure that states that weave welding is not to be used is CPM-6.9, to the best of my recollection. This is also indicated on the Weld Parameter Guides issued from the rod shack to each welder when material is picked up. If you go over the maximum bead width, you'd be weave welding.

A: (Mrs. Stiner): The one I used most is 11032. It's interchangeable with and often used in place of 11065. 11032 states that stringer beads only shall be used, to the best of my recollection. Therefore, weave welding is not permitted even on the cap or the root as Applicants have stated can be done; that's the understanding I always had too. It seems to me that if this were not true, Applicants would have brought forward the procedures by now to prove what they were saying (especially since Henry and I discussed this in our 7/25/83 affidavit).

A: (Mr. Stiner): But even if weave beading over four-core-wire diameter is permitted at Comanche Peak, there is still a problem because weave beading over four-core-wire diameter is also done. I've seen it done many times and I've done it myself.

A: (Mrs. Stiner): That's right. It's a common practice at Comanche Peak.

Q: Mrs. Stiner, have you seen it done yourself?

A: (Mrs. Stiner): Yes, I have, and I've also done it myself when I was a welder.

Q: Please continue.

A: (Mr. Stiner): In the process of learning to be a better welder, I have become familiar with the effect of heat as well as cold on the structure of metal and what happens to metal when certain alloying elements are added to it. I also became familiar with what safeguards must be followed in welding metals because when heat is applied during a welding process, the very elements originally added to strengthen the metals may destroy them. Metals expand and contract, setting up great stresses that sometimes result in severe distortion.

Improper welding of stainless steel may result in a complete loss of its corrosion-resistant qualities, and welding high carbon steel in the same manner as low carbon steel may produce such brittle welds as to make the welded mass unusable. When I testified before, I used the term "weave welding" (or "weave beading"). Now I know that was the wrong term to use to describe the problems with welds made at Comanche Peak. The weave welding itself and whether or not it is done to procedure is only one of the many facets of the problem. Weave welding (or weave beading, as it is called in some books) is one of the ways in which problem welds were made at CPSES.

In his affidavit attached to Applicants' 7/15/83 Summary of the Record Regarding Weave and Downhill Welding, Mr. Brandt stated:

> " . . . the only material on which weave welding resulting in excessive bead width is considered to be of concern in the ASME Code is material that requires Charpy impact testing."

He then stated that someone (he doesn't state that he personally did it) identified "the particular areas which the Stiners believed contained weave welding." He identifies five areas which I had identified and two instances which Darlene had identified. He stated:

> "Specifically, Mr. Stiner identified five areas in which he contended weave welds existed (CASE Exhibit 666 at 11). These five areas are (1) South Yard Tunnel; (2) Auxiliary Building; (3) North Yard Tunnel; (4) North Pump Room; and (5) Reactor 1 Demineralized Water Tank Room."

But if you look at my testimony, that's not what I said. What I actually said was (Tr. 4213/7-10, CASE Exhibit 666 at 11):

> "I told them that in the Auxiliary Building, the North Yard Tunnel, the North Pump Room, the Reactor 1 Demineralized Water Tank Room, and every place I had ever worked, weave welds, porosity, undercut and overlap could be found . . . unless the surfaces of the welds were ground off and the welds were capped (as the I&E Report states)." (First emphasis added; second emphasis in the original.)

I would like to say that I worked in the Containment Building in the Reactor and in various parts of the plant where I feel sure impact testing is required. I don't remember hanger numbers or exact locations; after you've covered hundreds of welds, you tend to forget exactly where most of them are. I'd have to look around some to find any now.

The welding practices at CPSES have got to be changed, and for the foregoing reasons, here is a more detailed explanation of why weave beading (using over four-core-wire diameter) is a serious safety defect. The book which Darlene used at Comanche Peak to try to help her understand more about welding also has some helpful information about welding metallurgy. (See Attachment B to this testimony.)

Q: Mr. Stiner, are you a metallurgist?

A: No, I'm not. But you don't <u>have</u> to be a metallurgist to understand some things. There is a discussion on pages 19 and 20 of Attachment B about Properties of Materials. I have personally observed welders making repeated passes with a weave bead without stopping to check heat input. When this happens, too much heat builds up, which can affect the parent metal substantially. (See Attachment B, pages 20-22, Structure of Metals.) From reading the referenced information, you can see why weave beading of over four times the rod diameter is a defect. If you apply too much heat, the parent metal cools slower, affecting the grain structure. I have personally observed welders welding without using a heat indicating crayon or any other device to check the heat input.

Also, on several occasions, I was instructed to repair hangers where the weld was in excess of four-core-wire diameter where the parent metal was heated so hot that the parent metal for four or five inches out from the weld was blue tempered, causing brittleness. (See Attachment B, pages 23 through 28, especially page 28, Brittleness.) On other days, when the temperature was below freezing, I was instructed to make welds on Class 3 hangers that were not preheated. The effects of welding on metal not preheated is also a factor in setting up bad welds. (See Attachment B, especially page 28, Cryogenic properties, and pages 23-24, Other Factors Altering Strength and Structure.)

The following factors must be included in any testimony about weave welding in order to understand the full extent of the problem at Comanche Peak:

1. Too much heat is often applied.
2. Impurities are entrapped in the weld.
3. Most of the hangers I'm talking about were not preheated.
4. The interpass temperature was not controlled.
5. Unacceptable welding techniques are used, such as weave welding over four-core-wire diameter.
6. Weave welding has been done all over Comanche Peak, including areas where Charpy impact testing was required.

(See Attachment B: Page 24, Effects of Heat of the Welding Process; Page 31-32, Welding Defects; page 32-37, Residual Stresses, especially first paragraph.)

There is also another example of weave welding which I personally have performed on tube steel type hangers. I was instructed by Fred Coleman, my Foreman (who told me he was instructed by Forest Dendy, his General Foreman) to take a welding rod and beat the flux off and use it to fill in a bad fit-up (too much gap) by placing the bare electrode into the gap and weave welding another electrode with the flux still on it over the bare wire. This was all done as an effort to keep from cutting the hanger down and calling the fitters back to refit the hanger.

Q: Mrs. Stiner, have you ever made the kind of weave welding which Mr. Stiner just discussed (taking a welding rod, beating the flux off, and using it to fill in a bad fit-up by placing the bare electrode into the gap and weave welding another electrode with the flux still on it over the bare wire)?

A: (Mrs. Stiner): Yes, I have. I didn't know how to beat the flux off my electrode and use it as extra filler when I had to weld up a bad fit-up until one of the foremen (Fred Coleman) showed me how. He was temporarily foreman while I worked in the fab shop.

Q: Is there anything else you'd like to clarify regarding weave welding?

A: (Mr. Stiner): Yes. Regarding weave welding and the heat input, Mr. Brandt says in his affidavit (attached to Applicants' 7/15/83 Summary of the Record Regarding Weave and Downhill Welding)(page 2):

> "The purpose of limiting bead width for welds on materials requiring impact testing is to control effective heat input because excessive heat input could cause broadering and subsequent embrittlement of the heat affected zone." (Emphasis added.)

So when we're talking about maximum bead width, we're talking about the effective heat input also. During the whole term of my employment at Brown & Root, the only time that I was given a temperature indicating crayon was in the Welding Qualification Test Center (WQTC), and I had to ask for it.

Q: Is it a requirement at Comanche Peak that a temperature indicating crayon be used?

A: (Mr. Stiner): I do know it's required by some procedures. But it's not a practice that is used by the structural welders at Comanche Peak.

In regard to Applicants' Exhibits 141N-141V, which Mr. Brandt stated permit the use of weave welding at Comanche Peak, on those procedures under preheat on the Welding Procedure Specification (4th box, left-hand column), the preheat temperature and interpass-temperature range is indicated. At Comanche Peak, they don't check the preheat temperature or the interpass temperature. When I tested at the WQTC, they gave me a temperature indicating crayon to check and be sure that each consecutive pass was not heating the parent metal up above the interpass temperature range which was in the procedure. Even on your test coupons if you rise above that interpass temperature, when they do the bend test on the strips that they'll cut out of your test coupon, you will fail the test because you will have created embrittlement of the parent metal which will show cracks in the weld of the test coupon.

But out in the field, I have very seldom seen anyone use the temperature indicating crayons or any other kind of temperature measuring device. I never used the crayons myself. Generally, because of my experience with welding, I could tell when it was getting too hot if I held my hand near the metal. But we were under such pressure to put up the hangers that most of the time we didn't take time to check the temperature. Under one foreman, we had a quota that we had to meet every day. I talked about some of the pressures we were under in my testimony (see especially Tr. 4220-4221).

A: (Mrs. Stiner) The welders didn't have an hour or two to wait for it to cool off; they had to get the weld made because they had so many to get done each day. Plus the fact that they always had to worry about somebody else coming along and stealing their welding machine or their lead while they went to the restroom or something. At the end of the day, your foreman didn't understand why you didn't have more hangers done. Most of the time, the foreman sent the welder to look for their machine and their lead when it was stolen; they didn't have you check out another machine. You might spend hours looking for a machine that nobody is going to admit was yours.

A: (Mr. Stiner) They created such adverse conditions for the welder that he just had a limited amount of time to complete the required amount of hangers. Welders shouldn't have to work under such adverse conditions.

A: (Mrs. Stiner) I'd like to say something else about the weave welding. As an example, if you took a rod and struck an arc and held it to the metal and just kept it burning in the same spot, your metal would just fall right out after a time. Also, the longer you hold it there, the hotter it gets. So when you weave weld, the longer it takes you to progress up the piece of metal, the hotter the piece is going to be in one specific area. Therefore, the parent metal would become brittle because you are not controlling your heat input.

Q: Mrs. Stiner, did you ever use a temperature indicating crayon?

A: (Mrs. Stiner) Only in WQTC. I've never used it other than in WQTC. During my inspections, only a few times have I seen anyone using a temperature stick and that was generally pipe welders, heliarcers, and so forth. Most of the time it was not on pipe supports; I don't recall ever seeing it used on pipe supports.

Q: How can they check the effective heat zone and be sure they don't get it too hot?

A: (Mr. Stiner) They can't. There are other heat checking devices they could use, but they don't use them at Comanche Peak.

A: (Mrs. Stiner) There's no way they can be sure they're not getting it too hot, because they don't use any heat checking devices at all most of the time.

Q: How does grinding down help correct weave welding?

A: (Mrs. Stiner) It does not help it at all. The weld underneath is still a weave weld, which is weaker because there has been no control over the heat input.

Q: How could you correct weave welding then?

A: (Mrs. Stiner) You grind it completely down to base metal and reweld it with a stringer bead. It would really be better to cut the whole thing down and redo it, because you've still got damaged parent metal.

Q: Was that what you did, Mr. Stiner?

A: (Mr. Stiner): No. As I testified (Tr. 4211-4215, 42[illegible]5-4236, 4255), I had to go along and repair bad weave welds that other welders had made most of the time, and I was told not to grind all of the base metal out but just to grind off the surface and cap it so it would appear to be a sound weld. In other words, it was just covered up, not corrected.

Q: Is there anything else about weave welding?

A: (Mrs. Stiner): Yes, there's one more thing which needs to be clarified on page 25 of my testimony, lines 2 through 8 (CASE Exhibit 667, 9/1/82). On page 10 of Applicants' 7/15/83 pleading, it is stated "It is clear that the 'repair' alleged by the Stiners to have been performed was not required because of some structural weakness in the weld or welded material. Rather, the repair was cosmetic, there being no structural reason for limiting weave welding on materials not requiring Charpy impact testing." I thought it was clear in my testimony on page 25 that the weave welds were discovered when I was inspecting the hanger for torquing; the welds were in the process of being made -- it was not an initial root pass or merely a cover pass for cosmetic reasons, as indicated by Applicants. Later, when I returned for final inspection of the torquing, I again noted the weave welds, which were still in process of being made; they were not merely cosmetic problems, and I wrote an NCR on them accordingly. As stated in my testimony, the superintendant whom I took to see the welds himself told me to have them cut the hanger down. You don't cut a hanger down for "cosmetic reasons."

Q: Mr. Stiner, is there anything further you'd like to say about weave welding?

A: Just that it's been a continuing practice at Comanche Peak as long as I can remember. And it's my understanding that effective heat input was even a problem identified by the ASME team in, I believe, 1981, when ASME allowed Comanche Peak's N stamp to expire.

Downhill Welding

Q: Do you have anything to say about downhill welding in addition to your previous testimony?

A: (Mr. Stiner): Yes. One of my concerns with downhill welding was based on the fact that I was instructed to make downhill welds on hangers that had a limited access weld on them instead of sending me to the test center to test to the criteria for that type of situation. One of the hangers I told Mr. Driskill about is the one I referred to as the one I was fired for. It contained a downhill weld. If anyone had examined the hanger, he could have seen the downhill weld, as I was not even able to get a grinder in the limited space to grind the surface off so QC wouldn't see it. But it was not even addressed by the investigators in their report.

A number of downhill welds were made at CPSES because of limited access welds. They were not only made on root and cover passes, but in the consecutive layers in between. I have observed welders making downhill welds because of limited access; one was Roy Combs, under orders of his foreman -- I believe that was on a Class 3 hanger, because he had to weld stainless steel lugs to the pipe. I don't have the hanger number, but I know the general location and might be able to find it.

Joe Greene, one of the welding engineers at CPSES, told me that there was no such thing as limited access welds at CPSES. This type of attitude has set up a bad situation with the welders being instructed to get the work done fast, and the inability to get the proper work and lead angle needed to make the required bead.

One of the problems with downhill welding is lack of deep penetration, trapped slag caused by the molten puddle falling over the slag coating, which also causes lack of fusion. On heavy plate 1/4" or more, upward welding is preferred (see Attachment B, pages 114 and 115, Position and Movement of the Electrode).

Q: Mrs. Stiner, did you do any downhill welding at Comanche Peak?

A: Yes, I did. I talked about downhill welding some in my testimony (CASE Exhibit 666, 9/1/82, pages 45-46). I don't think I made it clear in my testimony, but I also have done downhill welding.

Q: And is it your understanding that some downhill welding at Comanche Peak was done illegally or contrary to procedures?

A: (Mrs. Stiner): Yes, probably most of it, because I don't believe most of the welders had been qualified to do it.

A: (Mr. Stiner): I'd like to point out that AWS states, regarding downhill welding (see Attachment A, AWS D1.1):

> AWS D1.1, 4.6.8:
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> "The progression for all passes in vertical position welding shall be upward, except that undercut may be repaired vertically downwards when preheat is in accordance with Table 4.2, but not lower than 70^{o}F (21^{o}C). However, when tubular products are welded, the progression of vertical welding may be upwards or downwards but only in the direction or directions for which the welder is qualified."
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> AWS D1.1, 5.16.5:
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> "For the qualification of a welder the following rules shall apply:
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> ". . . 5.16.5. A change in the position of welding to one for which the welder is not already qualified shall require requalification."

AWS D1.1, 5.16.7:

"When the plate is in the vertical position, or the pipe or tubing is in the 5G or 6G position, a change in the direction of welding shall require requalification."

Q: So downhill welding is not supposed to be used normally, but only in certain specific instances?

A: (Mr. Stiner) That's right. And then the welder is supposed to be qualified or requalified to do it.

Q: Is there anything further you'd like to say about downhill welding?

A: (Mrs. Stiner) Whenever you do a downhill weld, you don't get proper penetration -- it's sort of like skimming across the top. I have made downhill welds myself at Comanche Peak, under orders. Like if I came up on a weld that was in a particularly hard position to get to, sometimes my foreman would tell me to just go ahead and run a downhill weld over my stringer bead weld.

Q: Were you qualified for downhill welding?

A: (Mrs. Stiner) No, I wasn't.

A: (Mr. Stiner) No, I wasn't. I talked about downhill welding some in my testimony (CASE Exhibit 666, 9/1/82, pages 45-46). I don't think I made it clear in my testimony, but I also have done downhill welding.

Q: But you hadn't been qualified to do it?

A: (Mr. Stiner) No, but I was told to do it anyhow.

Weld Rod Control

Q: Do you have any comments regarding weld rod control at Comanche Peak?

A: (Mr. Stiner). Yes. My concern with weld rod control is that if a welder keeps his rods out longer than four hours, the electrodes will absorb moisture which creates a bad weld. For instance, one time I was working on a hanger on the Turbine deck. I had taken all of my rods out of the heat can and took them with me to the Turbine deck. As I was repairing a weld (I should say covering up a bad weld), an inspector from the NRC came up to me and asked where my rod can was plugged in. I told him that it was located clear down at the rod shack but I could show it to him; but he said it wasn't necessary. However, if he had checked, he would have found out that the rod can was not plugged in. A common practice of the welders is to take all of their rods out of the heat can and take them with them, and if asked why their rod can was not plugged in they would say, "Well, I haven't had my rod out of the can longer than four hours"(which is not a violation of weld rod control). But many welders most of the time didn't even put the rods in the heat can to warm them up. On some occasions, the rod shack would issue rods straight out of the open cans that were still cold.

I told NRC investigator Mr. Driskill in our initial meeting that if he would go out there, the only way to catch the welder was to find the rod cans unplugged, then record the can number and time by visually watching the can to see how long it took for the welder to come back to the can. And he would have seen that the rods were out of the cans for longer than four hours. On some days I have seen approximately 50 rod cans unplugged at the same time. Welders will keep rods from one hanger and save them to do repair work on other hangers, and after the rods have set in the welder's tool bucket for two or three days, they absorb moisture and the flux becomes contaminated. I've seen many welders do this. They have very little control over the stubs that are supposed to be turned back in. Welders even loan rods out of their cans to others to do repair work, so the welder won't have to get rods issued from the rod shacks. This is why the welders save a few rods in their tool buckets, to avoid returning to the rod shacks.

Q: Were you ordered to do this?

A: No, not directly. The welders do it for convenience. They are under so much pressure to get the work done and get the hangers up that they try to do anything they can to speed up their work. So even though nobody tells the welders directly to do it, it's encouraged because nobody ever really checks on it or makes a big thing out of it. Everybody knows it goes on. It's sort of a monkey-see, monkey-do sort of thing.

Q: Mrs. Stiner, do you have any comments regarding weld rod control?

A: (Mrs. Stiner): Yes. Weld rod control is a very important problem at CPSES. Moisture content is very important concerning the quality of welds made on pipes and supports at the plant. When rods are drawn for a particular support, a reasonable number is drawn to complete the hanger. When the job is completed or at the end of the work shift, all rods are returned to rod houses and all rods or used stubs must be counted and accounted for; this is the way it's supposed to be done. Without this counting of rods, there is no way to assure where these rods are used or whether they are ever returned to the rod house at all.

Q: Is this the way rods are actually controlled at Comanche Peak?

A: (Mrs. Stiner): No. For example, on Hanger SI-1-035-032-S35R, this support was referenced in my testimony because the design of the hanger doesn't warrant the number of rods shown to have been used -- not even it if was taken apart and rewelded over again. I have personally found bundles of unburned rods wrapped in a rubber band and put in an area for safekeeping and for future use. I turned them in to Harry Williams, who told me to take them to the area foremen and ask if they belonged to them. It doesn't stand to reason that they would acknowledge the fact that they belong to them even if they really did. Everybody knows this sort of thing goes on, but the foremen wouldn't openly admit it. It seems to me that Mr. Williams should have known that.

When I started in Class 5 inspection, the rest of my group and I were instructed when doing an inspection that had partially been cut down and rewelded with no IRN (Interim Removal Notice, which is required by procedures) in the traveler package, there was no need to verify weld symbols. I would like to point out that if new welds are made on the support and old weld symbols are not removed, QC would be likely to assume that they still had rods burned on the hanger, making it impossible to have rod traceability.

Moisture content, as stated previously, is very important in weld filler material. Welders at CPSES check out rods from rod houses where cans containing the rods are to be kept heated at all times. E-7018 type electrodes can be exposed in an unheated atmosphere for not more than four hours. This is a common type electrode used onsite. In many cases, the cans are never plugged in at all. Even if welders do plug in their cans, many times they remove all the rods and carry them around in their stub bucket so they won't need to crawl down off their scaffold in order to get more rods from the heated can; the point being that even if the heat can is left heated, the rods are still subject to moisture contamination because they are not in that heat can, but rather are in an open stub can all day. Also, if a welder drops some rods and can't find them, who knows what they will end up being used for?

I have even personally witnessed an employee drying his dirty, wet socks in the large stationary rod ovens inside the rod houses. I certainly don't think such a thing is helping the moisture control in the electrodes at all. Workers also heat food inside rod ovens. Also, jewelry and ashtrays, etc., are made onsite frequently. I was instructed by my foreman that Hal Goodson needed some ashtrays and told to make them. I did so along with a fitter. I personally delivered them to Hal Goodson. If rods were controlled at CPSES, how were rods obtained with no requisition? I simply asked for them for Mr. Goodson's ashtrays.

I think that the Board may have misunderstood that when welds are made using rods contaminated with moisture, porosity results from this and inner passes containing porosity would be covered up. If electrodes containing moisture are used, the weld is going to be as bad in the root or inner passes as on the cap. Inspection is not done on the root and inner passes; therefore, this condition would be covered up. Surface examination would not show any inner porosity or anything else. This is confirmed by what the Applicants said in their July 15, 1983, Summary of the Record Regarding Weave and Downhill Welding, pages 12 and 13. Although they were speaking about Applicants' Exhibit 141H at pages 4 and 6 in regard to downhill welding, it also applies here:

> ". . . it is clear that the cover pass is the finishing layer of weld material which covers the underlying weld layers. Thus, viewing the weld from the top, the weld passes underneath the cover pass are completely covered and not visible to one inspecting a finished weld." (Emphasis added.)

Plug Welds

Q: Do you have any further comments you'd like to make about plug welds?

A: (Mr. Stiner): I was also instructed by Fred Coleman, my foreman, to make plug welds on holes drilled in the wrong place. I don't remember if I made it clear that these plug welds were made in the cable spread oom; I made 20 or 30 at least. There were never any QC inspectors present before or after and my foreman would run watch for QC while we did them. I also made plug welds in other safety-related areas in the plant. I was told to grind the plug weld down to the top of the parent metal and buff the surface so you could not tell it was there, then take a can of grey paint like they use on the metal and paint it so no one could see it. This is what all or most of the welders do. They all know that it is not allowed by the code, but to keep their jobs and to speed up production, they do it anyway.

(Mrs. Stiner): I would like to add a couple of items on plug welds. I feel this is a very important issue because when plug welds are done, there is slag entrapped inside the welded area. I don't personally, through personal experience, know of any way to make a plug weld without entrapment of slag. One side is welded, then flipped over to make the other side weld. When side #1 is welded, slag rolls under and gathers on the bottom of the weld. The piece is then turned over and you have to chip out the slag as best you can before finishing the weld, thus entrapping slag which is held in cracks, etc. I have made plug welds under orders many times. I have never had QC check on the plug welds I made and I also have never drawn special rods for this purpose. If I was welding on one hanger and the foreman brought a piece requiring pluging to me, he would tell me we didn't have time to draw one rod for this and to just use one of the ones I already had. I don't know where all of these plug welds are now in the plant. I did most of them on fab tables and wasn't told where they were to be used other than what class hanger it was. We ground and painted the surface so QC would not have been able to detect such a weld.

Q: Do you have anything further to say?
A: (Both): Not at this time.

ATTACHMENT A

ANSI/AWS D1.1-81

An American National Standard
Approved by
American National Standards Institute

Structural Welding Code—Steel

Fifth Edition

Superseding
AWS D1.1-80

Prepared by
AWS Structural Welding Committee

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Effective January 1, 1981

AMERICAN WELDING SOCIETY, INC.
2501 N.W. 7th Street, Miami, FL 33125

Table 4.5.2
Permissible atmospheric exposure of low hydrogen electrodes

Electrode	Column A (hours)	Column B (hours)
A5.1		
E70XX	4 max	Over 4 to 10 max
A5.5		
E70XX	4 max	Over 4 to 10 max
E80XX	2 max	Over 2 to 10 max
E90XX	1 max	Over 1 to 5 max
E100XX	1/2 max	Over 1/2 to 4 max
E110XX	1/2 max	Over 1/2 to 4 max

Notes:
1. Column A. Electrodes exposed to atmosphere for longer periods than shown shall be redried before use.
2. Column B. Electrodes exposed to atmosphere for longer periods than those established by testing shall be redried before use.

4.5.4 Redrying Electrodes. Electrodes that conform to the provisions of 4.5.2 shall subsequently be redried no more than one time. Electrodes that have been wet shall not be used.

4.5.5 Manufacturer's Certification. When requested by the Engineer, the contractor or fabricator shall furnish an electrode manufacturer's certification that the electrode will meet the requirements of the classification.

4.6 Procedures for Shielded Metal Arc Welding

4.6.1 The work shall be positioned for flat position welding whenever practicable.

4.6.2 The classification and size of electrode, arc length, voltage, and amperage shall be suited to the thickness of the material, type of groove, welding positions, and other circumstances attending the work. Welding current shall be within the range recommended by the electrode manufacturer.

4.6.3 The maximum diameter of electrodes shall be as follows:

4.6.3.1 5/16 in. (8.0 mm) for all welds made in the flat position, except root passes.

4.6.3.2 1/4 in. (6.4 mm) for horizontal fillet welds.

4.6.3.3 1/4 in. (6.4 mm) for root passes of fillet welds made in the flat position and groove welds made in the flat position with backing and with a root opening of 1/4 in. or more.

4.6.3.4 5/32 in. (4.0 mm) for welds made with EXX14 and low hydrogen electrodes in the vertical and overhead positions.

4.6.3.5 3/16 in. (4.8 mm) for root passes of groove welds and for all other welds not included under 4.6.3.1, 4.6.3.2, 4.6.3.3, and 4.6.3.4.

4.6.4 The minimum size of a root pass shall be sufficient to prevent cracking.

4.6.5 The maximum thickness of root passes in groove welds shall be 1/4 in. (6 mm).

4.6.6 The maximum size of single-pass fillet welds and root passes of multiple-pass fillet welds shall be

4.6.6.1 3/8 in. (9.5 mm) in the flat position

4.6.6.2 5/16 in. (8.0 mm) in the horizontal or overhead positions

4.6.6.3 1/2 in. (12.7 mm) in the vertical position

4.6.7 The maximum thickness of layers subsequent to root passes of groove and fillet welds shall be

4.6.7.1 1/8 in. (3 mm) for subsequent layers of welds made in the flat position

4.6.7.2 3/16 in. (4 mm) for subsequent layers of welds made in the vertical, overhead, or horizontal positions

4.6.8 The progression for all passes in vertical position welding shall be upward, except that undercut may be repaired vertically downwards when preheat is in accordance with Table 4.2, but not lower than 70° F (21° C). However, when tubular products are welded, the progression of vertical welding may be upwards or downwards but only in the direction or directions for which the welder is qualified.

4.6.9 Complete joint penetration groove welds made without the use of steel backing shall have the root gouged to sound metal before welding is started from the second side, except as permitted by 10.13.

Part C
Submerged Arc Welding

4.7 General Requirements

4.7.1 Submerged arc welding may be performed with one or more single electrodes, one or more parallel electrodes,[11] or combinations of single and parallel electrodes. The spacing between arcs shall be such that the slag cover over the weld metal produced by a leading arc does not cool sufficiently to prevent the proper weld deposit of a following electrode. Submerged arc welding with multiple electrodes may be used for any groove or fillet weld pass.

11. See Appendix I

(1) Partial joint penetration groove welds shall have the designated effective throat.

(2) Fillet welds shall have fusion to the root of the joint, but not necessarily beyond.

(3) Minimum leg size shall meet the specified fillet weld size.

(4) The partial joint penetration groove welds and fillet welds shall:

(a) Have no cracks.

(b) Have thorough fusion between adjacent layers of weld metals and between weld metal and base metal.

(c) Have weld profiles conforming to intended detail, but with none of the variations prohibited in 3.6.

(d) Have no undercut exceeding the values permitted in 9.25.1.5.

5.12.4 All-Weld-Metal Tension Test (electroslag and electrogas). The mechanical properties shall be no less than those specified in 4.16.

5.12.5 Nondestructive Testing. For acceptable qualification, the weld, as revealed by radiographic or ultrasonic testing, shall conform to the requirements of 8.15, 9.25, or 10.17, whichever is applicable.

5.12.6 Visual Inspection—Pipe and Tubing. For acceptable qualification, a pipe weld, when inspected visually, shall conform to the following requirements:

(1) The weld shall be free of cracks.

(2) All craters shall be filled to the full cross section of the weld.

(3) The face of the weld shall be at least flush with the outside surface of the pipe, and the weld shall merge smoothly with the base metal. Undercut shall not exceed 1/64 in. (0.4 mm). Weld reinforcement shall not exceed the following:

Pipe wall thickness, in. (mm)	Reinforcement, max. in	mm
3/8 (9.5) or less	3/32	2.4
Over 3/8 to 3/4 (19.0) incl.	1/8	3.2
Over 3/4	3/16	4.8

(4) The root of the weld shall be inspected, and there shall be no evidence of cracks, incomplete fusion, or inadequate joint penetration. A concave root surface is permitted within the limits shown below, provided the total weld thickness is equal to or greater than that of the base metal.

(5) The maximum root surface concavity shall be 1/16 in. (1.6 mm) and the maximum melt-thru shall be 1/8 in. (3.2 mm).

5.12.7 Visual Inspection—Plate. For acceptable qualification, the welded test plate, when inspected visually, shall conform to the requirements for visual inspection in 9.25.1.

5.13 Records

Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

5.14 Retests

If any one specimen of all those tested fails to meet the test requirements, two retests for that particular type of test specimen may be performed with specimens cut from the same procedure qualification material. The results of both test specimens must meet the test requirements. For material over 1-1/2 in. (38.1 mm) thick, failure of a specimen shall require testing of all specimens of the same type from two additional locations in the test material.

Part C
Welder Qualification

5.15 General

The qualification tests described in Part C are specially devised tests to determine the welder's ability to produce sound welds. The qualification tests are not intended to be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the procedure specification.

5.16 Limitation of Variables

For the qualification of a welder the following rules shall apply:

5.16.1 Qualification established with any one of the steels permitted by this Code shall be considered as qualification to weld or tack weld any of the other steels.

5.16.2 A welder shall be qualified for each process used.

5.16.3 A welder qualified for shielded metal arc welding with an electrode identified in the following table shall be considered qualified to weld or tack weld with any other electrode in the same group designation and with any electrode listed in a numerically lower group designation.

Group designation	AWS electrode classification*
F4	EXX15, EXX16, EXX18
F3	EXX10, EXX11
F2	EXX12, EXX13, EXX14
F1	EXX20, EXX24, EXX27, EXX 28

*The letters "XX" used in the classification designation in this table stand for the various strength levels (60, 70, 80, 90, 100, and 120) of deposited weld metal.

5.16.4 A welder qualified with an approved electrode and shielding medium combination shall be considered qualified to weld or tack weld with any other approved electrode and shielding medium combination for the process used in the qualification test.

5.16.5 A change in the position of welding to one for which the welder is not already qualified shall require requalification.

5.16.6 A change from one diameter wall pipe grouping shown in Table 5.26.1 to another shall require requalification.

5.16.7 When the plate is in the vertical position, or the pipe or tubing is in the 5G or 6G position, a change in the direction of welding shall require requalification.

5.16.8 The omission of backing material in complete joint penetration welds welded from one side shall require requalification.

5.17 Qualification Tests Required

5.17.1 The welder qualification tests for manual and semiautomatic welding shall be as follows:

5.17.1.1 Groove weld qualification test for plate of unlimited thickness

5.17.1.2 Groove weld qualification test for plate of limited thickness

5.17.1.3 Fillet weld qualification tests for fillet welds only

(1) For welds in joints having a dihedral angle (ψ) of 75 deg or less, qualification tests shall be as required by 5.18 or 5.19. Such qualification will be valid for fillet welds having angles greater than 75 deg.

(2) For welds in joints having a dihedral angle (ψ) greater than 75 deg and not exceeding 135 deg, tests shall be as required by 5.22, Option 1 or Option 2—contractor's option.

5.17.2 The pipe or tubing qualification tests for manual and semiautomatic welding shall be as follows:

5.17.2.1 Groove weld qualification test for butt joints on pipe or square or rectangular tubing

5.17.2.2 Groove weld qualification test for T-, K-, or Y-connections on pipe or square or rectangular tubing

5.17.2.3 Groove weld qualification test for butt joints on square or rectangular tubing tested on flat plate

5.17.3 The welder who makes a complete joint penetration plate groove weld procedure qualification test that meets the requirements is thereby qualified for that process and test position for plates and square or rectangular tubing equal to or less than the thickness of the test plate welded. If the test plate is 1 in. (25.4 mm) or greater in thickness, the welder will be qualified for all thicknesses. The welder is also qualified for fillet welding of plate and pipe, as shown in Table 5.23.

5.17.4 The welder who makes a complete joint penetration groove weld pipe procedure qualification test, without backing strip, that meets the requirements is thereby qualified for that process. His qualification will include the test position for pipe having a wall thickness equal to or less than the wall thickness of the test pipe welded. If the test pipe welded is 6 in. (152 mm) Sch. 80 or 8 in. (203 mm) Sch. 120 pipe, he will be qualified for all thicknesses. This welder is also qualified for fillet welding of plate and pipe as shown in Table 5.23. If the diameter of the job-size pipe or tubing used in qualification is 4 in. (102 mm) or less, the qualification is limited to diameters 3/4 in. (19 mm) through 4 in. (102 mm), inclusive. If the diameter of job-size pipe is over 4 in. (102 mm), the qualification is limited to a minimum diameter of greater than 1/2 test diameter or 4 in. (102 mm), whichever is larger. The wall thickness qualified and the number of test specimens required shall be as specified in Table 5.26.1.

5.18 Groove Weld Plate Qualification Test for Plate of Unlimited Thickness

The joint detail shall be as follows: 1 in. (25.4 mm) plate, single-V-groove, 45 deg included angle, 1/4 in. (6.4 mm) root opening with backing (see Fig. 5.18A). For horizontal position qualification, the joint detail may, at the contractor's option, be as follows: single-bevel-groove, 45 deg groove angle, 1/4 in. root opening with backing (see Fig. 5.18B). Backing must be at least 3/8 in. (9.5 mm) by 3 in. (76.2 mm) if radiographic testing is used without removal of backing. It must be at least 3/8 in. by 1 in. (25.4 mm) for mechanical testing or for radiographic testing after the backing is removed. Minimum length of welding groove shall be 5 in. (127 mm).

5.19 Groove Weld Plate Qualification Test for Plate of Limited Thickness

The joint detail shall be as follows: 3/8 in. (9.5 mm)

ATTACHMENT B

WELDING skills and practices

Joseph W. Giachino, William Weeks
Western Michigan University
Kalamazoo, Michigan

American Technical Society CHICAGO, ILL. 60637

ATTACHMENT B

CHAPTER 3 welding metallurgy

In preparing to become a skillful welder you should become familiar with the effects of heat on the structure of metal and with what happens to metal when certain alloying elements are added to it.

You will also need to know what safeguards must be followed in welding metals because application of heat during the welding process may destroy the very elements which were originally added to improve the structure of the metal. For example, metals expand and contract, thereby setting up great stresses which often result in severe distortions. Improper welding of stainless steel may result in a complete loss of its corrosion-resistant qualities, and welding high-carbon steel in the same manner as low-carbon steel may produce such a brittle weld as to make the welded piece unusable.

This chapter deals with the metallurgy of welding, that is, the formation of impurities and the effects of heat on the chemical, physical, and mechanical properties of metals.

PROPERTIES OF MATERIALS

Chemical, physical, and mechanical properties have a very significant influence in any welding operation. This will become more apparent in later chapters dealing with specific welding techniques. These properties can be defined as follows:

Chemical properties. Chemical properties are those which involve corrosion, oxidation, and reduction. *Corrosion* is a wasting away of metal due to various atmospheric elements. *Oxidation* is the formation of metal oxides which occur when oxygen combines with a metal. *Reduction* refers to the removal of oxygen from the surrounding molten puddle to reduce the effects of atmospheric contamination.

In any welding situation, it is important to remember that oxygen is a highly reactive element. When it comes in contact with metal, especially at high temperatures, undesirable oxides and gases are formed, thereby complicating the welding process. Hence, the success of any welding operation depends on how well oxygen can be prevented from contaminating the molten metal.

Physical properties. Physical properties are those which affect metals when they are subject to heat generated by welding such as *melting point, thermal conductivity,* and *grain structure.* Solid metals change into a liquid state at different temperatures. When cooling from a liquid state the atoms will form various crystal patterns (lattices). The strength of a weld often depends on how these lattices are controlled and how much heat is necessary to produce proper fusion of metal. Equally important is being aware that some metals have a high rate of heat conductivity while others have slower thermal conductivity. Also a welder needs to understand how heat will affect the grain structure of metals since the grain size of the crystalline structure has a direct bearing on the strength of a welded joint.

Mechanical properties. Mechanical properties are those which determine the behavior of metals under applied loads. These include a wide range of properties such as *tensile strength; ductility, toughness, brittleness* and others, all of which are extremely important in their relationship to welding.

STRUCTURE OF METALS

When you examine a polished piece of metal under a microscope, you will see small grains. Each of these grains is made up of smaller particles, called atoms, of which all matter is composed.

The grains, or crystals as they are often called, vary in shape and size. The arrangement of the atoms determines the shape of the crystalline structure. In general, the crystals of the more common types of metals arrange themselves in three different patterns. These are known as *space-lattices.*

A space-lattice is a visual representation of the orderly geometric pattern into which the atoms of all metals arrange themselves upon cooling from a liquid to a solid state.

The first type of space-lattice, illustrated in Fig. 3-1, is the *body-centered cube.* Here you will find nine atoms—one at each corner of the cube and one in the center. This crystal pattern is found in such metals as iron, molybdenum, chromium, columbium, tungsten, and vanadium.

The second crystal pattern is the *face-centered cube.* Notice in Fig. 3-2 how the atoms are arranged. Metals having this space-lattice pattern are aluminum, nickel, copper, lead, platinum, gold, and silver.

The third space-lattice is called the *close packed hexagonal form.* See Fig. 3-3. Among the

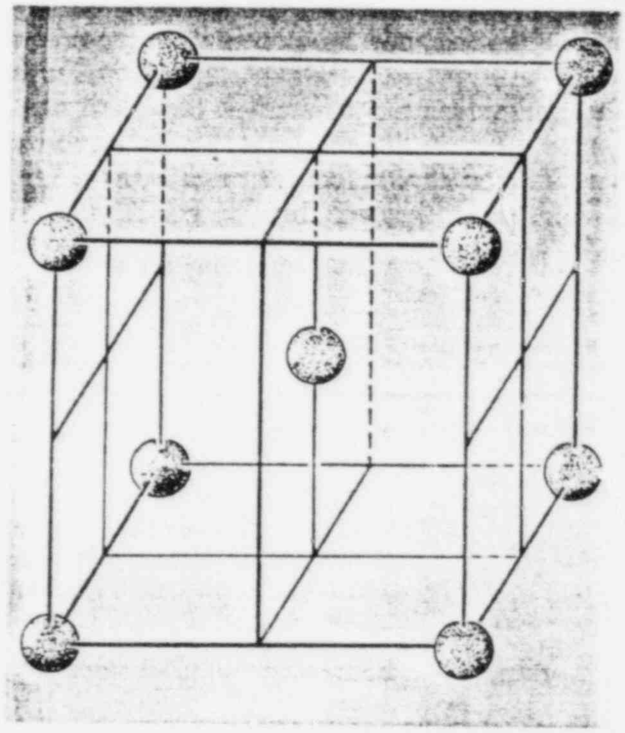


Fig. 3-1. Here is the arrangement of atoms in a body-centered cubic crystal.

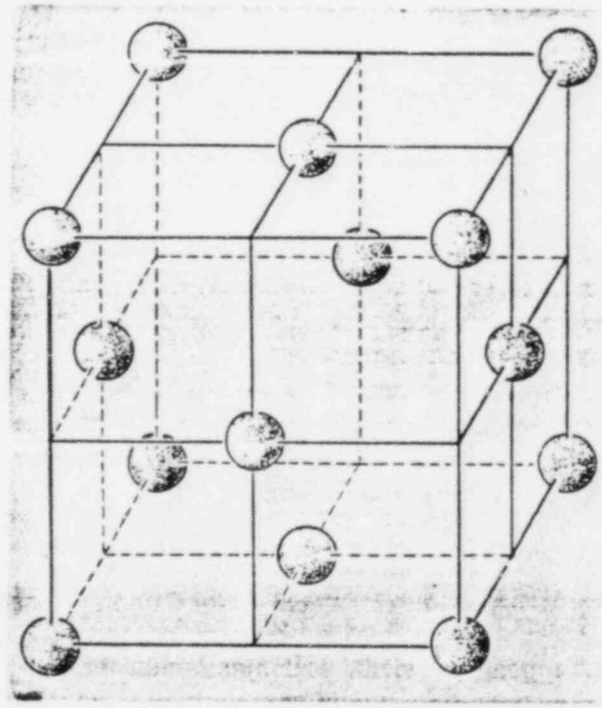


Fig. 3-2. The atoms in a face-centered cubic crystal assume this arrangement.

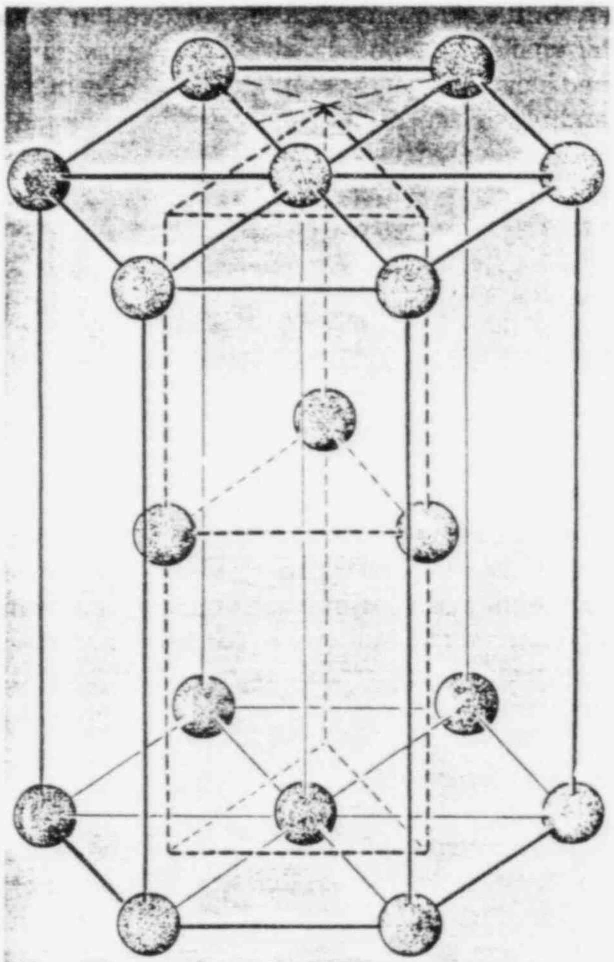


Fig. 3-3. This is the arrangement of the atoms in a hexagonal close-packed crystal.

metals having this type of crystalline structure are cadmium, bismuth, cobalt, magnesium, titanium, and zinc.

Metals with the face-centered lattice are generally *ductile;* that is, plastic and workable. Metals with close-packed hexagonal lattice lack plasticity and cannot be cold-worked, with the exception of zirconium and titanium. Metals with body-centered crystals have higher strength but lower cold working properties than those with the face-centered pattern.

Crystallization of Metals

All metals solidify in the form of crystals. Each metal has its own characteristic geometric pattern. Some metals may even change from one crystal structure to another crystal structure at various temperature levels. For example, iron when heated changes completely to a face-centered cubic structure at a temperature of 1670°F [910°C].

As liquid metal is cooled it loses thermal energy (heat) to the air and walls of the container. At the *solidification temperature* the atoms of the metal assume their characteristic crystal structure. Crystals begin growing at random in the melt at points of lowest energy. If the rate of cooling is fast, more crystals will form instantaneously than at slow rates of cooling. The more crystals that are growing simultaneously the finer will be the grain size of the metal.

Grain size is important since fine-grained steels have far superior mechanical properties than coarse-grained steels. Hence, it is important for a welder to preserve the grain size of the parent metal. The use of excessive heat leads to a slow rate of cooling, thus producing coarse grains and brittleness in a weldment.

Heating Effect on Grain Structure of Steel

When steel, which is carbon and iron, is heated from room temperature to above 1333° F [835°C], the pearlite grains change from a body-centered lattice to a face-centered structure. Such an arrangement of iron atoms is known as *gamma iron*.

What has happened is that while the steel went through its *critical temperature* (temperature above which steel must be heated so it will harden when quenched), the iron carbide separated into carbon and iron, with the carbon distributing itself evenly in the iron. The material is now called *austenite*.

If the heating is continued beyond the critical point, the grains grow larger or coarser until the melting point is reached. When the steel melts, the crystal structure is completely broken and the atoms float about without any definite relationship to one another.

Cooling Effect on Grain Structure of Steel

If you cool a metal from a molten state to room temperature, the change that takes place, under proper conditions, is exactly the opposite of what occurs while the metal is heating.

As the metal begins to cool, the crystals of pure iron start to solidify. This is followed by a crystallization of austenitic grains, and eventually the entire mass becomes solid.

During the range of temperatures at which various stages of solidification takes place, the metal passes from a mushy condition to a solid solution. While in a mushy stage the metal can be shaped easily. After it has reached a solid state, even though the alloy is still hot, it can be formed only by applying heavy pressure or hammering (forging).

With continued cooling of the solid metal, the austenite contracts evenly as the temperature falls. When it reaches its *transformation temperature*, the temperature drop stops for a time. At this point there occurs a rearrangement of *gamma iron* to *alpha iron* as well as a separation of iron carbide and pure iron into *pearlite* grains.

The transformation of the metal from a liquid to a solid is important because the proper rearrangement of the atoms depends on the rate of cooling. If, for example, a piece of 0.83 percent carbon steel is cooled rapidly after its critical temperature is reached, certain actions are arrested before the pearlitic structure can be formed. The result is a metal that is hard, but very brittle, known as *martensite*. See Fig. 3-4. Martensite is the constituent found in fully hardened steel which is hard and brittle. On the other hand, if the rate of quenching (cooling) is somewhat slower, the structure will be much more ductile.

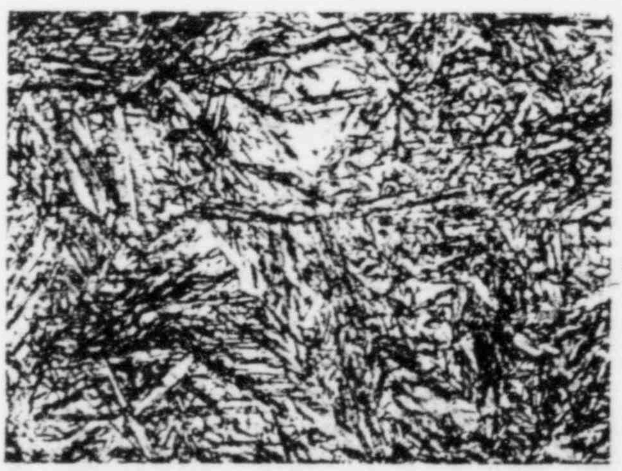


Fig. 3-4. Structure of martensite.

IMPORTANCE OF CARBON IN STEEL

Carbon is the principal element controlling the structure and properties that might be expected from any carbon steel. The influence that carbon has in strengthening and hardening steel is dependent upon the amount of carbon present and upon its microstructure. Slowly cooled carbon steels have a relatively soft iron pearlitic microstructure; whereas rapidly quenched carbon steels have a strong, hard, brittle, martensitic microstructure.

In carbon steel, at normal room temperature, the atoms are arranged in a body-centered lattice. This is known as *alpha iron*. Each grain of the structure is made up of layers of pure iron (ferrite) and a combination of iron and carbon. The compound of iron and carbon, or iron carbide, is called *cementite*. The cementite is very hard and has practically no ductility.

In a steel with 0.83 percent carbon, the grains are *pearlitic*, meaning that all the carbon is combined with iron to form iron carbide. This is known as a *eutectoid mixture* of carbon and iron. See Fig. 3-5.

If there is less than 0.83 percent carbon, the mixture of pearlite and ferrite is referred to as *hypoeutectoid*. An examination of such a mixture would show grains of pure iron and grains of pearlite as shown in Fig. 3-6.

When the metal contains more than 0.83 percent carbon, the mixture consists of pearlite and iron carbide and is called *hypereutectoid*. Notice in Fig. 3-7 how the grains of pearlite are surrounded by iron carbide. In general, the greatest percentage of steel used is of the hypoeutectoid type, that which has less than 0.83 percent carbon.

Fig. 3-5. Here is how the pearlite grains arrange themselves in a eutectoid mixture.

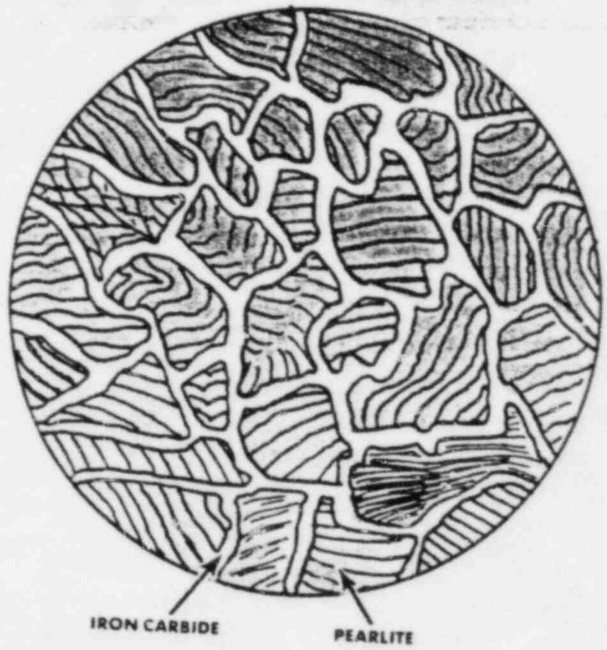


Fig. 3-7. This is an example of a hypereutectoid structure.

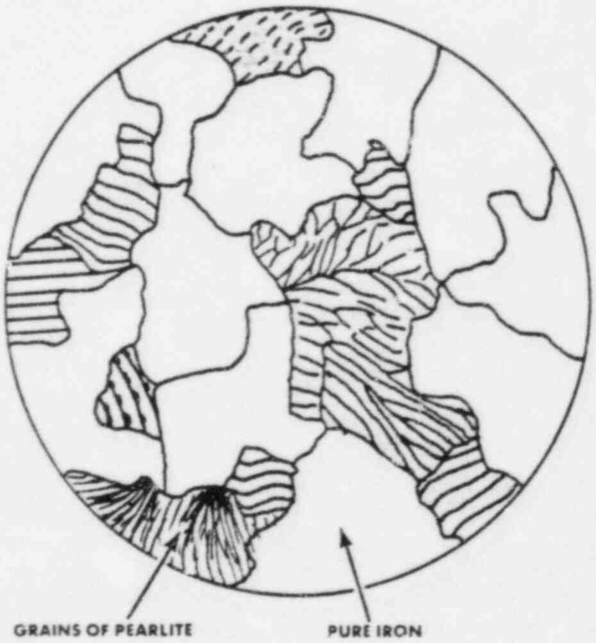


Fig. 3-6. An example of hypoeutectoid grain structure.

Other Factors Altering Strength and Structure

When a metal is *cold-worked* (that is; hammered, rolled or drawn through a die) the ferrite and pearlite grains are made smaller and the metal becomes stronger and harder. If, after cold working, the metal is heated and allowed to cool, the grain size is again increased and the metal softened.

The grain size of some metals is reduced and the strength improved through a heating and quenching process. Thus, if a high-carbon steel is heated to a prescribed temperature and then immediately quenched in oil or water, followed by a tempering process, the grain size remains fine. But if you allow the same metal to heat for a long time or if you subject it to temperatures beyond the critical range, then the grain size increases and the metal is weakened. This point is particularly important to remember in welding various steel alloys. The problem of structural change is not too serious in welding mild steel. On the other hand, alloy steels are greatly dependent on space-lattice formation and grain size for their strength. Therefore, you must take extreme care during welding to avoid seriously altering a metal's space-lattice pattern through excessive application of heat or improper treatment of the weld during its cooling stages to avoid this problem.

Effects of Heat of the Welding Process

In welding you must realize, too, that one edge of the metal may cool rapidly, thereby resulting in the formation of hard spots which cause cracks or failure in the weld. Also, there will be conditions where the metal is in a molten state at one point while the surrounding areas may have a temperature ranging from near the molten point down to room temperature. This means that in some areas the crystal structure is completely broken down while elsewhere recrystallization is taking place.

Keep in mind that when hardenable steels are being fused, and you make no effort to control the structural changes either through preheating or by slowing down the cooling rate, the completed weld will be too brittle to be of any value. If a piece of steel, such as an automobile spring, is welded, the heat will remove the springiness from the metal. Moreover, you must remember that if a weld is made on a hardened structure, the act of welding will usually soften the steel and lower its strength. Such metals must then be heat treated to restore their original properties. It is evident then, that in welding any alloy steel, an understanding of the effects of heating and cooling is important.

Heat Treating Metals

Heat treatment is used to soften metal and relieve internal stresses (annealing), harden metal, and temper metal (to toughen certain parts). An understanding of these processes is important to a welder because often he must be aware of how welding heat will affect the structure which he is welding.

Annealing is a softening process which allows metal to be more readily machined and also eliminates stresses in metal after it has been welded. The steel is heated to a certain temperature and held at this temperature to allow the carbon to become evenly distributed throughout the steel. The degree of annealing temperature varies with different kinds of steel. After the metal has been heated for a sufficient period, it is allowed to cool slowly either in the furnace or by burying it in ashes, lime, or in some other insulating material.

For some metals, the *normalizing* treatment is used. It differs from standard annealing in that the steel is heated to a higher temperature for shorter periods and then air cooled.

Stress relieving is a means of removing the internal stresses which develop during the welding operation. The process consists of heating the structure to a temperature below the critical range (approximately 1100°F [594°C] and allowing it to cool slowly. Another method of relieving stresses is *peening* (hammering). However, peening must be undertaken with considerable care because there is always danger of cracking the metal.

Stress relieving is done only if there is a possibility that the structure will crack upon cooling and no other means can be used to eliminate expansion and contraction forces.

Hardening increases the strength of pieces after they are fabricated. It is accomplished by heating the steel to some temperature above the critical point and then cooling it rapidly in air, oil, water, or brine. Only medium, high, and very-high-carbon steels can be hardened by this method. The temperature at which the steel must be heated varies with the steel used.

The tendency of a steel to harden may or may not be desirable depending upon how it is going to be processed. For example, if it is to be welded, a strong tendency to harden will make a steel brittle and susceptible to cracking during the welding process. Special precautions such as preheating and a very careful control of heat input and cooling will be necessary to minimize this condition. During welding, an extremely high localized temperature difference exists between the molten metal of the weld and the metal being welded. The cold parent metal acts as a quench to the weld metal and the metal nearby which has been heated above the upper *critical temperature* (the metal's temperature of transformation). The resulting structure of these areas is hard, brittle martensite. The greater the hardenability of a steel, the less severe the rate of heat extraction necessary to cause it to harden. This is one of the reasons that alloy and high-carbon steels have to be welded with greater care than ordinary low-carbon steels.

Case Hardening

Case hardening is a process of hardening low-carbon or mild steels by adding carbon, nitrogen, or a combination of carbon and nitrogen to the outer surface, forming a hard, thin outer shell. The three principal case hardening techniques are known as carburizing, cyaniding, and nitriding.

Carburizing consists of heating low-carbon steel in a furnace containing a gas atmosphere with the desired amount of carbon monoxide. An alternate method is to heat the steel in contact with a carbon material such as charcoal, coal, nuts, beans, bone, leather or a combination of these. However, modern methods of carburizing use gas atmospheres almost exclusively.

The piece is heated to a temperature between 1650° and 1700°F [899° to 927°C] where steel in the austenitic condition readily absorbs carbon on its surface. The length of the heating period depends on the thickness of the hardened case desired. After heating, the steel is quenched, which produces a material with a hard surface and a relatively tough inner core.

Cyaniding involves heating a low-carbon steel in sodium cyanide or potassium cyanide. The cyanide is heated until it reaches a temperature of 1500°F [815°C] and then the steel is placed in the liquid bath. This produces a very thin outer case which is harder than that obtained by the carburizing process.

Nitriding is a case hardening method which produces the hardest surface of any hardening process. Hardness is obtained by the formation of hard, wear-resistant nitrogen compounds in certain alloy steels where distortion must be kept to a minimum. The alloy is heated to about 900° to 1000°F [482° to 538°C] in an atmosphere of dissociated ammonia gas.

MECHANICAL PROPERTIES OF METALS

Mechanical properties are measures of how materials behave under applied loads. Another way of saying this is how strong is a metal when it comes in contact with one or more forces. If you know the strength properties of a metal, you can build a structure that is safe and sound. Likewise, when a welder knows the strength of his weld as compared with the base metal, he can produce a weldment that is strong enough to do the job. Hence strength is the ability of a metal to withstand loads (forces) without breaking down.

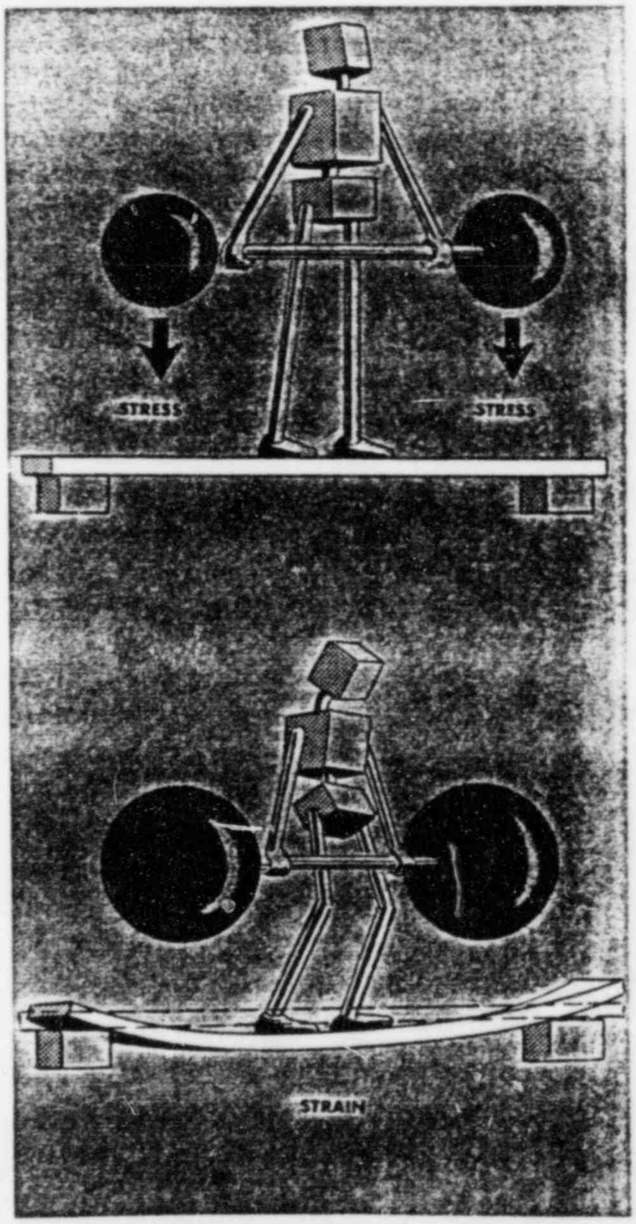


Fig. 3-8. Example of stress and strain.

ATTACHMENT B

Some of the basic terms that are associated with mechnical properties of metals are included in the paragraphs that follow. A welder should become familiar with them because they are often directly related to his ability to produce sound welds.

Stress is the internal resistance a material offers to being deformed and is measured in terms of the applied load over the area. See Fig. 3-8 top.

Strain is the deformation that results from a stress and is expressed in terms of the amount of deformation per inch. See Fig. 3-8 bottom.

Elasticity is the ability of a metal to return to its original shape after being elongated or distorted, when the forces are released. See Fig. 3-9. A rubber band is a good example of what is meant by elasticity. If the rubber is stretched, it will return to its original shape after you let it go. However, if the rubber is pulled beyond a certain point, it will break. Metals with elastic properties react in the same way.

Elastic limit is the last point at which a material may be stretched and still return to its undeformed condition upon release of the stress.

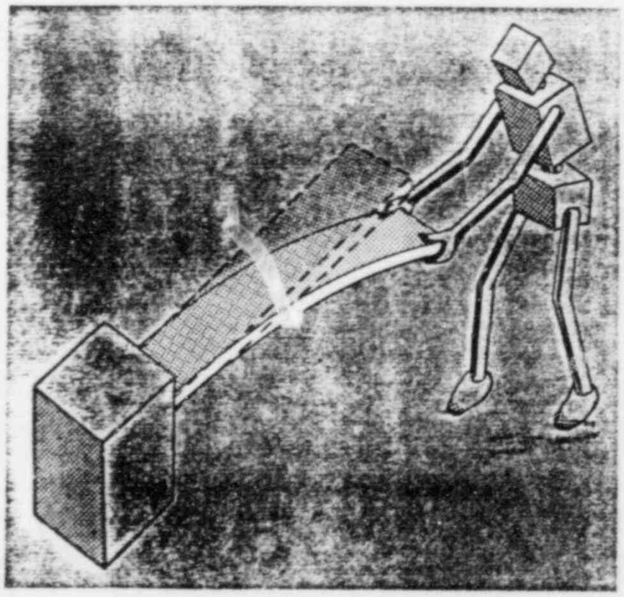


Fig. 3-9. A metal having elastic properties returns to its original shape after the load is removed.

Modulus of elasticity is the ratio of stress to strain within the elastic limit. The less a material deforms under a given stress the higher the modulus of elasticity. By checking the modulus of elasticity the comparative stiffness of different materials can readily be ascertained. Rigidity or stiffness is very important for many machine and structural applications.

Tensile strength is that property which resists forces acting to pull the metal apart. See Fig. 3-10. It is one of the more important factors in the evaluation of a metal.

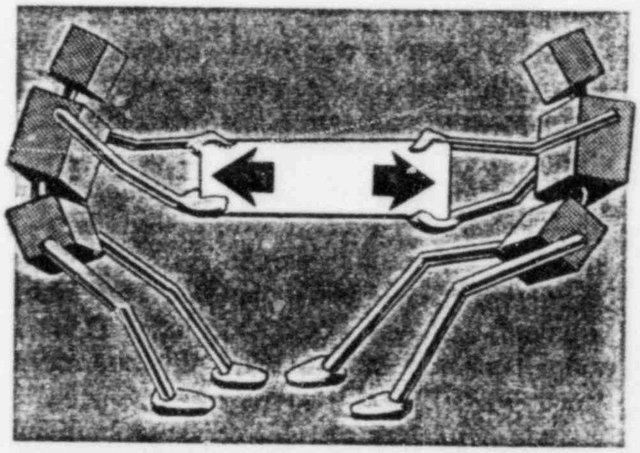


Fig. 3-10. A metal with tensile strength resists pulling forces.

Compressive strength is the ability of a material to resist being crushed. See Fig. 3-11. Compression is the opposite of tension with respect to the direction of the applied load. Most metals have high tensile strength and high compressive strength. However, brittle materials such as cast iron have high compressive strength but only moderate tensile strength.

Bending strength is that quality which resists forces from causing a member to bend or deflect in the direction in which the load is applied. Actually a bending stress is a combination of tensile and compressive stresses. See Fig. 3-12 top to grasp the idea.

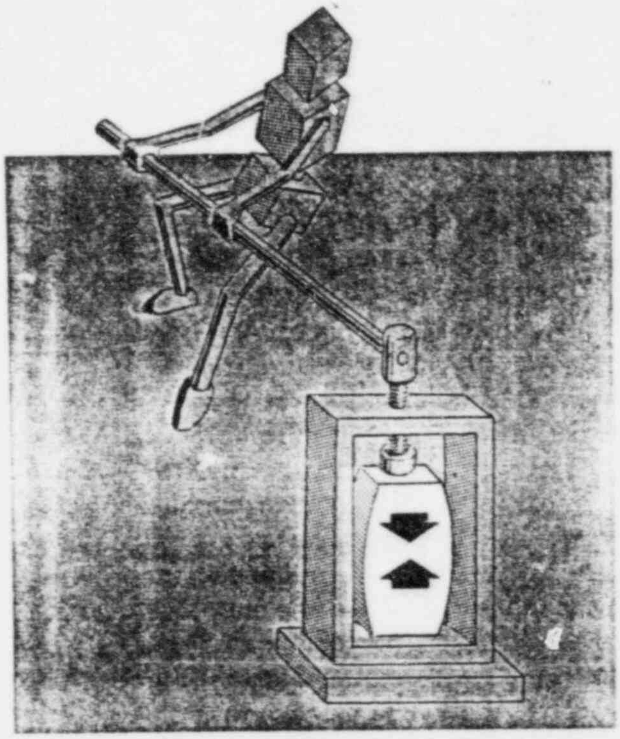


Fig. 3-11. Compressive strength refers to the property of metal to resist crushing forces.

Torsional strength is the ability of a metal to withstand forces that cause a member to twist. See Fig. 3-12 middle.

Shear strength refers to how well a member can withstand two equal forces acting in opposite directions. See Fig. 3-12 bottom.

Fatigue strength is the property of a material to resist various kinds of rapidly alternating stresses. For example, a piston rod or an axle undergoes complete reversal of stresses from tension to compression.

Impact strength is the ability of a metal to resist loads that are applied suddenly and often at high velocity. The higher the impact strength of a metal the greater the energy required to break it. Impact strength may be seriously affected by welding since it is one of the most structure sensitive properties.

Ductility refers to the ability of metal to stretch, bend, or twist without breaking or cracking. See Fig. 3-13. A metal having high ductility, such as copper or soft iron, will fail or break gradually as

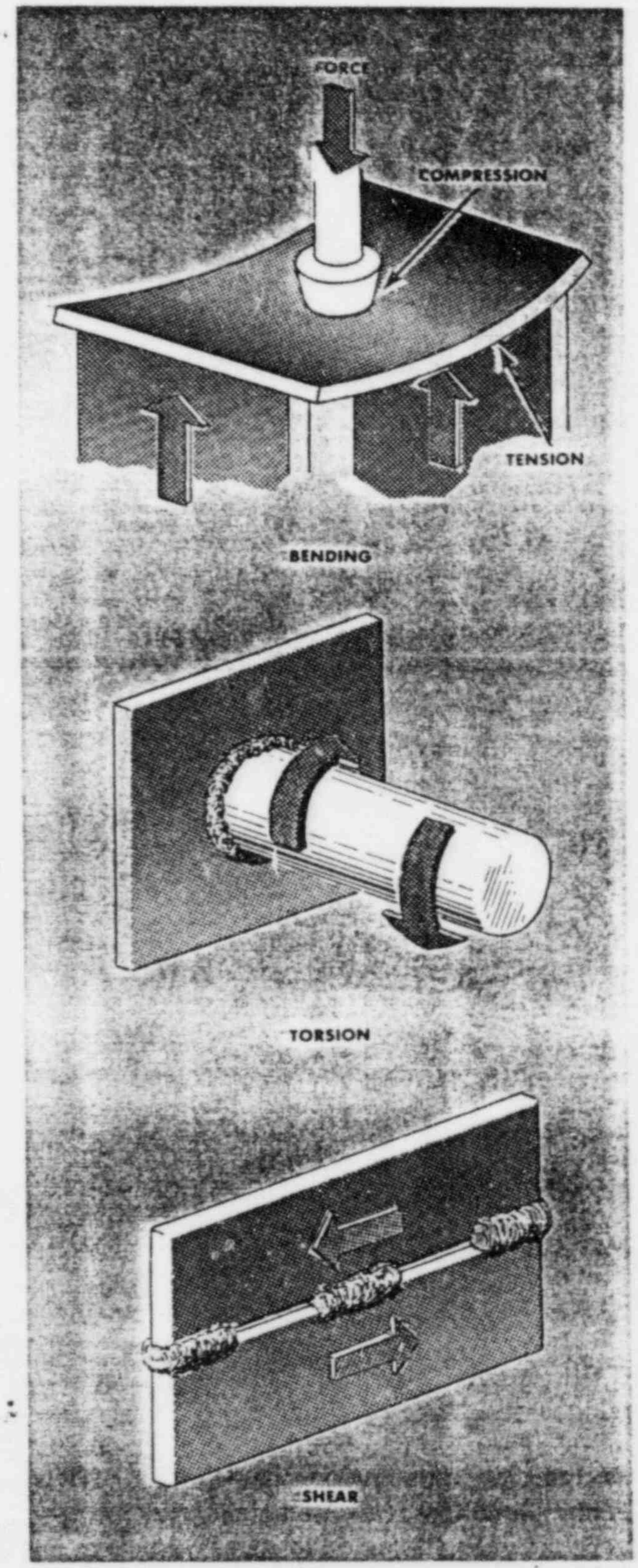


Fig. 3-12. Examples of bending, torsion, and of shearing stresses.

Fig. 3-13. A ductile metal can easily be shaped.

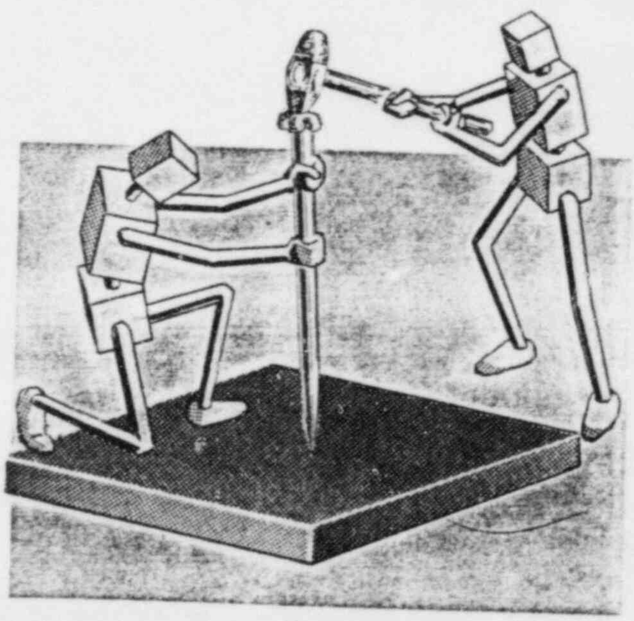


Fig. 3-14. Hardness resists penetration.

the load on it is increased. A metal of low ductility, such as cast iron, fails suddenly by cracking when subjected to a heavy load.

Hardness is that property in steel which resists indentation or penetration. See Fig. 3-14. Hardness is usually expressed in terms of the area of an indentation made by a special ball under a standard load, or the depth of a special indenter under a specific load.

Brittleness is a condition whereby a metal will easily fracture under low stress. It is a property which often develops because of improper welding techniques. Brittleness is a complete lack of ductility.

Toughness may be considered as strength, together with ductility. A tough material or weld is one which may absorb large amounts of energy without breaking. It is found in metals which exhibit a high elastic limit and good ductility. Welding materials of this kind must be done with a great deal of care. For example, improper application of heat may change the grain size and carbon distribution in the metal so its inherent toughness will be completely destroyed.

Malleability is the ability of a metal to be deformed by compression forces without developing defects, such as encountered in rolling, pressing, or forging.

Creep is a slow but progressively increasing strain, usually at high temperatures, causing the metal to fail.

Cryogenic properties of metals represent behavior characteristics under stress in environments of very low temperatures. In addition to being sensitive to crystal structure and processing conditions, metals are also sensitive to low and high temperatures. Some alloys which perform satisfactorily at room temperatures may fail completely at low or high temperatures. The changes from ductile to brittle failure occurs rather suddenly at low temperatures.

Coefficient of expansion is the amount of expansion in one inch or one foot produced by a temperature rise of 1°F. The expansion rate of metals is always an important factor in welding.

CLASSIFICATION OF CARBON STEELS

A plain carbon steel is one in which carbon is the only alloying element. The amount of carbon in the steel controls its hardness, strength, and ductility. The higher the carbon content, the

Type of Steel	Series Designation
Carbon steels	1XXX
Plain carbon	10XX
Free machining, resulfurized (screw stock)	11XX
Free machining, resulfurized, rephosphorized	12XX
Manganese steels	13XX
High-manganese carburizing steels	15XX
Nickel steels	2XXX
3.50 percent nickel	23XX
5.00 percent nickel	25XX
Nickel-chromium steels	3XXX
1.25 percent nickel, 0.60 percent chromium	31XX
1.75 percent nickel, 1.00 percent chromium	32XX
3.50 percent nickel, 1.50 percent chromium	33XX
Corrosion and heat resisting steels	30XXX
Molybdenum steels	4XXX
Carbon-molybdenum	40XX
Chromium-molybdenum	41XX
Chromium-nickel-molybdenum	43XX
Nickel-molybdenum	46XX and 48XX
Chromium steels	5XXX
Low chromium	51XX
Medium chromium	52XXX
Corrosion and heat resisting	51XXX
Chromium-vanadium steels	6XXX
Chromium 1.0 percent	61XX
Nickel-chromium-molybdenum	86XX and 87XX
Manganese-silicon	92XX
Nickel-chromium-molybdenum	93XX
Manganese-nickel-chromium-molybdenum	94XX
Nickel-chromium-molybdenum	97XX
Nickel-chromium-molybdenum	98XX
Boron (0.0005% boron minimum)	XXBXX

AISI also uses a prefix to indicate the steel-making process. These prefixes are:

A—Open-hearth alloy steel
B—Acid Bessemer carbon steel
C—Basic open-hearth carbon steel
D—Acid open-hearth carbon steel
E—Electric furnace steel of both carbon and alloy steels

Examples:

C1078—Basic open-hearth carbon steel; carbon 0.72 to 0.85 percent

E50100—Electric furnace chromium steel 0.40 to 0.60 percent; chromium, 0.95 to 1.10 percent carbon.

E2512—Electric furnace nickel steel, 4.75 to 5.25 percent nickel; 0.09 to 0.14 percent carbon.

WELDING DEFECTS

In the process of welding various materials, precautions must be taken to prevent the development of certain defects in the weld metal otherwise these defects will severely weaken the weld. The following are some of the principal defects that are significant in any welding or brazing process.

Grain growth. A wide temperature differential will exist between the molten metal of the actual weld and the edges of the heat-affected zone of the base metal. This temperature may range from a point far above the critical temperature down to an area unaffected by the heat. Thus the grain size can be expected to be large at the molten zone of the weld puddle and gradually reducing in size until recrystallization is reached. Grain growth can be kept to a minimum by effective control of preheating and postheating.

Where heavy sections require successive passes, it is possible to use the heat of each successive pass to refine the grain of the previous pass. This can be done only if the metal is allowed to cool below the lower critical temperature between each pass. High-carbon and alloy steels are especially vulnerable to coarse growth if cooled rapidly. These metals usually require a certain amount of preheating before welding and then allowed to cool slowly after the weld is completed.

Blowholes. Blowholes are cavities caused by gas entrapment during the solidification of the weld metal. They usually develop because of improper manipulation of the electrode and failure to maintain the molten pool long enough to float out the entrapped gas, slag, and other foreign matter. When gas and other matter become trapped in the grains of the solid metal, small holes are left in the weld after the metal cools.

Blowholes can be avoided by keeping the molten pool at a uniform temperature throughout the welding operation. This can be done by using a constant welding speed so the metal solidifies evenly. Blowholes are most likely to occur during the stopping and starting of the weld along the seam, especially when the electrode must be changed.

Inclusions. Inclusions are impurities or foreign substances which are forced in a molten puddle during the welding process. Any inclusion tends to weaken a weld because it has the same effects as a crack. A typical example of an inclusion is slag which normally forms over a deposited weld. If the electrode is not manipulated correctly, the force of the arc causes some of the slag particles to be blown into the molten pool. When the molten metal freezes before these inclusions can float to the top, they become lodged in the metal, producing a defective weld.

Inclusions are more likely to occur in overhead welding, since the tendency is not to keep the molten pool too long to prevent it from dripping off the seam. However, if the electrode is manipulated correctly and the right electrodes are used with proper current settings, inclusion can be avoided, or at least kept to a minimum.

Segregation. Segregation is a condition where some regions of the metal are enriched with an alloy ingredient while surrounding areas are actually impoverished. For example, when metal begins to solidify, tiny crystals form along grain boundaries. These so-called crystals or dendrites tend to exclude alloying elements. As other crystals form, they become progressively richer in alloying elements leaving other regions without the benefits of the alloying ingredients. Segregation can be remedied by proper heat treating or slow cooling.

Porosity. Porosity refers to the formation of tiny pinholes generated by atmospheric contamination. Some metals have a high affinity for oxygen and nitrogen when in a molten state. Unless an adequate protective shield is provided over the molten metal, gas will enter the metal and weaken it.

RESIDUAL STRESSES

The strength of a welded joint depends a great deal on the way you control the expansion and contraction of the metal during the welding operation. Whenever heat is applied to a piece of metal, expansion forces are created which tend to change the dimensions of the piece. Upon cooling, the metal undergoes a change again as it attempts to resume its original shape.

No serious consideration is given these factors when there are no restricting forces to prevent the free movements of the expansion and contraction forces or when welding ductile metal, because the flow of metal will usually relieve the stresses. When free movement is restricted there is likely to occur a warping or distortion if the metal is malleable or ductile, and a fracture if the metal is brittle, as with cast iron.

To better understand the effects of expansion and contraction, assume that the bar shown in Fig. 3-16 is thoroughly and uniformly heated. Since the bar is not restricted in its movements,

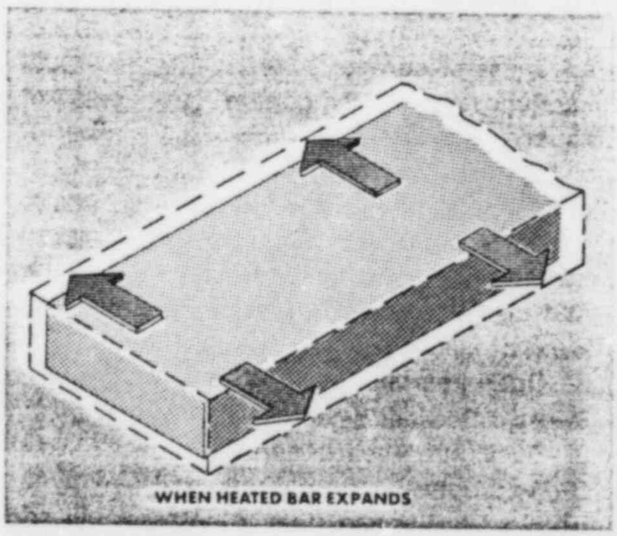


Fig. 3-16. This is what happens when a bar is heated.

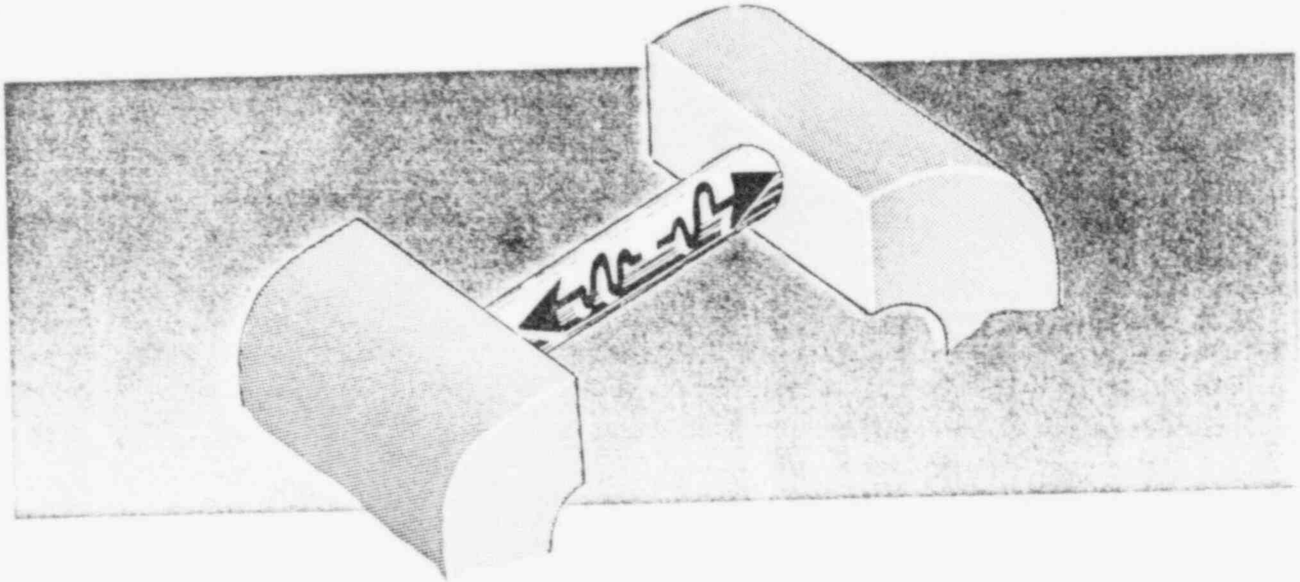


Fig. 3-17. The expansion forces are hindered when the bar has restricting forces like this.

expansion is free to take place in all directions. Consequently, the overall size of the bar is increased. If the bar is allowed to cool without restraint of any kind, it will contract to its original shape.

Suppose now that a similar bar is clamped in a vise, as shown in Fig. 3-17, and heated. Because the ends of the bar cannot move, expansion must take place in another direction. In this case the expansion occurs at the sides.

If heat is applied to one section only, the expansion becomes uneven. The surrounding cold metal prevents free expansion and the displacement of metal takes place only in the heated area. When this area starts to cool, contraction will also be uneven and some of the original displaced metal will become permanently distorted as illustrated in Fig. 3-18.

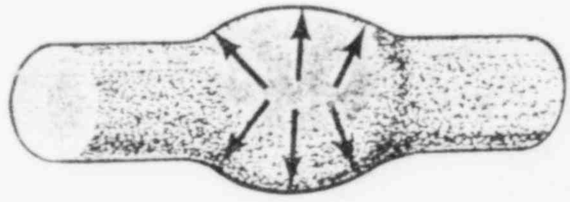


Fig. 3-18. This piece has been distorted because expansion forces were restricted.

To show just how the expansion and contraction forces affect metal, study the results of welding two different pieces. In the first case, assume a break has occurred in the middle of a bar, as in Fig. 3-19. Upon welding the break, the heat naturally will cause the metal to expand. Since there are no obstructions on the ends of the bar the metal is permitted to move to whatever limits it desires. When the piece begins to cool, there are still no forces to prevent the metal from assuming its original shape.

Suppose the break was in a center section as shown in Fig. 3-20. Note that in this case the ends of the bar are rigidly fastened to a solid frame. If the same procedure is used to weld the fracture as in the first case, something is bound to happen to the casting if no provisions are made for expansion and contraction. Since the vertical and horizontal sections (outside) of

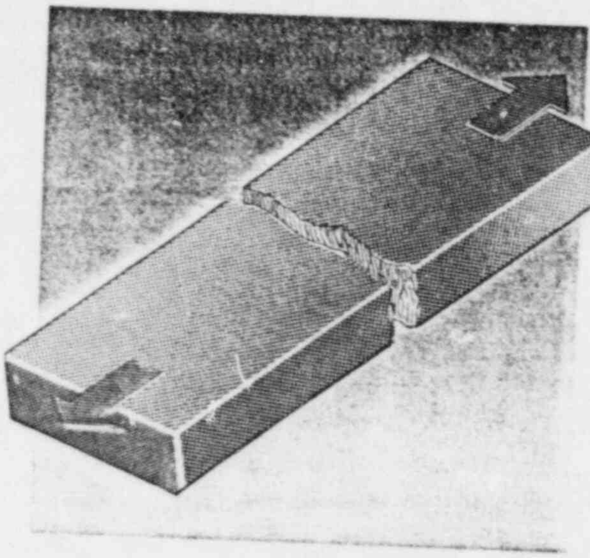


Fig. 3-19. In welding this break, expansion forces are free to move as heating and cooling occur.

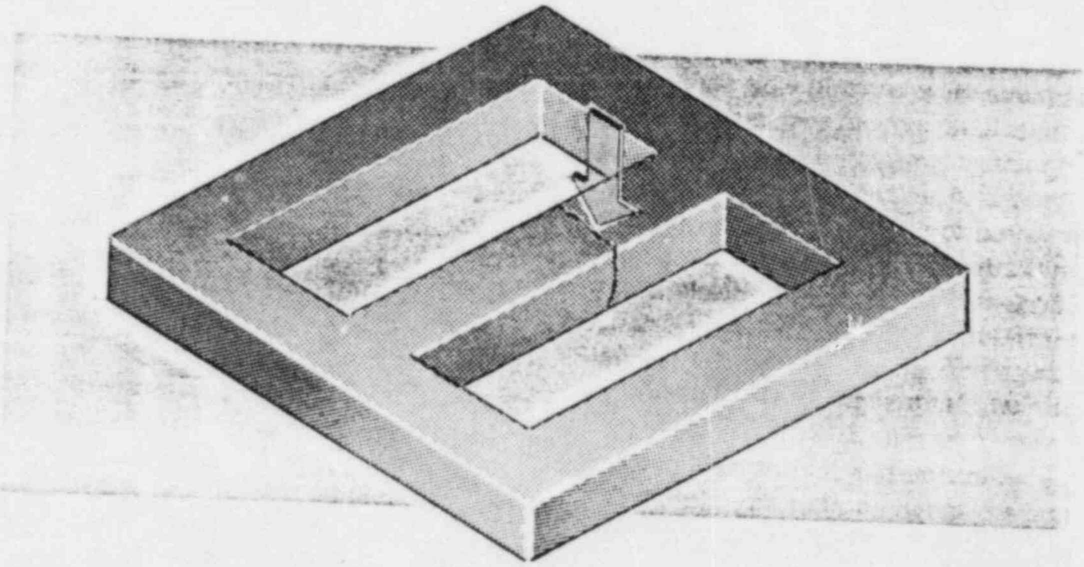


Fig. 3-20. Welding the frame in this confined portion will cause the frame to crack.

the frame will prevent expanding the ends of the center piece, there is only one direction in which this movement can go while the metal is being heated. That is at the point where fusion takes place. Now consider what will happen when the section begins to cool. The frame around the center section has not moved and, when contraction sets in, the center piece will be shortened. When the rigid frame resists this pull, a fracture or deformation at the line of weld or in some other place is bound to occur.

Controlling Residual Stresses

The following are a few simple procedures which will help control the forces caused by expansion and contraction:

Proper edge preparation and fit-up. Make certain that the edges are correctly beveled. Proper edge beveling will not only restrict the effects of distortion but will insure good weld penetration. See Fig. 3-21. Although sometimes the bevel angle can be reduced, care must be

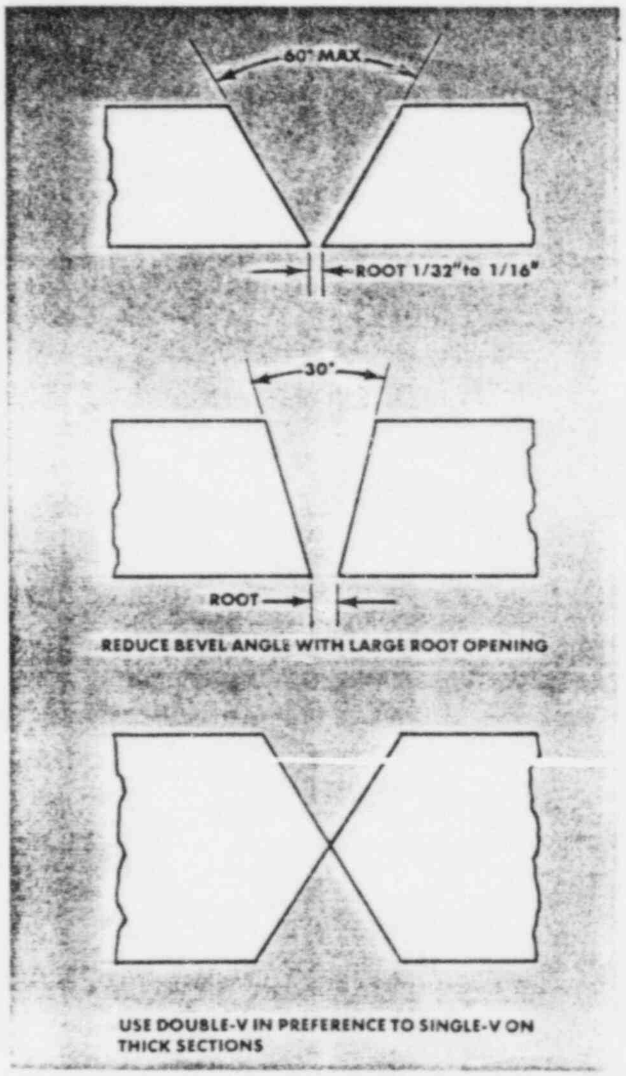


Fig. 3-21. Proper edge-preparation will minimize distortion.

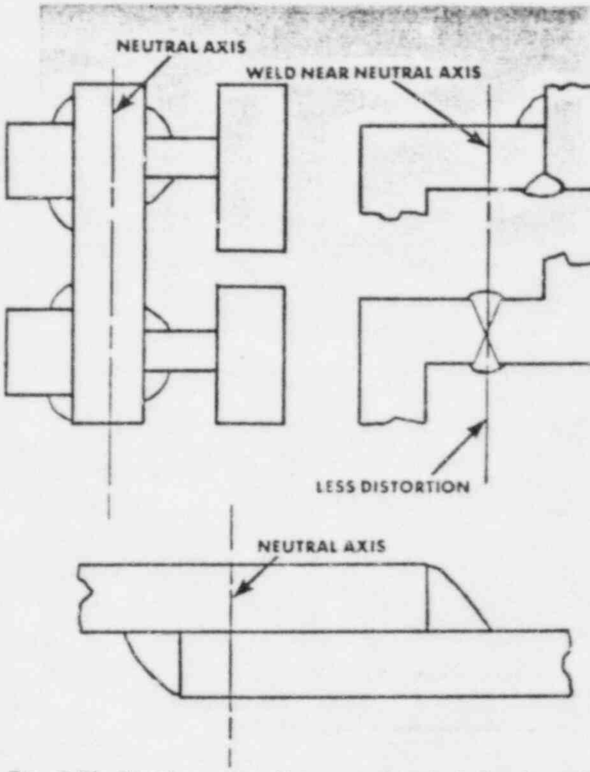


Fig. 3-22. Welding near the neutral axis helps to reduce distortion.

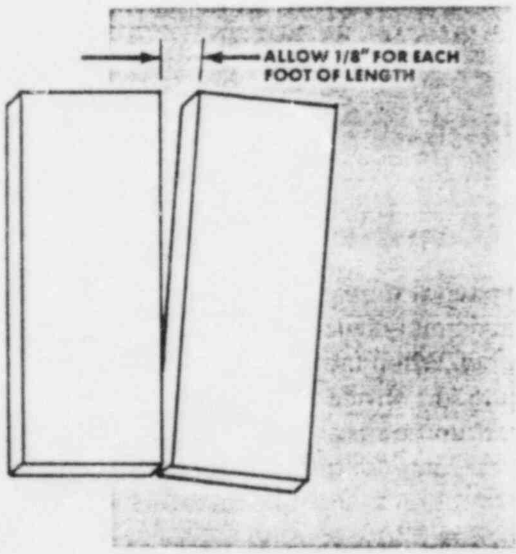


Fig. 3-23. Provide a space between the edges to be welded.

taken to insure that there is sufficient room in the joint to permit proper manipulation of the electrode when doing the weld.

Less distortion will occur if the welds are balanced around the center of gravity which is designated as the *neutral axis*. See Fig. 3-22 top, left. Furthermore, distortion is reduced if the joint nearest to the neutral axis is welded first, followed by welding the unit that is farthest from the neutral axis, Fig. 3-22 top, right, and bottom.

On long seams, especially on thin sections, the practice is to allow about 1/8" [0.125"] at the end for each foot in length of the weld for expansion. See Fig. 3-23 for example.

Tack welds are also used to control expansion on long seams as shown in Fig. 3-24. Tack welds

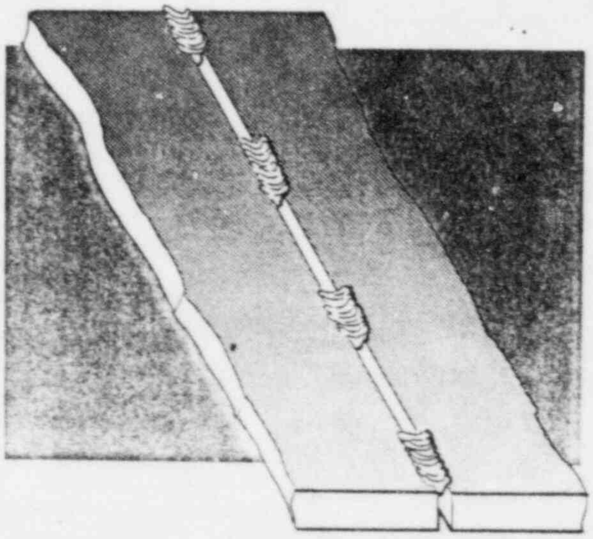


Fig. 3-24. Tacking the plates will hold them in position.

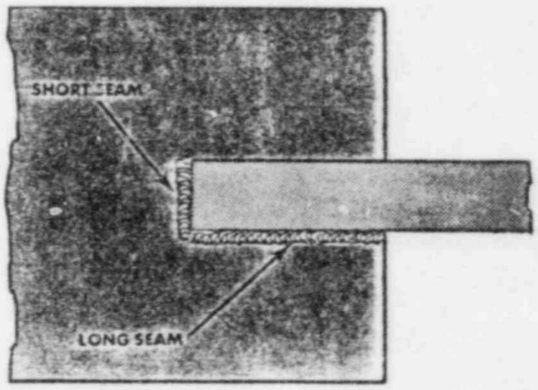


Fig. 3-25. Weld long longitudinal seam first.

are spaced about 12" [305 mm] apart and run approximately twice as long as the thickness of the weld. When tack welds are used, progressive spacing is not necessary. The plates are simply spaced an equal amount throughout the seam. Also, a long longitudinal (end-ways) seam is welded before a short transverse (side-ways) seam. See Fig. 3-25.

Minimizing heat input. Controlling the amount of heat input is somewhat more difficult for the beginner. An experienced welder is able to join a seam with the minimum amount of heat by rapid welding.

A technique often employed to minimize the heat input is the *intermittent*, or *skip weld*. Instead of making one continuous weld, a short weld is made at the beginning of the joint. Next a few inches is welded at the center of the seam, and then a short length is welded at the end of the joint. Finally you return to where the first weld ended and proceed in the same manner, repeating the cycle until the weld is completed. See Fig. 3-26.

The use of the *back-step*, or *step-back*, welding method also minimizes distortion. With this technique, instead of laying a continuous bead from left to right, you deposit short sections of the beads from right to left as illustrated in Fig. 3-27, along the entire seam.

Preheating. On many pieces, particularly alloy steels and cast iron, expansion and contraction forces can be better controlled if the

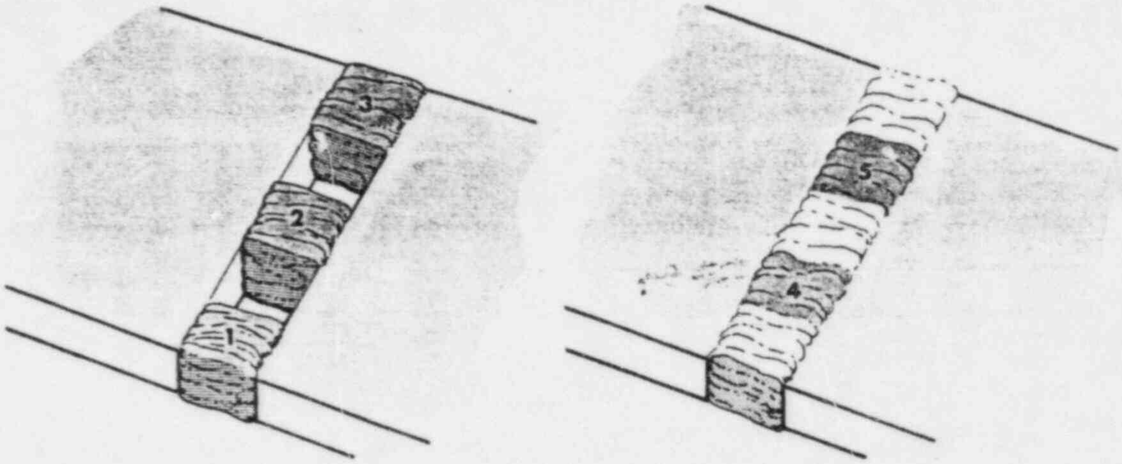


Fig. 3-26. The intermittent weld, sometimes referred to as the skip weld, will prevent distortion.

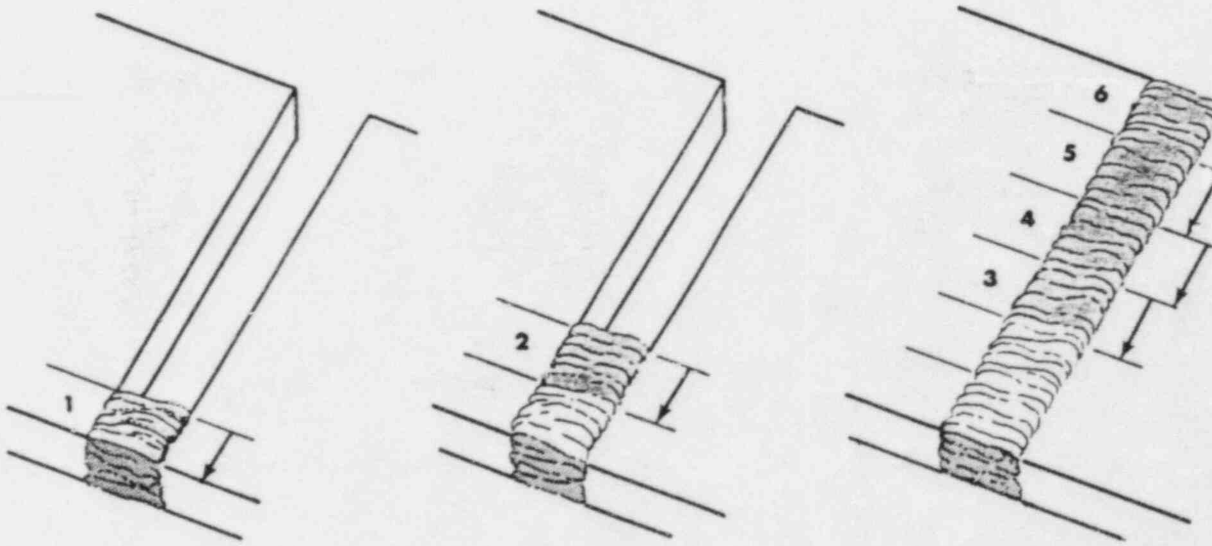


Fig. 3-27. This is how the back-step welding technique is done.

entire structure is preheated before the welding is started. To be effective, preheating must be kept uniform throughout the welding operation, and after the weld is completed the piece must be allowed to cool slowly. Preheating can be done with an oxyacetylene or carbon flame. Usually for work of this kind a second operator manipulates the preheating torch.

Peening. To help a welded joint stretch as it cools, a common practice is to peen it lightly with the round end of a ball peen hammer. However, peening should be done with care because too much hammering will add stresses to the weld or cause the weld to work-harden and become brittle. See Fig. 3-28.

Stress relieving. A common stress relieving method is heat treating. The welded component is placed in a furnace capable of uniform heating and temperature control. The metal must be kept in a soaking temperature until it is heated

shielded metal-arc welding

CHAPTER 11 the vertical position

In the fabrication of many structures such as steel buildings, bridges, tanks, pipelines, ships, and machinery, the operator must frequently make vertical welds. A vertical weld is one with a seam or line of weld running up and down as shown in Fig. 11-1.

One of the problems of vertical welding is that gravity tends to pull down the molten metal from the electrode and plates being welded. To prevent this from happening, fast-freeze types of electrodes should be used. Puddle control can also be achieved by proper electrode manipulation and selecting electrodes specifically designed for vertical position welding.

POSITION AND MOVEMENT OF THE ELECTRODE

Vertical welding is done by depositing beads either in an upward or downward direction, (sometimes referred to as *uphill* and *downhill)* *Downward welding* is very practical for welding light gage metal because penetration is shallow, thereby forming an adequate weld without burning through the metal. Moreover, downward welding can be performed much more rapidly, which is important in production work. Although it is generally recommended for welding lighter materials it can be used for most metal thicknesses.

Fig. 11-1. After tacking the metal strips together, this operator lays vertical welds. (Hobart Brothers Co.)

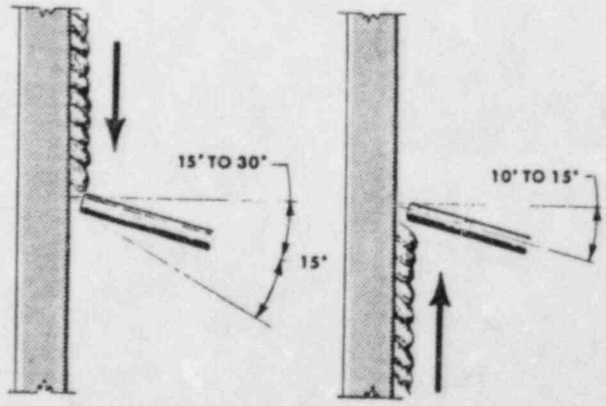


Fig. 11-2. Position of the electrode for downward (left) and upward (right) vertical welding.

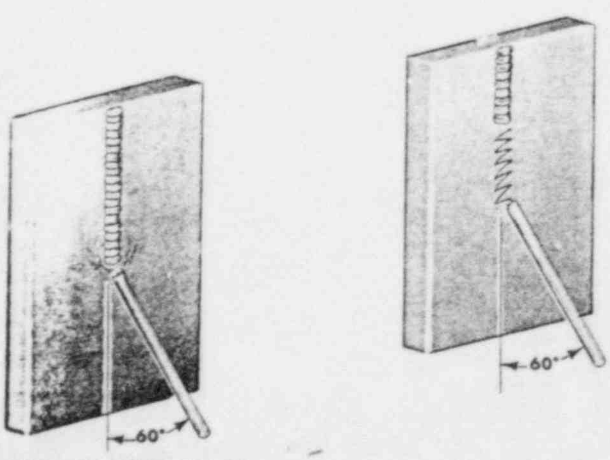
On heavy plates of 1/4" or more in thickness, *upward welding* is often more practical, since deeper penetration can be obtained. Welding upward also makes it possible to create a shelf for successive layers of beads.

For downward welding, tip the electrode as in Fig. 11-2 left. Start at the top of the seam and move downward with little or no weaving motion. If a slight weave is necessary, swing the electrode so the crescent is at the top.

For upward welding, start with the electrode at right angles to the plates. Then, lower the rear of the electrode, keeping the tip in place, until the electrode forms an angle of 10°–15° with the horizontal as shown in Fig. 11-2 right.

Laying Straight Beads in Vertical-Downhill Method

Set up a practice piece in a vertical position with a series of straight lines drawn on it. Start at the top of the plate with the electrode pointed upward about 60° from the vertical plate. Keep the arc short and draw the electrode downward to form the bead. Travel just fast enough to keep the molten metal and slag from running ahead of the crater. Do not use any weaving motion to start with. Once this technique is mastered try weaving the electrode but very slightly with the crest at the top of the crater. See Fig. 11-3.



DOWNHILL WELDING WITH NO WEAVE MOTION

DOWNHILL WELDING WITH SLIGHT WEAVE MOTION

Fig. 11-3. Downhill welding methods.

Laying Straight Beads in a Vertical Position—Uphill Method

1. Obtain a 1/4" plate and draw a series of straight lines. Then fasten the piece so the lines are in a vertical position.

2. Strike the arc on the bottom of the plate. As the metal is deposited, move the tip of the electrode upward in a rocking motion as shown in Fig. 11-4. This is often called a whipping motion. In rocking the electrode, do not break the arc but simply pivot it with a wrist movement so the arc is moved up ahead of the weld long enough for the bead to solidify. Then return it to the crater and repeat the operation, working up along the line to the top of the plate. *Remember, do not break the arc while moving the electrode upward.* Withdraw it just long enough to permit the deposited metal to solidify and form a shelf so additional metal can be deposited. Continue to lay beads from bottom to top until each line is smooth and uniform in width.

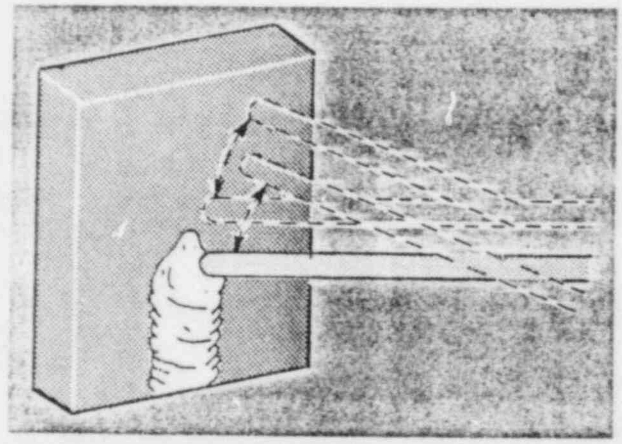


Fig. 11-4. A whipping motion helps to control the puddle in uphill welding.

Laying Vertical Beads with a Weaving Motion

On many vertical seams in uphill welding it is necessary to form beads of various widths. The width of the bead can be controlled by using one of the weaving patterns shown in Fig. 11-5. Each