EXPLORING ADVANCEMENTS IN PIPE CUTTING OPERATIONS

By James Blackburn

In the mid-1980s, U.S. heavy industry underwent significant evolution. Shipbuilding, heavy construction, petrochemical processing, and power generation was lost to overseas firms as the U.S. sought clean, light manufacturing and service sector jobs. Hundreds of pipe fabrication shops were liquidated or mothballed. U.S. companies downsized and restructured in an attempt to regain their competitive edge. During that period, improvements to pipe fabrication equipment continued though sales of machinery slumped.

Throughout the 1940s, 1950s, and 1960s, pipe fabricators were content to manually lay out and hand burn profiles and holes. Mechanical "pantograph" machines with adjustable cams and levers made simple cuts. More complex cuts were performed using templates designed using descriptive geometry. Oxyfuel torches and rotary milling machines were the sole methods of profiling steel shapes.

Microelectronics, computer software, and computer numerical control (CNC) motion control have been incorporated into cutting machine design. Computer technology and the sheer volume of information have grown exponentially.

To keep up, companies adopted new technologies and processes to improve their profitability. Management is actively applying microelectronics and information systems to their fabricating operations. The Information Age has come to pipe fabrication.

Knowing Your Costs

Successful fabrication shop management depends on the allocation of limited resources. Good decision-making is based on experience and facts, not impressions and intuition. Profit contribution is mandatory if fabrication shops are to survive.

The recent surge in output per labor hour for U.S. companies is largely due to management's investment in new plant and equipment; that is, in more modern machines and processes.

The process of evaluating new equipment, however, has forced management to examine current shop practices and material flow. Analysis of established procedures and processes has raised interesting questions and prompted new approaches to pipe fabrication.

In addition to lower prices, improved delivery, and quality, information management has become instrumental to survival. Information promotes good decisions, so it is imperative to get control of costs, to accurately forecast sales, and to employ state-of-the-art technology within the shop. It is not only a means to improve productivity, but also to expand and explore new markets.

Improvements in welding technology have emphasized automated positioning, robotics, vision systems, and material deposition. However, recognition of the proper fit-up and cut quality as an identifiable profit contribution is long overdue.

Uses of Fabricated Pipe

Pipe is used for two purposes: structural support and flow control of liquids, solids, and vapors. The complexity of cuts varies with the application, but advances in cutting machine design and operation accommodate all uses of pipe.

Architectural and structural purposes include offshore construction and space frames, such as oil production platforms, airline terminals, and sports arenas. Another unique application of pipe is self-augurring supports for outdoor electrical panels, switching gear, and signposts.

Structural piping involves greater numbers of complex profiles where multiple pipe members overlap into a single intersection. The exact angle of intersection coupled with critical weld preparation angles leave little margin for error. Excessive grinding and filing contributes significantly to labor content.

However, today's computer technology, which can calculate the proper torch path and torch orientation, makes this type of fabrication simple and quick. Precision hardware and CNC guide mechanized assemblies for smooth, accurate cut quality.

Process piping includes mechanical contracting, HVAC shops, pressure vessel fabrication, and shipbuilding. Process pipe fabrication involves greater numbers of simpler cuts, from simple one-on-one saddles to multiple holds in pressure vessels. Straight lengths or "spools" are fit with flanges, fittings, and connectors.

These types of cuts require more manual layout, measuring, and marking but less complex geometric calculations than structural pipe. Computer controls and precision mechanical design eliminate manual layout, hand burning, and cutting irregularities.

Dedicated software employs point-to-point programming for accurate location of cuts and holes, as well as contouring routines with simultaneous movement of several axes to yield smooth curvelinear tool paths. Accurate, repeatable torch movement is guaranteed. Automated equipment and good shop layout can improve productivity regardless of which type of fabrication is performed.

Types of Cutting Machines

Cutting machines can be broken down into several categories. Some are lightweight, portable tools that affix to the pipe. Mechanized torch carriages travel the circumference of the pipe on chains or tracks.

"Strap-on" machines are less expensive than permanent "machine tool" type machines and are useful for small shops, short runs, and field service. They can be equipped with flame-cutting torches, rotary cutters, abrasive wheels, and grinders.

Some types of cutting machines are similar to machine tools. They require more floor space, are permanently attached to the shop floor, and require that pipe be transported to the machine.

The cutting process proceeds in a production line manner from raw length to finished piece. Finished pipe is prefabricated in volume for fit-up elsewhere in the shop or out in the field. Permanent machines include cold cutting machines like band saws and pipe lathes as well as flame-cutting systems.

One type of permanent machine grips the pipe in a fixed height chuck with adjustable jaws. Short lengths are manually loaded into and rotated by the chuck. To rotate longer lengths, outboard supports are raised and lowered to fit different diameters. Overhead cranes, forklifts, and extra shop people move material between operations.

Another type of permanent machine employs a bed of turning rolls to rotate the pipe. Material is loaded and unloaded automatically by an integrated pipe conveyor system. The pipe is self-centering and fully supported and rotated its full length. The pipe can be cut anywhere along the length of the turning rolls.

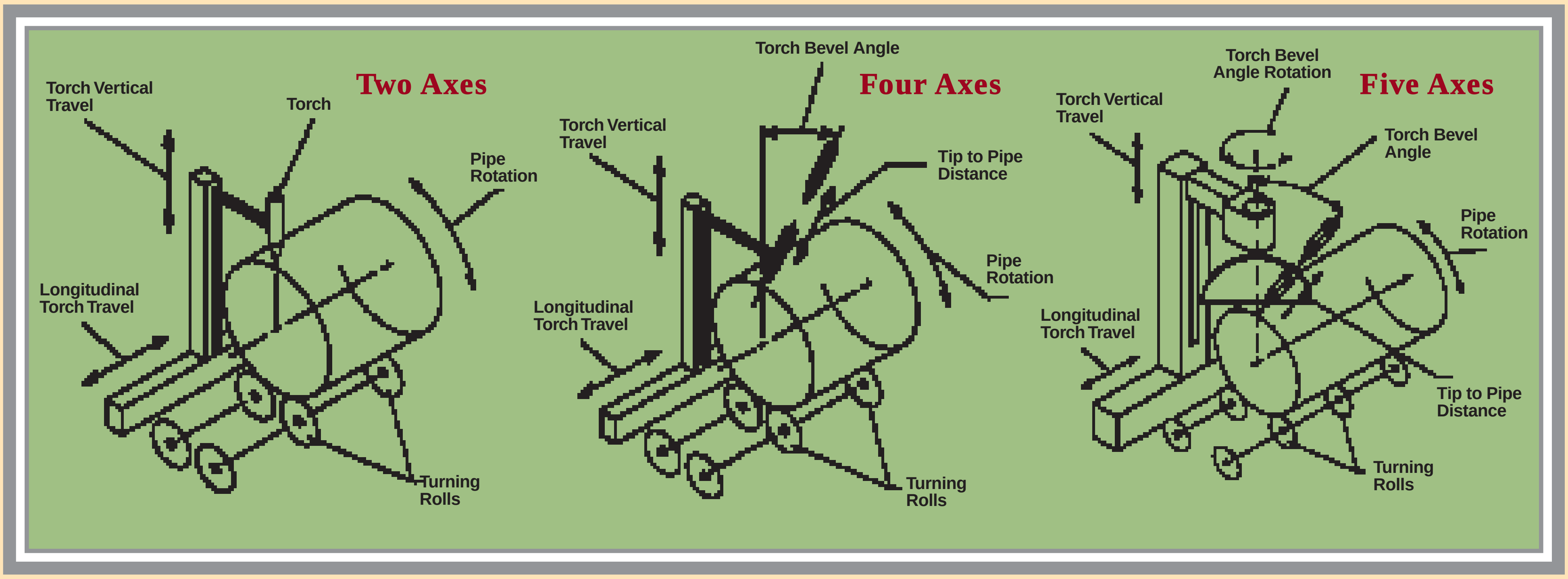

Figure 1
The computer controls of pipe cutting machines can offer two to six axes of simultaneous motion. Three options are shown here.

Material Handling

Shop layout contributes to profit. Efficient material handling systems reduce unit cost. It is important to consider the total process, including layout, handling, burning, and cleanup. Material handling often accounts for up to 80 percent of overall fabrication time and costs. Extra people and extra lifting devices contribute to labor costs.

Safety and speed are critical factors to efficient throughput. This is especially true in spool shops and pipe supply warehousing operations. When laying out a pipe shop, follow a few simple ideas:

1. Organize the material flow so that it flows in one direction from raw material to finished pieces.

2. Minimize the number of times material is handled. Employ powered conveyors and automatic feed systems instead of overhead lifting devices. Pipe stands with casters or carts transport pipe efficiently after flanges and fittings have been fit up.

3. Provide buffers between operations to accommodate different cycle times, production run interruptions, downstream bottlenecks, and scheduling changes. Pipe storage racks allow you to roll pipe into and out of the conveyor line to suit production efficiency.

4. Centralize cutting operations for improved organization, cleanliness, and supervision. Distribute finished pipe by conveyors or carts, but allow overhead clearance for bridge or jib cranes with which to remove scrap and remnant pieces.

5. Compare cutting carriage speeds versus conveying speeds when analyzing your operations. Sometimes, it is more logical to move the cutting carriage than to reposition the pipe between cuts, especially when the distance and axial angle between cuts is important. Variables to the optimal sequence for cutting include the length of carriage travel, the rapid traverse speed of the cutting carriage, the lengths and types of finished pieces, and the material handling time between cuts.

Automatic Equipment

Automatic equipment improves speed, precision, and quality of the cutting process while remaining simple to use and maintain. Blending well-engineered mechanical assemblies with computer controls lends flexibility and consistency to fabrication operations.

Long production runs do not alone justify machinery purchase. Pipe volume multiplied by the per unit savings is a more appropriate measure than the number of hours per day that a machine runs. Quick setup, simple software, rapid calculation time, and efficient material handling (all components of labor per piece) are more important than the average production run size.

Based on informal surveys, automated pipe cutting machines reduce costs in the following percentages:

30 to 50 percent savings in layout labor

5 to 10 percent savings in cutting time

30 to 40 percent savings in fit-up and welding costs

An offshore fabricator remarked that the justification for the machine was not based so much on cutting time savings as it was on savings from manual layout and reduced fit-up and welding time. Impressive savings resulted from tight fit-up, less welding labor, and reduced filler material in each joint because the machine burned a constant weld preparation opening between members.

The better the cut surface and shape, the less labor and material cost per connection.

Cutting Systems

A variety of cutting systems are adaptable to new cutting machines. The most advanced pipe cutting machines adapt to several different methods of cutting.

While oxyfuel is perhaps the most common and reliable method of cutting carbon steel, other systems are gaining acceptance. New systems of plasma, laser, and high-pressure waterjet cutting are emerging.

Plasma. The advantages of using plasma include rapid cutting speeds; cleaner, dross-free surface finish; no preheat cycle; smaller heat-affected zone (HAZ); and the ability to burn nonferrous materials.

Plasma is being used to burn exotic materials and types of tubular shapes. A recent test piece was burned from stainless steel mesh pipe. It was mitered on either end and subsequently cut longitudinally and flattened to serve as a water treatment filter.

Manufacturers of plasma cutting systems have produced two new interesting innovations:

1. Air plasma systems that substitute inexpensive compressed air for bottled gases as the cutting medium and shield gas. Under certain circumstances, bottled gases still produce a superior surface finish and less dross, but the cost and availability of air make it very attractive.

2. High-definition plasma power supplies that concentrate the arc to yield a very fine cut. Proponents claim that high-definition plasma rivals the accuracy and finish of lasers. Maximum material thickness ranges between ¼ inch and ⅜ inch.

Because the effective material thickness increases as the torch bevel angle changes, high-definition plasma has not been extensively employed in pipe fabrication. However, it is popular in thin-gauge sheet metal and tubing fabrication. In the future, plasma suppliers will introduce higher amperage high-definition power supplies and torch shapes that will accommodate thicker materials.

Lasers. Lasers have been adapted to thin-wall tubing applications for wall thicknesses less than ¼ to ⅜ inch. Surface finish, precision, and small HAZ are the principal advantages of this method. A common application is stainless steel vacuum chambers and high-precision instruments.

1,500- to 3,000-watt CO_2 lasers are now cutting material up to 1 inch thick. Laser cutting is limited to certain materials because of reflection back into the delivery system.

Cut quality on carbon steel is extremely precise but can be affected by the metallurgical content and raw surface quality. Rust and mill scale, common to general pipe fabrication, can result in surface finish inconsistencies.

The initial investment of laser cutters often exceeds the cost of the mechanized equipment to which it is attached, so its widespread acceptance in pipe fabrication may be some years in the future.

High-Pressure Waterjet. High-pressure waterjet systems have been employed to sever pipe. The cutting speeds are slower and the initial investment is higher than with flame cutting systems such as oxyfuel or plasma. However, waterjet systems can also cut nonmetallic materials.

The absence of a spark and a small HAZ make high-pressure waterjet an alternative to flame cutting systems, especially in flammable environments. Obstacles to using high-pressure waterjet on pipe cutting machines include overcoming the thrust from the nozzle, increasing the cutting speed, and collecting the overspray.

Cold Cutting. Although cold cutting is slower than flame cutting, it produces a machine finish and curved bevel surfaces such as compound and "J" bevels.

Unlike flame, laser, or waterjet cutting, the cutting tool contacts the workpiece. Consequently, the pipe must be rigidly restrained, or the travel carriage must be securely attached to the pipe to overcome opposing forces.

Microelectronics and Miniaturization

Microelectronics and miniaturization have improved the size, quality, and maintenance of hardware components. Smaller space requirements, digital control, and dependability are byproducts of this trend.

Solid-state electronics have revolutionized machinery design. Modular design, easy troubleshooting and replacement, and improved durability contribute to machine longevity and lower operating costs.

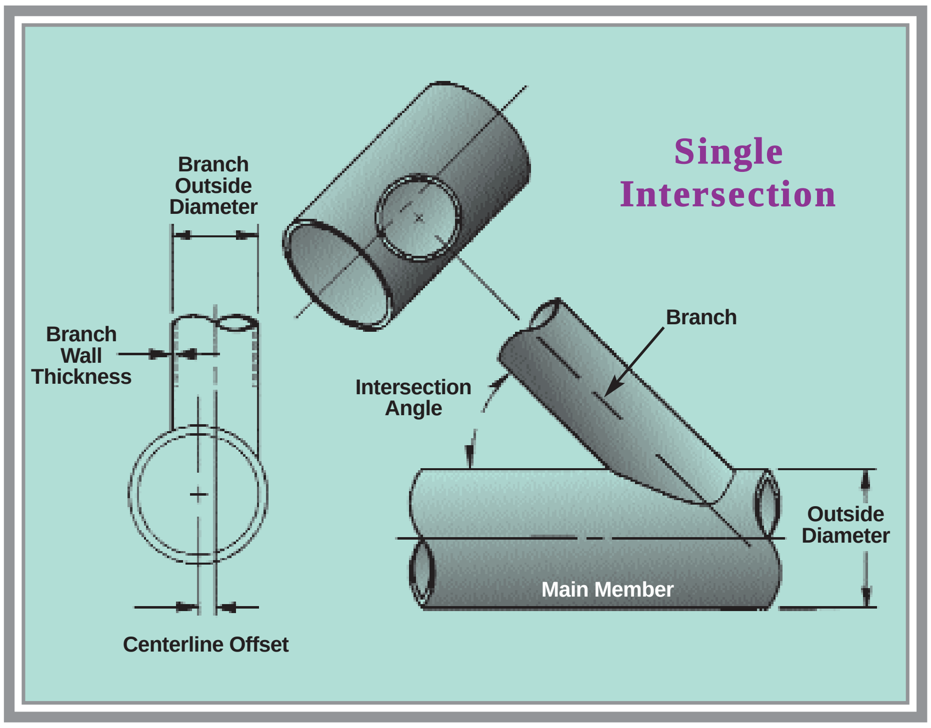

Figure 2
With pipe cutting software, the user answers English-language prompts on the console monitor to describe the pipe intersection.

Programmable controls have replaced mechanical relays. Ladder logic software replaces "hardwired" circuits and readily adapts to experimentation and modification. Electric proximity sensors are employed to compensate for out-of-round and bent pipe.

NEMA 12 industrialized enclosures protect components from the severe shop environment while complying with local and federal safety codes.

Membrane keyboards, protected disk drives, and flat-panel displays make machinery more compact, durable, and operator-friendly. Supplied in modular form, these components are readily interchangeable for ease of maintenance.

Equally important are new manufacturing and assembly techniques that improve the mechanical design and operation of cutting machines. Components are CNC machined for improved precision. Rack and pinion and precision ball screw assemblies ensure accuracy and longevity at reduced price because they have become "off-the-shelf" commercial items. Reliable suppliers guarantee availability years from now.

Power transmission components such as antibacklash gearboxes and energy-efficient motors improve accuracy and lower operating costs. Product design includes maintenance considerations, so vulnerable components are clustered together for easy access.

Safety features and aesthetics are priority items on new pipe cutting machines. Flexible dust covers reduce exposure to cutting dust and shop grit. Chain covers on powered conveyors prevent accidents. Cable carriers reduce the risk of crimping or severing electrical lines and gas lines.

All power supplies and energized components are grounded to prevent accidental electrical shock. Flashback arresters are standard equipment in torch regulators. Emergency switches and interlocking disconnects prevent accidental start-up during maintenance. Electrical wire runways, connector plugs, and printed circuit boards are common in all electrical enclosures for both safety and simplicity.

CNC and Microprocessor Technology

CNC and microprocessor technology controls torch movement and auxiliary functions such as torches, sensors, and material handling. CNC introduces precision, repeatability, and speed into flame cutting operations. CNC upgrade packages are available from both new equipment and third-party suppliers.

IBM-compatible personal computer (PC) controls offer a degree of familiarity and dependability, internal diagnostics, and a ready supply of replacement parts. Custom circuit boards can have problems with reliability, availability, and obsolescence.

Input/output functions for the exchange and transmission of data are easy and reliable. In other words, when using familiar operating systems, disk drives, modems, printers, plotters, and other peripherals are readily adaptable to machine controls.

Microprocessors loaded with dedicated software are becoming commonplace in specialized burning machines. Low-cost "computers on a chip" are employed to execute internal programs into machine-readable instructions and to store part programs. Internal diagnostics pinpoint defective components and reduce maintenance costs.

Multiple Axes of Simultaneous Motion

Computer controls synchronize multiple axes of simultaneous motion for contour cutting. Servo drives and closed-loop encoder feedback use digital pulses to ensure precise movement to the exact location.

Pipe cutting machines now offer computer controls with two to six simultaneous axes (see **Figure 1**).

Two-axis machines are X and Y tables in which the torch reciprocates relative to the pipe rotation. The torch remains at a fixed bevel angle so the included weld preparation angle between members varies throughout the connection.

Four-axis machines incorporate two extra axes of motion to orient the torch to the proper weld preparation angle. The machine will vary the angle of bevel and maintain a constant torch-tip-to-pipe distance while burning the proper contour. The result is a constant included weld preparation angle between mating pieces.

When burning a weld preparation angle on pipe, however, out-of-round compensation becomes extremely critical. The computer-calculated tool path assumes a perfectly concentric workpiece. If the pipe is not concentric, the resulting fit-up between members may be unsatisfactory.

Many new pipe cutting machines offer an automatic feedback system to compensate for out-of-round conditions. They use a closed-loop direct current (DC) drive system and proximity sensors to raise and lower the cutting carriage independent of computer control to achieve the proper fit-up.

Five-axis machines incorporate another axis of motion to rotate the torch bevel angle so that it remains normal to the contour cut path. Similar in design to contour beveling heads on plate cutting machines, it orients the torch to any bevel angle at any location on the pipe.

Advantages of the five-axis design are a very accurate weld preparation angle and faster cutting speeds. Typical applications for the five-axis models are burning a constant circumferential bevel angle on pressure tank holes and inside diameter/outside diameter (ID/OD) transition bevel angles on offshore support structures.

Offshore construction companies burn ID/OD transition bevel cuts on heavy-walled structures. The capability to control five axes of motion allows them to tailor cuts to meet each customer's exact interpretation of American Welding Society (AWS) welding codes.

Dedicated Pipe Cutting Software

Another innovation is dedicated pipe cutting software written specifically for pipe fabricating needs. Programs take advantage of CNC's accuracy and speed by postprocessing English commands into machine-readable instructions.

Usually written by programmers experienced in pipe design and fabrication, this software shortens the learning period for new users. It ensures immediate production cutting without "teach and learn" programs or data processing operations common to general-purpose machine tools and robots.

User-friendly, menu-driven programs do not require college graduate skill levels. Neither the operator nor the data processing and engineering staff need to write programs.

To create a cut, the operator keys in data that defines the finished connection. Answering English-language prompts on the console monitor, the operator describes either a pipe-to-pipe or pipe-to-plate connection (see **Figure 2**).

Alternatively, this information may be retrieved from internal memory or from a remote computer. Postprocessing of this data into machine-readable instructions takes seconds.

Standard dimensions and machine parameters, such as the weld preparation angle, inch or metric measurements, torch dimensions, and oxyfuel or plasma cutting systems, can be set by the customer in internal machine setup tables.

For long-term changes to these standards, the customer can access and revise the respective default values. For intermittent changes, however, the machine operator can override certain default values while entering new cut data.

For instance, if the machine setup data specifies a typical weld preparation angle of 45 degrees but a desired cut calls for 37½-degree weld preparation, the operator can enter a 7½-degree bevel correction factor without making a permanent change to the setup parameters. This flexibility improves the speed and quality of the cutting process.

Data can be entered either on-line or off-line. On-line programming means that the machine operator can create part programs at the machine console without the aid of extra data processing equipment or personnel. Off-line programming refers to the ability to create part programs at a remote location and transfer them to the machine by floppy disk or direct serial link.

Machines that accept both on-line and off-line part programs increase management's ability to assign responsibility for program creation versus production operations. As the trend toward computer-aided design/computer-aided manufacturing (CAD/CAM) integration increases, this feature will become more important.

The simple advantages of CAD/CAM connection are to eliminate redundant data entry and to archive data files for future reference. Both benefits save time and reduce the possibility of human errors.

Comprehensive on-line programs address all types of fabrication, whether they are simple nozzles, vessel holes, or offshore platforms. Dedicated programs offer full capacity, simplicity, and adaptability for future changes in AWS welding codes.

Yet, new machine controls offer the ability to execute custom programs in ASCII-format numerical control (NC) instructions to perform special cuts, as well as to execute standard programs. Special cuts can include elbow or "dummy" pipe supports, crowns, elliptical holes, and helix-angle profiles. This capability is especially attractive to original equipment manufacturers (OEMs) and users actively reengineering existing products.

Screen graphics on the operator's console permit visual verification of finished dimensions and the final shape. Similarly, shop packets and wraparound templates are as simple as outputting data to a peripheral printer or plotter.

Evaluating Cutting Machines

If you are considering the purchase of new pipe cutting equipment, the following is recommended.

Invest in affordable, state-of-the-art technology, including efficient material handling systems, computerized motion control, advanced cutting systems, and dedicated software programs. Consider features and benefits as they apply to your application and fall within your budget.

Be careful to engage only the degree of automation necessary to do your work while anticipating future upgrades and efficiencies. Slowly employ more automation as your workload and your personnel can absorb it. A steady diet of small achievements and success will ensure productivity improvements. Computer overload and lack of planning can have detrimental effects on your operations.

Software is available – from basic mechanical design to structural analysis to CAM packages. The level of computerization you choose depends on your type of fabrication and level of sophistication. Strive to reduce redundant data entry and assign responsibility that is commensurate with the resources and ability of your staff.

The appropriate cutting system for your fabrication depends on the types of material, their thicknesses, the ambient environment, local safety and air quality codes, the desired surface finish, and available financial resources.

Purchase of a computerized pipe cutting machine implies a long-term relationship between the buyer and seller. It involves mutual trust and cooperation, so solicit references from a published list of users. Questions should focus on the availability of service, availability of spare parts, and timeliness of program upgrades.

Use of commercially available components lessens dependence on the manufacturer, improves availability from alternative sources, and generally improves the reliability of the machine.

Investigate the hardware-software integration and the advantages of single-source responsibility. Successful, proven integration will greatly affect output from initial start-up to production run economies in future years.

Application-specific machinery and software, such as computerized pipe cutting machines, incorporate field-proven experience to solve common fabrication problems. General-purpose equipment and robots offer universal appeal while compromising performance and material handling efficiency.

Another important aspect is adaptability to future changes. The capabilities of the machine not only improve your existing production but encourage entry into other fields of fabrication and exploration of new design possibilities.

The degree of flexibility within the machine's software, its ability to accommodate future CAD/CAM connections, and the availability of software upgrades are important factors. Likewise, new machines should be compatible with a variety of different cutting systems, such as oxyfuel, plasma, laser, or waterjet.

The thoughtful, efficient use of the information is the key to superior shop management. It is integral to reducing unit costs, shortening delivery time, and improving quality.

Your most important resource is your people. They can make or break any capital investment because the machine is only as good as its operator.

People responsible for installing and operating the new equipment should be actively involved in the purchase decision. If given the opportunity and responsibility for the ultimate success of the machine, they will take a more attentive and personal role in its output. In turn, the company will have a more educated, reliable employee and a superior end product.

Accuracy, repeatability, and speed are marketable commodities in pipe fabrication. Today's pipe cutting machines bring these qualities to the shop floor. ■

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