Excerpt 2 from

Working Knowledge: Skill and Community in a Small Shop

by
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[illegible]hed, no one knows what he's done nor has any authority about it. A man has no [illegible]est but in pay day and quitting time" (Baskin 1976, 66).

Ch[illegible]iminishes for the consumer as the price of repair increase[illegible]matically. This [illegible]rtly due to the cost of the new repair machines. (I[illegible] past the repairman ow[illegible]early all the tools he used, and they migh[illegible]very limited. When I was grow[illegible] it was said that you could do an e[illegible] job on any General Motors car with a[illegible]-sixteenths wrench and a[illegible]driver.) Customers, ironically (because it is no[illegible]ssarily in their be[illegible]rests), also come to view repair as the replacement of a [illegible] In the pas[illegible] probably accepted the judgment of the mechanic who fixed a[illegible]art [illegible]be only by cleaning or adjusting. But customers now expect that repairs [illegible] expensive and equate the quality of the solution with the cost and num[illegible]arts installed. The distrust of the mechanic who cleans and files [illegible]ll part an[illegible]ests a bit of preventive maintenance is similar to the att[illegible]of patients who de[illegible]d that the doctor do something dramatic to relie[illegible]ir malaise. In a subtle w[illegible]nsumers, as well as repairmen, come to [illegible] their consciousness defined by th[illegible]nique. Consumers find themse[illegible]ore willing to accept the dictates of the [illegible]uter than the concrete an[illegible]libly attuned" knowledge of the repairman.[12]

All o[illegible]e elements of rationalized repair can be contrasted with [illegible]Willie lea[illegible]how he teaches, and how he works.

Learning and Teaching

In the beginning of Willie's working life, cars were still a recent addition to American culture. The life of Willie's father, a blacksmith, began in the horse age and ended only a few years after the widespread adoption of the automobile. Horses remained the main engine in farm work, however, coexisting with and gradually giving way to the tractor for—depending on the region of the country—three or four decades after the introduction of the automobile. It was not until the decade following the Second World War that the last teams in American agriculture were retired, and these changes were put off ten to fifteen more years in most parts of Europe. The farrier/blacksmith, then, was a holdover from an earlier era at the same time as he became an important part of the new age.

Willie's father was one of these transitional figures, with one foot in the horse-driven age and one in the engine age. Willie relates:

"A blacksmith in my father's day, along with shoeing horses, did blacksmith's welds—he built the parts for machinery—well, almost the same principle as

I'm doing now. It would be a garage and a blacksmith's shop at the same time. My father worked on cars as well as doing blacksmith's work: '31, '32—that's as far back as I can remember. When I'd get home in the evenings from school I'd have to stand on a box to help turn the forge. I was seven years old."

This was part of a life, Willie says, where "there were not that many things you owned that you didn't make." Even if you did buy something you couldn't make, preparing it for use often required handwork:

"You would buy a gun, then take it to a gunsmith who would make the parts fit. A lot of gunsmiths made their own parts for a handcrafted gun. There was no such thing as manufacturing identical pieces. They were tooled by a blacksmith. The gun barrel, for instance, was drilled."

In addition:

"When you bought a car, especially the Model T's, you got a wrench kit with it to adjust your bearings and everything else with. Your bearings were all shimmed. You'd pull a little base pan off the bottom to adjust your bearings. You did most of that yourself. But a lot of people didn't know enough about mechanical work, so they'd take it to the blacksmith's shop. Some of the people had regular little car shops set up, but not many. I believe that more people understood machines back then. They knew more of the fundamentals of them—how they were supposed to operate—than they do now. Now a person goes to school and just learns just what they're teaching them there—he learns nothing on his own from his parents because their parents don't have any interest in it."

Willie's father dealt with basic problem solving: getting machines back to work. This was especially necessary when fixing agricultural machinery; farming had to be done when the time was ripe. In this setting a worker comes to view nearly all machine breakdowns as repairable simply because the practical necessities demand that the repair be done.

It was, then, the blacksmith who became the first auto mechanic, as he had been the farm equipment repairman. Their auto work was often similar to the work they did in repairing farm machines: fixing broken metal or making new pieces. What seems unusual in Willie's work, repairing broken parts and fashioning new ones, has been carried over from his father's work as a blacksmith. Willie has extended that knowledge to new technologies and even now makes many of the parts used in his repairs.

The contrast between the two methods of repair—the formal and the informal or the rationalized and the nonrationalized—is etched in the pattern of learning skills and passing them on. Willie learned from his father in the daily practice of a small shop. In his words:

"When my father was doing something I was eager; I was watching him. Maybe the next time I'd have to do it for him. But I watched him do it the first time. That made a lot of difference too.

"My father was a guy who didn't have much patience for teaching someone. If he sent you out to do something—that's it—you went out and did it. If you didn't know how, you learned how. Kids now don't get that pushed on them. So they don't learn anything from their parents."

It is perhaps easy to idealize such an arrangement, especially since parents' work is now so seldom passed on to children in a family context. The learning, however, was not always gentle or easy. The child's work was part of the work of the family and carried a lot of responsibility. Punishment for mistakes was as natural as the responsibility. Yet Willie characterizes what perhaps looks like a rather severe relationship between adult and child as a bond of interest and commitment. Recall Willie's earlier statement that now people learn only at school; that parents are less interested in their children than they were in the past. Willie speaks of his own childhood:

"My father always figured that you did something, and did it wrong, that was one lesson you learned. If you got kicked and sent back to do it again, you'd try to do it right because you're never going to forget the first time you did it wrong. My father always said: 'If you learned the hard way, you learned for good.' My grandfather was the same way."

Willie teaches his children similar methods in a similar setting. His son, now in his late twenties, grew up working with and learning the principles of repair at home. Willie recalls:

"When a car would come in, or a piece of farm machinery—our main work was farm machines when Skip was growing up—he was watching me. I'm hard of hearing so I use a stethoscope on the engines. I'd show him with a stethoscope—show him the different sounds—I showed him how to pick out those sounds. I was picking it up with the stethoscope, but he could take the stethoscope off and he could hear the sound, easier than I could.

"I taught him the sounds of different kinds of bad ignition. If a valve is skipping, or burned, it would sound different in the exhaust. Or if you pull the coil wire and turn the engine over you can tell if you've got a burned valve. It'll hiss through the exhaust. If it's burnt real bad you'll get the same thing when it's running at slow speed. On your tractors you can pick it up very distinctly because you can idle them right down to about a hundred rpm—you can hear every cylinder just about. If you learn mechanicking on farm equipment the automotive comes 100 percent easier."

Welding was taught in a similar way:

"When Skip was young," Willie begins, "I had a blacksmith's shop out here with my regular shop. He learned a little about it—that's where he learned how to weld. When he was about seven years old he set out here at the old blacksmith's shop—one day he struck up a bead and went across a piece of metal with it. When he stopped he threw the helmet back, looked at it, 'Humph!—that's as good as Frenchie's.' The guys sitting here busted right out laughing—they went over and looked at it, and they agreed with him! Well, nowadays you don't get the opportunity, actually. When I was teaching him all this—Billy and Mike Murphy—they were always around, and getting right into the same deal. Billy Murphy turned out to be a damned good mechanic, and a good welder—and Mike—he's a good mechanic—he works for Niagara Mohawk. They all grew up together, like brothers."

Of Willie's two girls the younger, now a preteenager, is a fixture in the shop. She hovers about Willie as he works, anticipating which tools he'll need and having them ready before he asks for them. She can guess the size of a wrench or socket better than most adult mechanics. She has picked up the shop lingo—frustration over stuck nuts or recalcitrant snap rings—and when she uses some of the sexually connotative expressions that link tools to functions of the body it is very humorous because of her innocence. She has become one more voice badgering Willie to help her out when she gets into a problem she cannot solve. She does projects of her own—rebuilding bicycles, making trailers, or repairing lawn mowers. Willie gives her jobs she is capable of—disassembling small engines, sanding surfaces to be painted, cleaning up machines to be worked on. She understands the rhythms of the shop and fits in completely. She helps people who are working on their own projects and often knows where esoteric tools have landed. One can sense that by her late teens she will have become a very competent mechanic. In just the way Willie's son Skip gained his reputation as a me-

4 Julie repairing her bicycle in anticipation of spring.

chanic, so will Julie. One wonders what form her entrance to a traditionally male occupation will take.

Willie also teaches anyone who comes to the shop who is willing to be taught. The shop becomes a school, and to get work done you must often become a student. This was made strikingly clear the first time I came there in need of help. I nursed my car—which was running terribly and smelling of gasoline—to the shop well after what I expected to be closing hours. A quick look showed gas leaking from the carburetor; I was lucky not to have burned up the car driving it to the shop. Willie, whom I had met but once before, looked the engine over briefly and told me to disassemble the linkages and gas lines. I had no tools in my car; he told me to use his by simply pointing at the rack in the corner of the shop. He kept busy with his own work, but I could see that he watched me out of the corner of his eye. When I had extracted the faulty piece he made a new fitting and gently tapped it into the carburetor. He then found a piece of used gas line to replace a section that was rotted and broken. After I reassembled the linkages he adjusted the carburetor and timed the distributor, asking as he worked, "Do you hear that now? . . . Listen while I turn this . . . hear how it goes in and out of tune." I arrived with what I think is the typical mentality of a customer: fearful of the after-hours shop rate, wondering about the honesty and competence of the

mechanic, and hoping he would fix my car. What I encountered was a man cheerfully willing to offer a stranger the use of his tools, then to stop his work to finish mine and make a part to complete my repair. I think the charge was a couple of dollars and the invitation to return later that evening to play country and western music.

Because of the way the shop is run, it becomes more like a public than a private space. Not everyone, however, shares the use of the shop and the tools. If you are interested and willing to learn, and if Willie has sensed that you will handle the tools properly, you are invited to use them. People work on their jobs (with Willie's tools) until they get stuck and then seek Willie's help. Customers help each other as well, often lending a hand while waiting for Willie to help them. Everyone who works there seems to pick up the rhythm of cooperative work and grade themselves into skill levels, helping others on lower levels. Willie often goes from project to project, focusing on the difficult problem in a long process, then moving on to another. He teaches, jokes, encourages. Customers compete for Willie's attention to move their own projects ahead. In this way, as Willie works he teaches.

In these photographs Willie has retrieved a wheel puller, a tool used to remove a car or trailer wheel, for a customer (my wife, in fact) who is about to repack the wheel bearings on her horse trailer (5, 6).

WILLIE "I was explaining to her that you have got to use a hammer on it, and when you do you've got to really rap it. You don't tap it—you rap it. Hard. Because if you don't you mess the tool up. If you hit it gentle you just burr the places where you are supposed to hit it. She was wondering what to do with it—she'd never pulled a wheel before."

DOUG: "You'll stop what you're doing and get a tool that's worth a lot of money and then explain to someone how to use it—you'll put it into somebody's hands who has never used it before."

WILLIE: "This wheel puller is sturdy, it's strong, all you've got to do is use a little strength on it. But you've got to hit it in the right place. You hit the end wrench that fits over the hex head; you hit it sideways to spin the shaft against the center of the wheel. If you hit the end you see sticking out on 6 you'll rivet the wrench right on. A person can *very* easily mess this up. But I think she has a kind of knowledge—a mechanical knowledge that comes to her when she is doing things like that. The average person you don't hand a tool like that to."

DOUG: "That day there were five people trying to get your attention; just taking your tools and using them, bringing them back, looking for parts—it's like a community shop!"

5 Willie retrieves a wheel puller for a customer working on her own project.

6 Willie hands the wheel puller to the customer and explains how to use it.

WILLIE: "You know, that's something I've never seen anywhere else, where they come in—three or four people—a lot of them know each other. While I'm doing a job for one person, another person, if he has something to take apart—they will all pitch in and do it! Somebody will be wanting to change a tire, and someone else will know how to use the tire changer, so they'll help them out."

DOUG: "When I first came up here it frustrated me. I was impatient to get my job done."

WILLIE: "How well I know! Curt was the same way. I slowed him way down. And Motor Mouth! He used to be running all the time when he first came here! He has slowed down a good 75 or 80 percent from what he used to be. I'd jump him right in front of his wife for that. He'd turn to say something to me, and then she'd get on him. He'd actually run! He didn't walk from one place to another, he ran. A lot of them are like that; after a while they slow down, they help each other, and eventually I get to them, too."

Disassembling Intuition

Willie's knowledge can be thought of as intuitive instead of rationally objective. But "intuitive" may just be used to name something that is not easy to understand. "Intuitive," I think, really applies to a more detailed objectivity, called into play in a freer and more imaginative manner. In the following studies of Willie's work, I have looked at how his understanding—"intuitive" or simply objective in a more detailed manner—is embodied in methods and kinds of knowing.

The basis of Willie's working knowledge is his deep understanding of many materials. It is knowing how metal, wood, plastic, or even paper and cardboard respond to attempts to alter their shape, density, or pliability. The knowledge is so detailed it leads to engineering: forming materials into machines or correcting design problems in the process of repair. Fixing and making are often very close together on the continuum of Willie's working knowledge, both grounded in a basic knowledge of the materials.

Willie learned about metal in his father's blacksmith shop. At the forge a person comes to understand metal in a fine and detailed way, through heavy handwork, altering metal with heat and then reforming it with the hammer and the cold of water or ice. Willie explains:

"In a manner of speaking the blacksmith was a machinist. Everything was molded and drilled. When it came to farm machinery, when you had a broken part—

usually it was steel—very little cast [iron] used at that time—you'd use what they call a 'blacksmith's weld' to weld them back. You'd get your metals to a certain temperature and then put the two pieces together and hammer them. You'd hammer them right back into one piece. If you wanted to weld two pieces together, you would heat one piece and work it out longer. You can stretch metal by working it. And do the same for the other piece, but do it the opposite way. You make each piece so it overlaps the other one. Then they had a—some of them used it and some of them didn't—they had a flux that they dipped them into. They'd put them in the forge and get them to almost melting hot, they'd dip it in the flux, slap it together and start hammering. A forge could be as big as this tabletop—it would have a three-, four-foot top. But you had a small pot in the center where it heated. Take the two pieces and band them together when they're almost melting hot. You judge that by color. You had to know your temperatures and you had to know your metals to do a blacksmith's weld. You've got to know the same things for gas welding—which metals will weld together and which ones won't. Each type of metal has its own heat range. Well, you had to do the same thing with your forge—you had to use a different heat range for different metals. You altered the amount of time you left it in the forge. If you get to white hot—the next step is melting. If you go too far you start all over again! You had to have an eye for it."

Tempering metal, adjusting its hardness or pliability with heat and cold, was a procedure similar to welding. Like welding, it depended on the eye as well as the hand. Willie explains:

"When you were tempering something you get it to what they call a cherry red. One piece of steel you might need to get to a cherry red, maybe another one a little redder. You cool it in certain ways as you go along. It draws the temper into the steel. Makes it harder. But if you cool it too quickly it gets tempered so hard it's just like glass—you can break it.

"They have what they call flame temper, an oil temper, or a water temper. Like if you sharpen a pick—you hammer the point out on a pick and then you want to temper it so it won't burr over when you hit a stone—that's a cherry temper. But if you temper it *too* hard and you hit a stone, it'll pop the end right off. You dip it in the water slow. And it'll turn a bluish color as the temper works out into it. And your coal temper—a temper out of a coal forge—is a lot better than your gas temper. See, they use gas forges now. Or I can temper with a torch, but you've got to be very careful with it. When you're using gas you're only heating one side at a time. When you're using coal you're poking the metal right into the hot ashes. It heats it more evenly, all the way through and around. Where with your gas you don't get that. And you only heat one side with the torch, and it's not as good."

Learning about metal through the blacksmith's techniques became, for the first generation of welders, the basis for gas welding. These welders, like Willie, could understand welding because they understood metal in a deeper and more fundamental way than welders who learn first with the torch. The progress at the forge was slow, the changes in the metal relatively gradual, all controlled by hand. The blacksmith's weld is an extension of forming, bending, and adapting metal. Gas welding, which evolved from the blacksmith's techniques, is a more efficient method of cutting and binding metal that, for basic work, requires less knowledge. The gas welder is a tool that can change metal relatively easily and very quickly. The operator of a gas welder, to do crude work, need know only the basics of how to use the tool. On the other hand, a modern welder who learned his or her trade as a blacksmith summons a detailed and many-sided knowledge that refines the use of the technique.

Traditional bodywork—straightening bent metal on automobiles, for example, depended upon techniques similar to those of the blacksmith. The traditional "body man" reformed metal rather than filling in dents with body fill, an epoxy compound that is applied to metal and then sanded to shape. Filling in dents with epoxy is relatively simple, but if the area being filled is large the repair may not be permanent. Traditional body men like Willie use epoxy compound for final, surface corrections after the large bends and dents in the metal have been reformed. Willie explains the connection between the two:

"The things I learned working with my dad in the blacksmith's shop, about how metal acts when it's heated up and cooled off—that's part of body and fender work. You can move metal any way you want to with bodywork. You can use heat to shrink metal, or you can use heat to expand metal. Ice, water . . . you've seen me use ice. I don't think you've seen me use heat. I've got a hammer up there they call a 'shrinking hammer.' It's knurled. One end of it is square and it's full of knurls. And it makes those knurls right into the metal. The other end is round with the same type of knurls in it. I don't use it very often. It actually draws the metal together. . . . They don't do that kind of bodywork any more—they use body fill."

The traditional method of bodywork involved not only different hand techniques, but a view of the mass of metal as an interconnected, interpendent entity:

"[To work metal this way] you do one thing at a time, but you're always thinking of the project as a whole and how it's being affected by what you're doing. You might have a dent on the top of the fender, but you don't work on it there—you work on it on the bottom, to draw it out. Most people don't see that you're working on it if you're not pounding right on it where you can see the dent. You never start bringing out the big bump first. You bring it out the way it went in. And it will come out 100 percent better. If you start pushing the big bump out first—on a fender, or a quarter panel, or something like that—you'll be leaving all this little crinkly stuff around that will be harder to work out later on. Where if you start working it out the way it came in it goes better."

These skills make the work of fixing and fashioning part of the same basic technique:

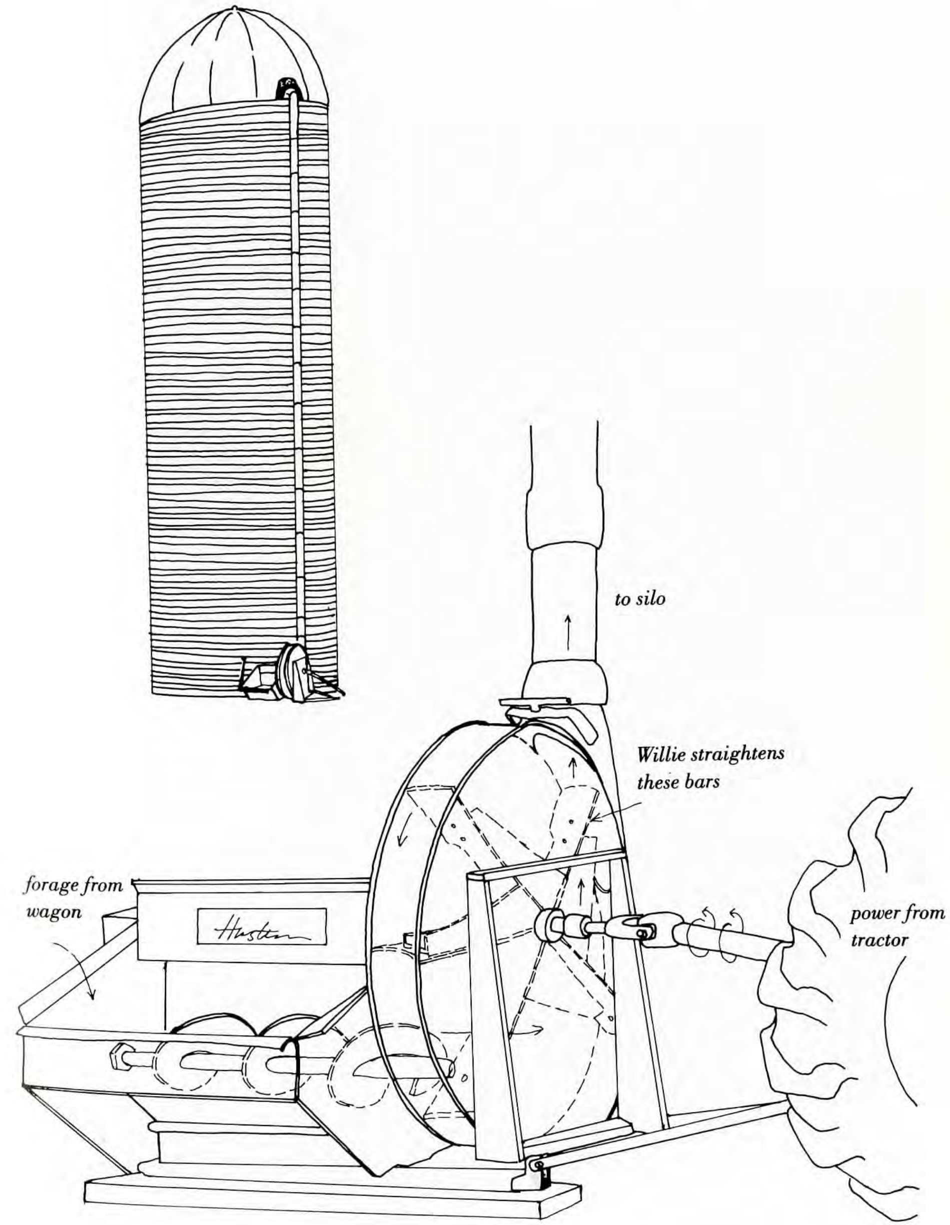
"A blacksmith could take a sheet of metal and do anything with it he wants to," Willie says. "If he's a *blacksmith.* We used to take a sheet of metal and make fenders—during World War II, when you couldn't get parts. We made Cadillac fenders, Chevrolet fenders; front ones, back ones—it didn't matter. We'd just take a sheet of metal; mold it. Heat and the hammer. All you had for a mold was the look of the one fender that was sitting there. You shaped it to that."

Material is pushed and bent, heated and cooled, pounded and twisted. Knowledge of the materials allows Willie to redefine the fixability of objects. It also lets him adopt the perspective of the engineer who designed the machine, to redesign as a part of repair. Examples of this kind of work follow.

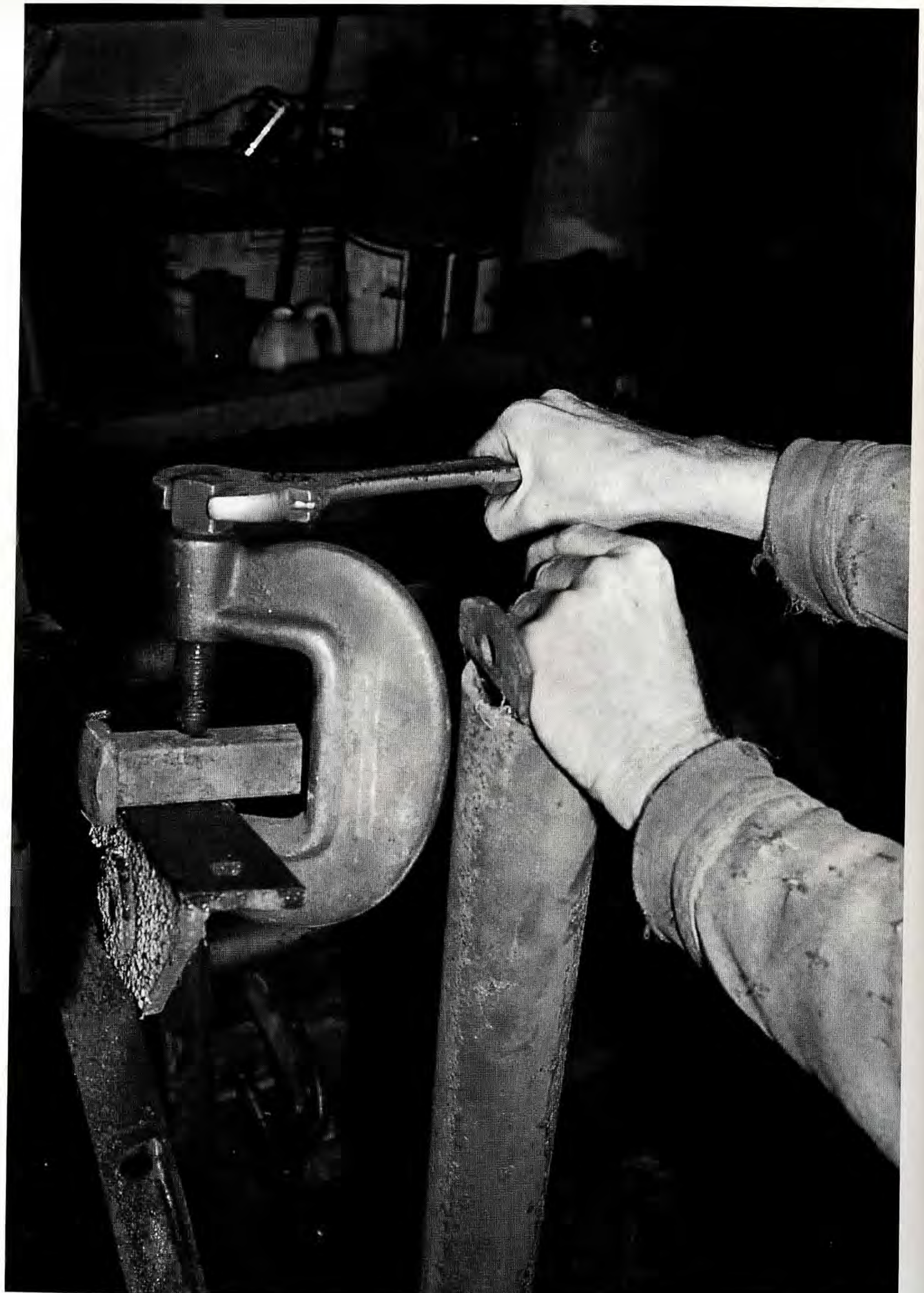
Making a Water Bend

The machine Willie repairs in this example is a *blower*—a piece of farm equipment used to transfer silage from a wagon into a silo. The blower looks like the propeller of an airplane inside a casing. Several heavy bars radiate from a central shaft. On the end of the bars are paddles that actually push the material through the blower and shoot it through a long tunnel running up the side of the silo. The blower runs at high speed, since it is sometimes necessary to blow the silage a hundred feet to the top.

"This blower got bent by one of Tom Rogers's men," Willie begins, "when he ran a ten-ton hydraulic jack through it. He was working on it, and he laid the jack right on the intake of the blower. He started it up, and that's what hap-



7 A silo blower.



8 Willie attaches an extension to the arm of the blower with a large C-clamp. He will mount the Porta-Power—a portable hydraulic jack—to the end of the extension to twist the arm of the blower.

pened. The blower drew it in because it's got rollers that push everything into it. It bent every paddle in it. Bent all the arms; as you can see, there's quite a twist in the arms.

"First (8) you put the leverage on it. I put a piece of metal on it to extend it so I can jack it back in place with the Porta-Power. You can't get the jack on the arm itself, so you twist it with the Porta-Power, as you can see in 9. You've got to be careful the Porta-Power doesn't slip out. There's a little V in the bottom of the Porta-Power—you can set it over a piece of metal and it won't slip one way or another, and you block the wheel so it can't turn."

"I'm heating the twist to bring it out, as you see in photographs 10 and 11. You can't just bend it without heating it. It's too heavy. Then I use the water to cool it (12); it helps bring it back more. The speed you pour the water depends on how much you're bending it. It was bent off to the side—it doesn't show that well in the photographs—it was bent around and away from the cover. I twisted it up with the Porta-Power, but it left too much metal on the backside of the bar, so I'm shrinking the metal on the one side to get it straight. So when I put the water on it, it cooled it faster and shrank it on that side—that's a 'water bend'. You don't always use heat to bend. You use cold water, ice, or whatever you've got. In the winter I just go out and pick up some ice to use.

"I drew that about three-sixteenths of an inch in a distance of about eight inches. I had to heat it on both sides to get the twist out, but I only put the water on one side.

"The heat is the most important thing when you're straightening. You've got to heat the right places so it will bend back where it is bent. The heat *relaxes* the metal so you can bend it. Here I'm using an acetylene torch, but I'm not using it full power. I heat it to color, and the color I bring it to depends on the heft of the metal. There's a range of colors, from white hot to cherry red."

"This blower was considered junk," Willie continues. "Tom traded it to George Weikoff, the dealer, and Bill Nash looked at it; took me down to look at it to see if I could fix it for him. Other people looked at it—they said it was too far gone to fix. They didn't have enough patience. Every one of those bars has to be bent exactly the same way. And they had welded the shaft in place, that's not supposed to be welded. It's supposed to be a slip shaft so it can be taken apart to disassemble the machine. I fixed that too. And when I finished I balanced the bars. Most people don't do that. I added weld to lighter bars until it was balanced perfectly. When it runs it sounds just like a fan—no vibration."

9 Willie pumping the Porta-Power to twist one arm of the blower.

10 Willie heats the arm of the blower with an acetylene torch so it will "take" the twist.

11 Heating the blower bar (close up).

12 Pouring water on the metal to make a water bend.

Building a Stove Door

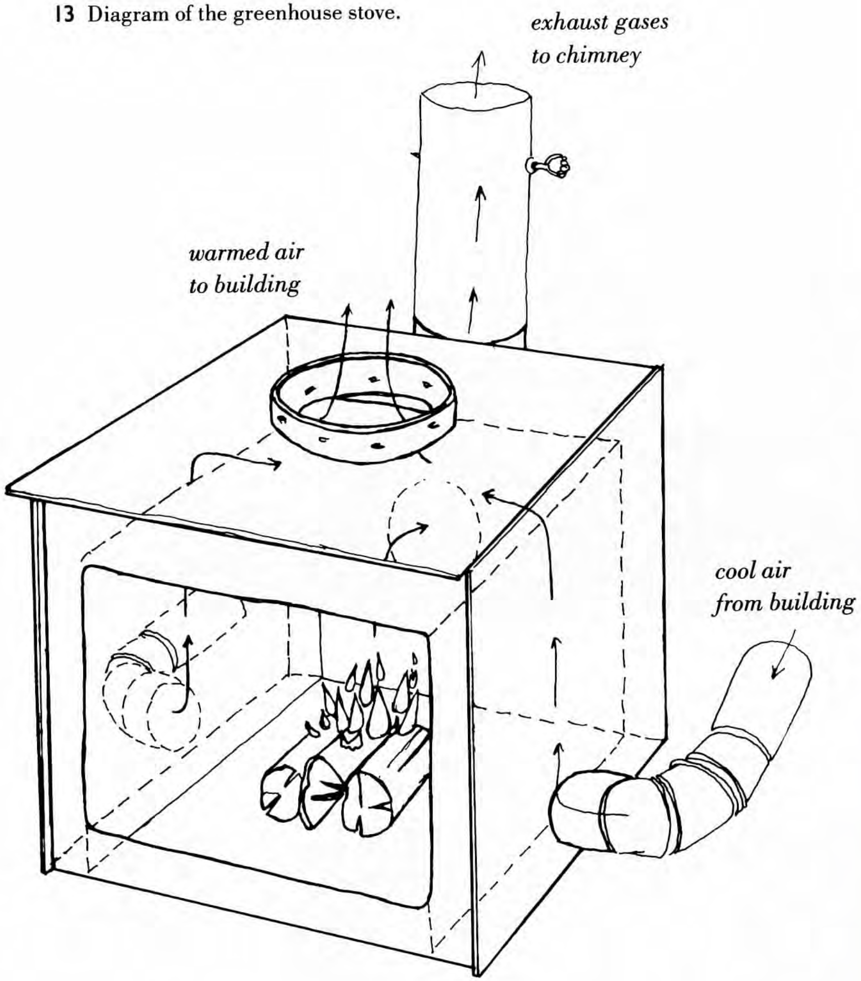
In the following passage I study how Willie's knowledge of materials contributes to his engineering skills. Willie is building the door for a wood furnace, to finish a heating system for my wife's solar greenhouse. Homemade stoves are common in the North Country, but most are roughly made and inefficient. Willie's designs, on the other hand, are engineered for specific purposes. Draft, interior space, and chimney dimensions must all be integrated into the design. The stove Willie designed for the greenhouse is double walled, with a blower that forces cool air into two openings cut into the lower part of the sides. The air is heated between the walls of the stove and then forced out an opening in the top to be distributed to planting beds, heat-storage chambers, or wherever in the greenhouse hot air is needed.

The stove was finished in the middle of a difficult winter. Although here I am interested in the relation between engineering and a deep knowledge of materials, I have included some of the circumstances that surrounded this job because they show how the seasons affect Willie's working life. His ability to design a wood stove comes in part from his own experience at managing the seasons.

Willie had made the stove, except for the door, two summers before. Finishing the door became one of the jobs that just didn't get done—we used the stove with a makeshift door while Willie kept promising to get to it. Finally in midwinter of the second year we broke the stove off its cement pad in the greenhouse, lugged it up the stairs, rolled it through the knee-deep snow to the car, and drove it to the shop.

It was a time of great difficulty around Willie's shop and house. Willie was suffering from lingering flu and recurrent immobility from an old industrial accident. In the fall he had worked hard getting his house finished enough to live in, and he'd had little time to cut firewood. By midwinter his supply had run out, and we were in the midst of a twenty-five below zero cold spell that lasted and lasted. Firewood had to be hauled from the woods every day with a snowmobile and sled. The sled held only a few armloads, which went directly into the house and usually into a waiting fire in one of Willie's homemade stoves. The cold took its toll on the chain saws and the snowmobile; breakdowns were frequent. The snow in the woods was waist deep, and the snowmobile kept getting buried. On the other hand, the early snow had kept the ground from freezing hard enough to get the Jeep into the woods. So energy was focused on the subsistence effort of keeping warm and maintaining the machines that ensured that warmth. And at twenty-five below zero the inefficiency of the small machines was dramatic—back and forth with the snow

13 Diagram of the greenhouse stove.



machine, back and forth—never getting very much ahead, even with considerable work.

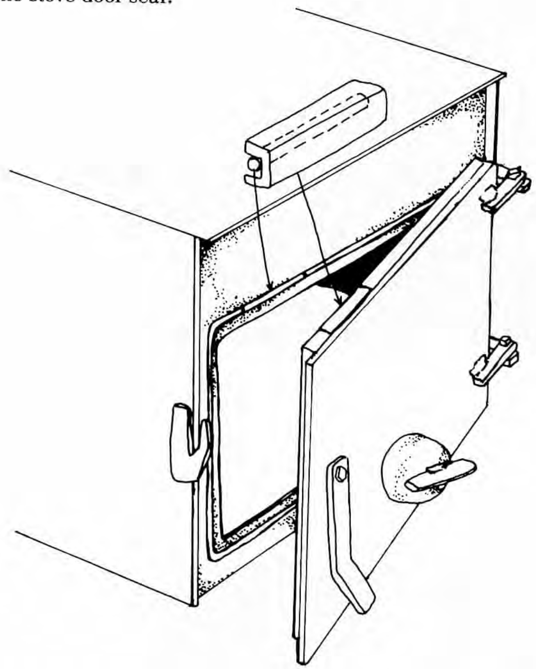
Not much was happening in the shop, which slowed the money flow to a trickle and aggravated the difficulties brought on by the cold. Sparing wood to heat the shop was itself an issue. And even with the two stoves in the shop going full blast the temperature seldom rose to a comfortable working level.

As Willie's flu finally receded, we arranged a day to make the door. It was a typically difficult winter day. I arrived in the morning; we spent forty-five minutes moving wood and lighting wood stoves in both ends of the shop. Several of Willie's friends arrived, all with their own problems that required Willie's solutions. Willie paused to work on Green's truck starter. Clyde Henry wanted help on his Ford tractor. Frank's bursitis had advanced until he could no longer gather his wood; Willie filled the trunk of Frank's old Chevy with some logs he said were too punky to use in

14 The greenhouse stove, with door parts waiting to be put together.

15 Clamping the mitered iron channel, part of the air seal, to the stove door.

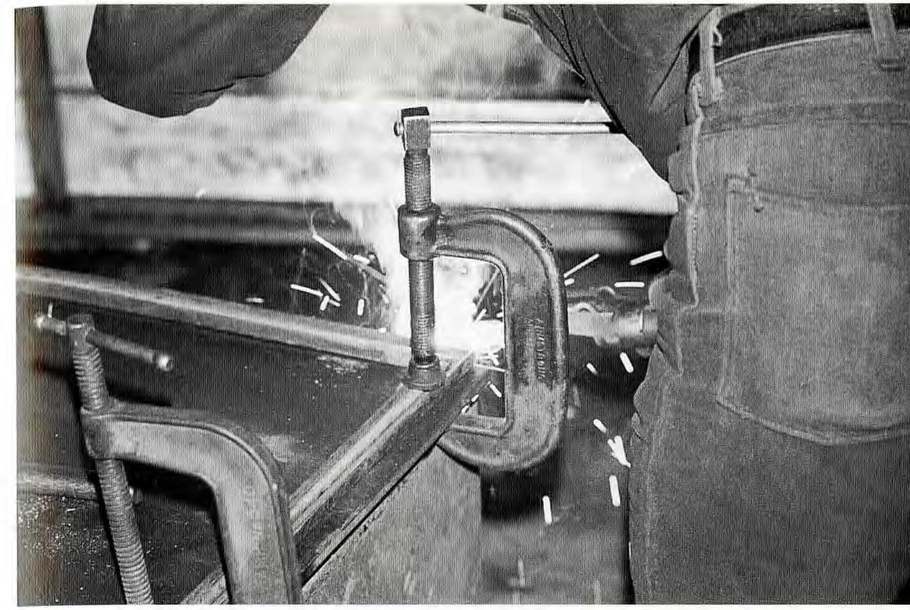
16 Detail: the stove door seal.



his own stoves. Of course they weren't; it was only a way to discount his generosity. After the long morning of preparation Pauline, Willie's wife, fed everyone stew made from a rabbit a neighbor had brought the day before. Finally, in the early afternoon, we returned to the shop and focused our attention on the stove door. Once begun the job, so long delayed, proceeded smoothly.

WILLIE: "The design of this stove was from the one I built for my cellar. The one for the greenhouse, that we're making here, is quite a bit larger—more efficient for a greenhouse—it'll hold a fire longer. But made on the same principle. If you don't have this type of a seal [see 16], you'd stand a chance of sparks coming out between the door and the stove. The door will warp a little when it heats, causing a gap, and it'll come back when it cools.

"When you heat one side of metal [as happens when you use the stove]—it's just like taking a dry board and making it wet on one side—it'll make it bow the other way. So the channel and bead we welded on the stove is a seal *and* a spark arrester.



17 Willie welds the channel to the door.

18 Willie welds the door. The reinforcing-rod seal sitting on top of the stove will be welded onto the front of the stove so that the channel closes over it.

"The channel is welded on the door, and we laid the seal, which is the re-rod [half-inch steel reinforcing rod], into the door when we were welding it into a square to make sure we got it the right size. Then the re-rod was welded onto the stove.

"I remember this square piece of welded channel laid around the shop for about a year," I say. "I've got a photo taken a year before showing you using it to line up the side pieces of a trailer you were making."

Willie laughs, "Yeah, I used it for a straightedge!"

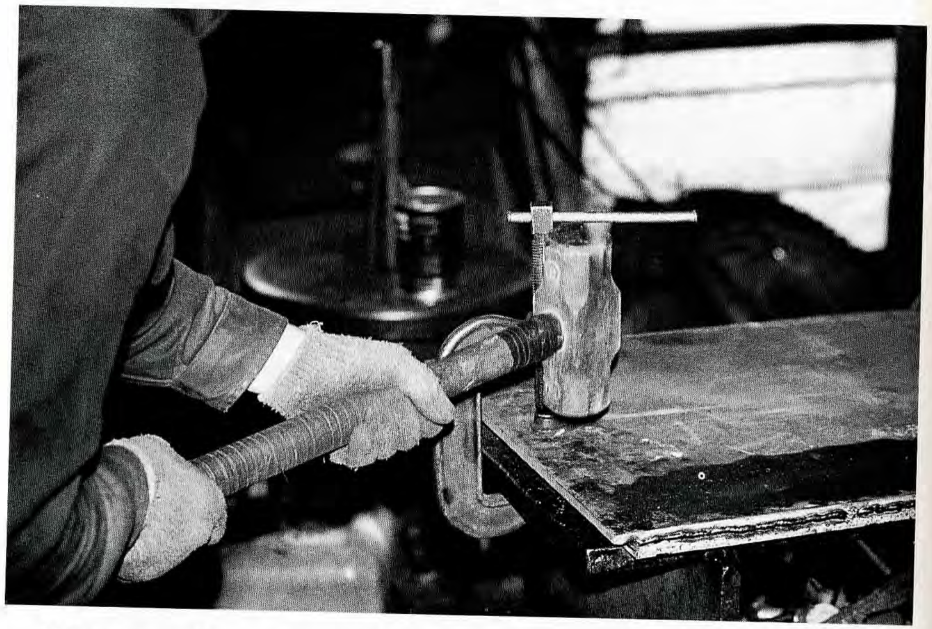
He studies the photos:

"If the piece I'm welding on isn't accurate the door won't close properly. But all this is the easiest welding there is—the long bead. You clamp the pieces and just run your rod along and let it flow in. Biggest problem a lot of people have is that they get in too big a hurry. The more time you take the better weld you get. The slower you move with the rod, the heavier the weld. If you move too fast it's what some people call bubblegum welding. I told you about that before. You just get bubbles of metal on it. You go so fast it doesn't blend together. It just lays there in beads as it comes off the rod. See, as your metal heats it comes off the rod in droplets. It doesn't pour off there like most people think it does. If you're not hot at the spot where that's dropping off—where it's molten metal—it cools off too quick and just lays there in a bead. You can see it with the dark mask on. But if you go too slow you can burn a hole in the metal you're welding, depending on its thickness and heat range.

"There's a problem on this weld because I'm welding light metal against heavy metal. You hold the rod a certain way to get a good bead, and you can't hold it as heavy on light metal as you can on heavy metal. So you've got to go accordingly. You can see the heat as you're working; you can see how it's blending. You're watching the colors of the two metals; you're watching it blend. That's why when you see someone welding, even if he's doing a tedious little job—you won't hear him talking. He's concentrating on his metals. Because if he doesn't, he hasn't got a weld that will hold up."

I say, "You got that welded and you set it upright next to the stove to let it cool. I looked at it and said, 'my God, it's warped—it's not going to seal!' Frank and Raymond are back there by the stove keeping warm. They walked over, wrinkled up their foreheads, and said, 'I guess you really did fuck that one up, Willie! His door ain't going to seal!'"

19 The warped door viewed from the edge. The channel is welded to the right side. The door leans up against the stove, here viewed from the front. Note the bow in the edge of the door facing the front.



20 Using an eight-pounder to straighten the door.

Willie answers, "Yeah, quite a bend in it. Heat bend. When you weld two pieces of metal that are different thickness together, the one that's lighter cools faster, and it draws the other one. It drew the door in a rainbow shape—the lighter metal actually bent the heavier. So it had to be straightened to be used. And if you could straighten it without heating it she'd never warp back. With a wood fire the two metals heat together and evenly—it's not like throwing a torch or an arc [welder] on it. The whole area heats up instead of just that small spot. I might have been able to straighten it by leaving it clamped when it was cooling off. But on this we didn't use clamps. There's a quarter-inch or more bow in that!"

"To bend it back I clamped the door to the big iron to hold it steady, so it wouldn't bounce off on my feet, and used the hammer on it. An eight-pounder. It took about half an hour, as I remember, but it was flat when I was finished."

"I was surprised you could take that little bit of a bend out of that big an area by pounding on it," I say, "God, you made a racket."

"You can take metal and work it just like you take sandpaper and work wood. But you do it with a hammer on metal. You figure—that was a two-foot span, and we're taking a quarter-inch out of three-eighths stock. Plus you've got to figure the metal welded onto it. It wouldn't mess up the channel because it was laying flush. If it wouldn't have been laying flush, on flat metal, it would have messed it up when you hit it. But it was laying flush enough that it worked out. You work with metal long enough, you know just about what you can do with it. This is like a blacksmith's work—you've got the same thing right here, straightening that door. Only thing, I did it cold instead of with heat. If I'd done it with heat I'd put the heat on the opposite side from where it's laying now. You would have heated it, put a small thickness of metal under both ends, and clamped it. And when it cooled off she'd probably come back to the shape you'd wanted it. Or you'd have to raise the ends of it because it would pull some of the bow back if you didn't. You'd have to go just beyond the point of straight. About an eighth of an inch. You'd need about a sixteenth of an inch on each end. But what I like about working with a hammer—you know where you've got to hit by looking at it. If you hit it hard enough, and if your iron is solid enough that you've got it laying on, she's going to move where you want it to move—not where *it* wants to move. You'll find the same thing hammering a saw for a sawmill. If a saw gets a lot of warp in it you don't take it someplace and have it straightened, you take it somewhere and have it hammered. You can hammer a warp right out of it by stretching the outer edge of the warp. If you've got a bow you generally hammer the outer edge, or sometimes the inner edge—whatever you need to get the warp out. You *pull* the metal. If you've got a bulge in the metal of your car and you want to shrink it—you don't hit it on the top of the bulge. You heat it—use water and shrink it. Bring it right back in. But if the bulge is too big you take a dolly on the inside and use a hammer on the outside as you heat around it and work it right back in. You can take a bulge right out of it. *You* want to hit the mountain—get it down there faster. But you can't do that. You've got to bring it down easy, work around it, work the metals in flat. Otherwise it would just wrinkle it up. Well, it's the same principle with this. When it cooled off it shrunk the metal. I had to bring it back, and the only way to bring it back was to expand it by hammering it. If you hammered enough you could hammer a bow into it in the other direction. It's like making something out of brass—it's done with a hammer. Here you are stretching two pieces of metal. The lighter one, the channel, would stretch easier than the heavy part. So you hit the heavy part, not the light part. There'd be no problem stretching the channel because that was light enough to stretch. The clamp was just to hold the metal on the iron. You don't clamp a bend out of metal that size—you work it out."

"That's on the drill press," Willie says, "drilling the openings in the door for the air to get to the fire—you just make a circle the size of the draft control and fit as many holes as you can into the circle. You keep the oil to it and it goes easier. I thought you were holding that door for me."

I comment, "I think the guy who brought the parts you used for the draft covers was holding it."

"Autry. He brought those pieces from his job—they're covers used to weld over the end of pipes. They make good dampers—I wish I could get more. And I wish I could find some more gloves like that. They're a special thermo—I can't buy them anywhere anymore."

21 Willie drills air holes in the door.

22 Damper holes. Willie will thread the center hole so the damper can be screwed in or out, regulating the amount of air blowing through the holes into the fire.

23 Willie cuts threads in the center hole with the air wrench. He has just threaded the hole in the damper, which is in the right foreground. He will weld bolt stock (cut from a long piece of threaded rod) into the damper, which can then be screwed into the door. With the damper turned in tight to the door, the fire is starved for air and burns more slowly. With the damper turned away from the door, the fire gets more oxygen and burns hotter.

WILLIE: "The hole in the center is to thread for your draft control. I started the threads with the big crescent; I finished them off with the air wrench that walks them right down through. I always figure you've got a little better job that way, too. You get quite a torque [with the air wrench], but I think it's easier on the tap [the tool that cuts the threads] with that steady torque than it is twisting that tap in with a big crescent. The taps are hard metal and they're easy to break.

"You can see the draft control in the photo; we've already drilled it and run threads through it."

Building a wood stove involves knowledge of the material it is made of, but designing one also requires knowledge of how things burn. You have to know how air behaves when it is heated and cooled. The air flow into and out of the stove—controlled by the damper and the chimney—regulates the rate at which the wood burns, the intensity of the heat, and the ability of the fire to hold for eight to ten hours. With the completed door in place the next spring, the stove had seemed starved for air. Fires had been hard to light and maintain. I thought the stove had not been designed with adequate draft. As we study the photographs I tell Willie: "You should hear that draw through those holes. It could probably use another draft just like that one."

But in Willie's eyes the problem involves a less obvious solution. "If you get too much of a draft," Willie says, "you won't get as good a heat. You get draft where the air is *blowing* in on the fire. You need to insulate the pipe up on the roof. It was getting too cold; it wasn't drawing right. The best would be a block chimney from inside the greenhouse. Because if you have cold pipes on the outside, or even cold pipes inside, you won't get the draft that you do if you've got the pipes heated. There's quite a vacuum to the pipe when it's heated up. It isn't really the size of the pipe. A lot of people think they have to have a real big chimney for a stove. But if you have it so that it gets the right amount of heat inside a chimney and the chimney heats right, you can get an awful draft through a small chimney. People who just put a regular pipe outside their window and up the side of their house don't get the efficiency out of their stove."

Our conversation illuminates the difference between the "quick and dirty" solution and the solution based on "deep knowledge" of materials and the natural forces that contribute to a stove's efficiency. The following summer we did build a masonry chimney in the greenhouse, and with this modification the stove worked with the efficiency Willie had described.

24 Willie: "To everyone else it looks like junk; to me it looks like stuff I can use. I was looking for something to make the hinges with."

DOUG: "You put me on that cut—and it was going so slow. You picked up the camera and got me when I wasn't looking!" [25]

WILLIE: It was going slow because you didn't *quite* understand how to run the hacksaw.'

DOUG: "The hacksaw was dull."

WILLIE: "No, it wasn't dull—that's your imagination. You were disgusted there. Your cut was wavering off to the side because you weren't holding your saw straight and you were laying on it too hard. The harder you laid on it the less straight it would go. A hacksaw *plays* its way through the metal. You do the same thing with a handsaw cutting wood. If you lay on it too hard it will not cut on a straight line. Take your time—let it play."

DOUG: "You welded this on and I said to myself, 'What the hell is he doing?'" [28]

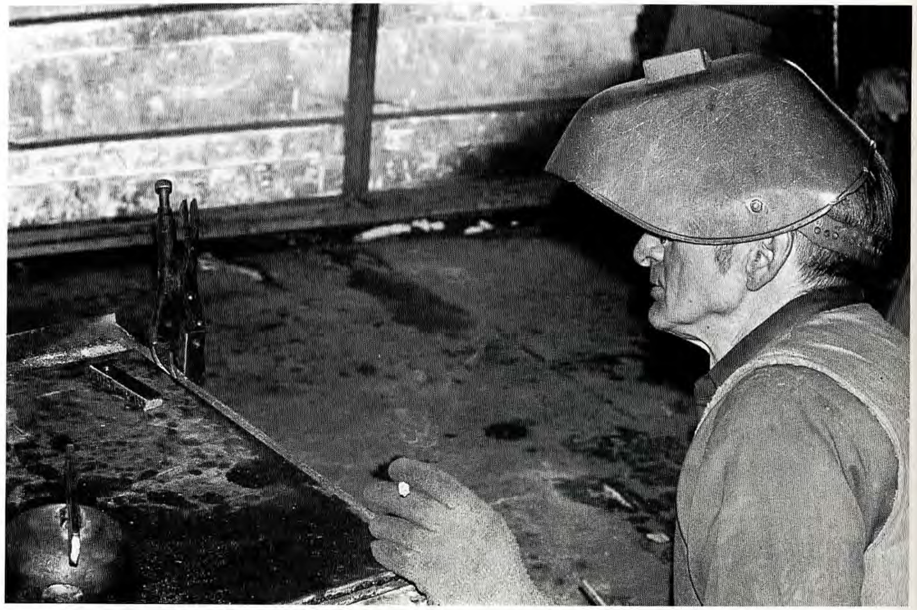
25 Cutting steel for a hinge.

WILLIE (laughs): "Yeah, it is a little ridiculous welding on a big piece, but I didn't burn my fingers holding it! That we made into the latch jaw, the piece the handle drops into."

WILLIE: "I cut a little out of the latch so it would draw up tight. I bent it a little, then cut a groove out of the backside so it would lock up against the jaw. It didn't force the door shut the way it was." [30, 31]

WILLIE: "The weather broke that next Saturday—we're finishing up—trimming and grinding—with the garage door open!" [32, 33]

The stove was completed, moved back to the greenhouse, and installed.

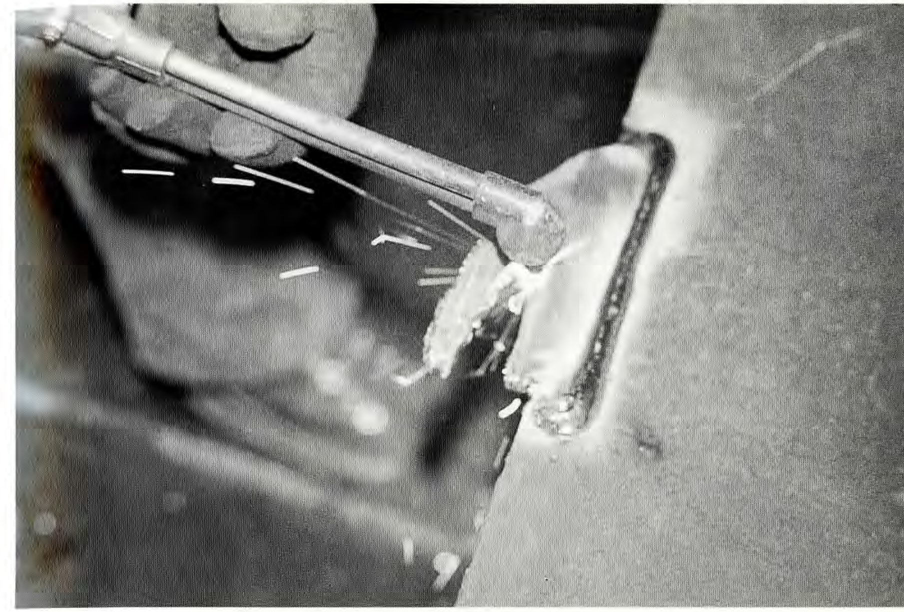


26 Willie positions the parts before beginning to weld the reinforcing rod onto the front of the stove.

27 Welding.

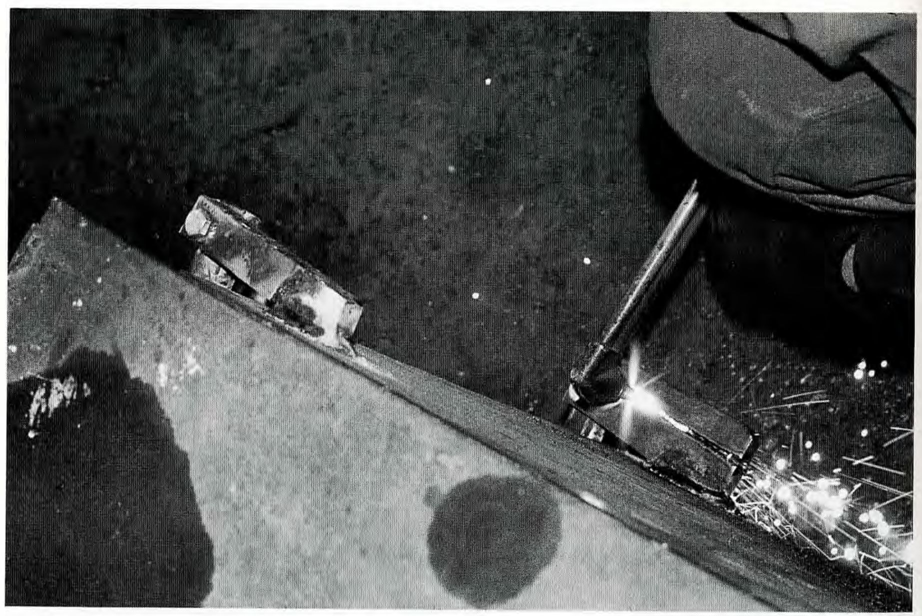
28 Making the latch jaw.

29 Trimming the latch jaw.



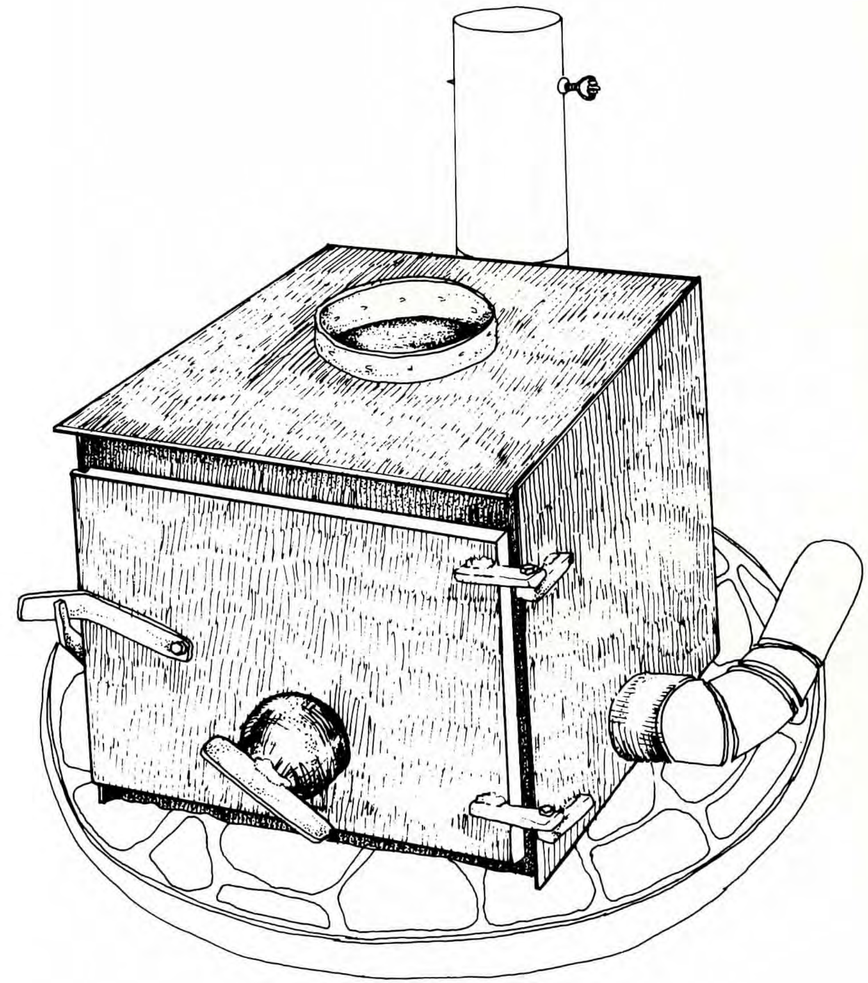
30 "Carving" the latch jaw with the torch.

31 Willie heats the handle and bends it so that pushing it into the jaw will draw the door tighter to the stove.



32, 33 Willie grinds and trims the hinges.

34 The finished stove.



Redesigning a Door Handle

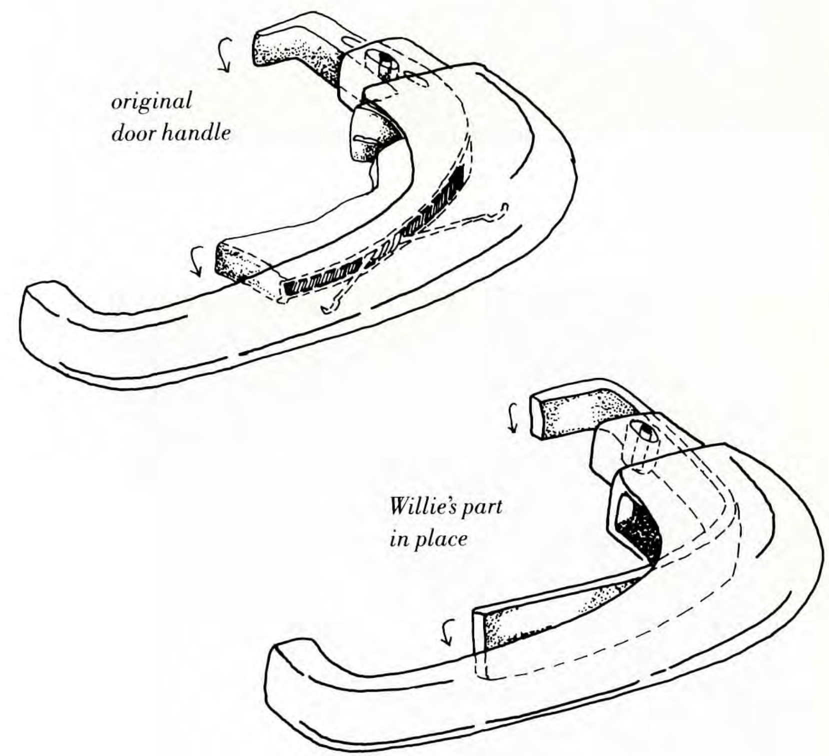
This example shows how Willie's work involves redesigning parts that have broken or worn out. In this case the engineers who designed the early Saab 99 door handle made a few small mistakes that Willie corrected in his repair. Willie's repair includes choosing materials, for example, that are more appropriate than those used originally.

The handles were designed to be squeezed open, but the part that takes most of the pressure was made of white metal, weak where a shaft passes through on which the lever pivots. The handle was designed to move freely on small plastic ball bearings that ran in a groove between the handle and the lever. It was a good design except that the handle was open to grit and snow, so that the plastic balls eventually deteriorated and fell out. The white metal part was then not strong enough to take the pressure required to squeeze the door open. One of my door handles broke on a twenty-below morning as I tried to get into my car; the other broke when my son's 250-pound baby-sitter yanked open the passenger door.

"Yours broke like lots of them do," Willie begins as we examine the photos of a still uncompleted repair. "All you have to do is pull on them just the wrong way and it will snap the white metal piece on the inside that unlatches the door. . . . Some of it's from abuse, but it's wear too. And that piece should be made out of something heavier, something besides white metal."

"I'm thinning down the piece I made so it'll fit behind the pin in the door handle. The piece trips the latch inside the door—that's all it does. . . . You need a metal grease between those two pieces. Graphite or something to make it slip. Now it's sticking to the metal. It isn't polished enough to slide. The design is all right—it slides up and down in the handle and trips the latch. But it should be polished more so when you pull it it'll slide better. The original had a little ball in there that it rolled up and back on. With the one we made you couldn't put that plastic ball in there. The groove on the original was in the part you pulled and in the handle itself. The plastic ball was a ball bearing, to roll out and in with the latch. Now, what usually happened—that roller would get a little dirt and stuff in there, and that's when they would break. You couldn't pull it easily, and people force it and break the white metal. So I did away with the roller because the roller is what broke it before. The dirt is bound to get in there because it's all open. Saab's gone to a different handle now. The new ones have a different design; they work a lot smoother."

35 Saab door handle.



36, 37 Willie makes a new part for the inside of the door handle.

38, 39 Filing and fitting the new latch.