Bulletin No. FB 1
File: Fabricating

Bulletin

Factors to Consider in Establishing, Operating and Maintaining a Fabrication Shop

This bulletin was developed as a group project for the 2015 Advanced Leadership Institute (ALI) class. Members of Team #6 included: Paul Battaglia of J.C. Cannistraro (Watertown, MA); Stephen Feathers of Nooter Construction Company (Trevose, PA); John Ferrucci of F+F Mechanical Enterprises (North Haven, CT); Donald Griffin of Emcor Services Arizona (Phoenix, AZ); Dan Hirst of University Mechanical & Engineering Contractors (El Cajon, CA); and Joe Pesci of GEM, Inc. (Walbridge. OH).

INTRODUCTION

Recent economic conditions have forced contractors to think outside of the box. Today's mechanical contractors are faced with increasing demands from owners and general contractors to increase production, shorten job duration and reduce costs. Contractors are prefabricating more in a shop setting than ever before. The benefits from this increased shop fabrication include reduced field crew size, controlled working conditions, minimized "on the job site" material storage, modularization, centralized staffing, control over company / project prioritization, and a streamlined workflow.

There are lessons that can only be learned first-hand in the field. Contractors interested in establishing, maintaining, and operating a piping fabrication shop should visit as many existing fabrication shops as possible, using this bulletin as a checklist and as a source of questions. Talk with operators to determine not only how they do the work now, but what would they do differently if they were to build a new shop from scratch.

Equipment vendors and material suppliers also can be good sources of information. Talk to more than one vendor for each piece of equipment and record where they agree and disagree. New products, tools and technology are coming onto the market constantly, which could improve fabrication, so it is important to stay informed. Our most important lessons are learned from networking with fellow MCAA members that are able to share their tips, techniques and pointers that were gained from their experience over the years.

WHY PREFABRICATION?

Time, cost, and quality requirements of service, commercial and industrial construction projects are an ever-increasing challenge to mechanical contractors today. Fabricating and assembling piping modules and other subassemblies in a fabrication shop will result in greater efficiency, higher quality craftsmanship, and a lower total cost than assemblies made at the jobsite.

The following provide sound reasoning for establishing a fabrication shop for your company.

1. Increased Productivity

Work performed in a pipe fabrication shop is quicker than work done in the field. Automation in machinery and the assembly line process will produce layout, cuts, and welds faster than in the field.

Faster installation improves job work flow along the line.
Once a spool, module, or subassembly is assembled and tested at the shop, it can be transported safely and conveniently to the jobsite and quickly installed as a single unit.

Control and location of field welds from field superintendents' feedback
Shop drawings generated from the model will decrease the amount of field welds and field fit welds.

2. Improved Quality

Pre-assembly allows fabrication to more critical tolerances.
Inspection and testing can be performed more efficiently in the shop, and any problems can be corrected before installation in the field.

3. Increased Efficiency

A fabrication operation greatly increases the efficiency of the shop activities.
The shop schedule and work hours are not subject to field delays, shutdowns, and weather disruptions. And, pre-fabrication prior to a customer's shut-down can decrease its operation's down time

Allow the contractor to establish a "just in time" delivery model to shorten field activity durations.
A shop's hydrostatic and pneumatic testing operation can be a great way to increase field productivity. Piping spools that are tested in the shop can be installed without the need for a field test.

4. Modularization

In addition to the standard prefabrication of piping systems typically involved in discussions about pre-fabrication, modularization of systems and assemblies should also be considered. Modularization provides unique opportunities for the fabrication shop to allow the parallel installation of structural steel, electrical and instrumentation followed by coating and insulation.

Completed skids, which include all structural steel, mechanical, instrumentation, electrical, coating and insulation, can be built in a controlled environment instead of being stick built in the field.

Similar to piping systems, testing can be completed prior to shipment, eliminating or reducing the amount of testing in the field. This testing includes non-destructive examination (NDE), hydrostatic and pneumatic testing.

5. Centralized Resources

Fabrication of multiple projects in one location allows for consolidation of resources, reduced duration for onsite field personnel, reduced onsite tools and equipment and streamlined weld procedures, weld map drawings, weld tracking and welder testing.

A central location also eases the labor tracking in the shop for pipe welding, cutting, material handling, beveling, fit-up, and supervision.

6. Reduced Safety Concerns

Fewer safety incidents due to less exposure to field conditions. Safety hazards from other trades is avoided.

LOCATING THE FACILITY

The location of the building is very Pimportant to the overall efficiency of the fabrication process. Selection of the location should take into consideration the need for a smooth flow of materials and supplies into the shop and the easy flow of the finished product out of the shop. Ideally, the material should be handled by as few hands as possible during its production.

The following outside material handling steps need to be considered in the planning process:

1. **Delivery of material to the fabrication shop**
   The delivery trucks are typically long flatbed trailers that require room to maneuver in and out of the facility.

2. **Unloading and transfer of the material to the storage yard and/or storage rooms.**
   Material can be moved with a fork truck, deck crane or overhead crane to the storage area.

3. **Transfer of material to the fabrication shop.**
   Materials transfer from storage will depend on the storage area location and shop layout, but the intent is to transfer material quickly and safely with minimal personnel.

   - **Transfer of fabricated products**
     A flatbed trailer is ideal for storage on larger fabrication jobs. The finished fabrication can be loaded onto the flat-bed until needed for direct pick up by the truck. This will eliminate the double handling of finished fabrication. However, flatbeds can take up considerable space, so scheduling fabrication and delivery of the product is critical. There must be serious consideration given to fabrication storage as detailed in the “Potential Set-Backs of Pre-Fabrication” section below.

   - **Pick-up and delivery of finished fabrication to the jobsite.**
     Since the delivery truck will typically be a flatbed truck, it will need room to maneuver.

Other material handling suggestions should be considered:

- **Never handle material twice when once will do**.
- **Keep the travel distances as short as your site will allow**.
- **All of the above material handling steps may have to occur simultaneously**, so make sure conditions outside the walls of the fab shop are well-planned and spacious.

It is important to perform material handling as far removed from welding and cutting operations as possible.

PHYSICAL REQUIREMENTS OF THE FACILITY

The shape of the fabrication shop building is determined by the rule of "Form Follows Function." No single shape will be appropriate for every contractor's site and fabrication needs. The shape of the building will be determined by the fabrication material flow inside and outside the building as described above. The number of work stations and the type of equipment the contractor chooses will also contribute to the shape of the building.

The following items need to be considered and thoroughly reviewed when planning the shop design:

- Building floor plan and height
- Roof structure
  - Overhead Crane loads
- Shop Access
  - Overhead doors
  - Standard doorways
  - Potential drive lane for incoming/outgoing trucks
- Workstation configuration and components
  - Allow for flexibility to a constantly changing market
- Storage, control and security of consumables (i.e. weld rod, gas)
- Ample lighting
- Heating and Ventilation
  - Consider the excess amount of smoke and fumes emitted by welding and cutting operations
- Ample electrical service for equipment
- Facilities for the personnel
  - Lavatories
  - Lockers
  - Lunch Room(s)
  - Smoking Area
  - Drinking fountains

Compliance with local building, OSHA, and ADA regulations must be taken into consideration when planning the facility.

Ultimately, the final layout and workflow of the shop will be very unique and custom tailored to every contractor's needs. Hasty decisions should not be made when establishing the shop layout as correcting them will be very costly. This can be a daunting task so engaging third party assistance should be considered. There are industrial engineers who specialize in fabrication/manufacturing shop design who can be of valuable assistance.

WORK STATION REQUIREMENTS

The number and type of work stations will be determined by each contractor's type and quantity of work, but the following list will give you an idea of the basic work stations that a fab shop will use:

1. Pipe Feed Rack and Conveyor Logistics

The pipe feed rack stores raw material that will be used during the fabrication process. It must be within a close proximity to the cutting station.

2. Cutting Station

Typical cutting station equipment includes: plasma cutter, flame cutter and a bandsaw.

The conveyor loads pipe from the feed rack. Cut lengths are moved to fitup stations or positioners using an

overhead crane, cart or conveyance system.

3. Fitup Station

Cut lengths of pipe and pipe fittings are brought to the layout station to be fitup and tack-welded according to the fabrication drawing.

The following list of equipment and tools is very typical of the tools needed at the layout station on any jobsite to complete a weld:

Arc / MIG welder	Gloves
Grinder	Nylon chokes
Levels	Jib crane
Squares	Acetylene gas
Two hole line-up pins	Argon gas
Work table	75/25 argon/CO2 gas
Bench vise	Compressed air
Files	Welding screens
Hammer	Floor fan
Face shield	Ladder
Welding hood	Smoke eater

4. Welding Station.

The Welding Station is used to receive/weldout fitup/ tacked spools from the fitup station. The welding station typically has a GMAW (MIG) welder.

Submerged arc welding can be used to fill up pipe welds greater than 8 inches. Automated welding systems are sometimes used for larger bore pipe welding (8-inch and above), since they provide a quick quality weld at a reasonable cost. However, consideration must be given to this process since the cost of this equipment is significant.

Positioners are outfitted with a chuck that will hold pipe from 2 1/2-inches to 48-inches, supplemented with a smaller 2-inch to 14-inch chuck that can be inserted quickly into the larger jaws for quicker size changes allowing the welders to expedite their welds.

Jobs requiring thin wall, high purity and sanitary welding can benefit from orbital welding, but the equipment is expensive and not very versatile. Therefore, a contractor must consider practicality before investing in this equipment

The following is a typical list of equipment and tools needed to complete a weld:

Grinder	Jib cane
Files	Acetylene gas
Hammer	Argon gas
Face shield	75/25 argon/ CO_2 gas
Welding hood	Arc / MIG Welder
Gloves	Compressed air
Nylon chokes	Welding screens
Floor fan	Smoke eater

5. Module Fabrication Station

Module or skid fabrication is another important market for the fabrication shop. The module not only requires pipe and fitting fabrication, but may also include valves, heat exchangers, pumps, meters, steam traps, structural steel, insulation, heat tracing, coating and other devices or trade work normally installed in the field.

Outside contractors may work on the module. A larger laydown area would be required to complete this work.

6. Hydraulic Punch Station

A hydraulic punch is used for making holes in steel plate.
The hydraulic punch is more efficient than a drill press when the work is repetitive.

7. Tee Pull Station

A tee puller is used to pull a nozzle from the side of a section of pipe. The nozzle is connected to a branch pipe and is used in place of a tee fitting.

8. Plumbing Assembly

There is generally substantial repetitiveness associated with standard plumbing projects (i.e water risers, head walls, fixture assemblies etc.).
Any assembly which can be built and then repeated is very efficient in a fabrication shop environment.
The work station should be configured to allow easy assembly of smaller piping with jigs and stands to streamline the production.

9. Grooving Station

Grooved pipe with mechanical joints is very common in the building heating and cooling market. It is very common for pipe fabrication to be a combination of welded brazed and mechanical joints.

10. Cast Iron Station

This area is used for cutting cast iron pipe (cold saw or snap cutters). It may also be used as an assembly area for bathroom batteries and cast iron assemblies.

11. Storage

A neat fabrication shop will promote neat work. To promote neatness, ample storage is needed for the following items:

Pipe and fittings	Paint
Cutting templates	Extension cords
Small tools	Chokes and chains
Welding wire spools	Ladders
Welding rod	Welding cables
Cutting oil	Consumables

12. Final Check Station

The final check station does not require a fixed location like a layout or welding stations. This area is where the fabrication drawing is checked against the finished fabrication to make sure it is complete and accurate.

No pipe fabrication product should leave the shop until it has been checked.

GAS SERVICES

Several types of gas are used in the cutting and welding process. All of these gases are supplied from high pressure tanks or lower pressure liquid refrigerated tanks. The size and type of tank will depend on the quantity of each gas used by the fabrication shop.

Gas can be supplied to the work stations by two methods. Individual high pressure tanks can be located at each work station or central tanks can feed into a piped distribution system. Individual tanks are appropriate for a small fab shop with only two or three work stations. Larger fabrication shops should invest in central tanks, since too much time will be spent moving individual tanks in and out of the work stations.

The gases typically used in the fabrication shop are:

1. **Oxygen**

   The most economical way to purchase oxygen is in a liquid refrigerated tank. This tank is at a lower pressure than the smaller capacity high pressure tanks. The liquid oxygen tank is hooked up to a pressure regulator set to supply approximately 60 psi pressure to the shop. A high pressure oxygen tank is hooked up to a different regulator that is set to supply 50 psi. When the liquid oxygen tank runs out, the high pressure tank automatically maintains a continuous flow of oxygen until the liquid oxygen tank is changed.

2. **Argon**

   The most economical way to purchase argon is also in a liquid refrigerated tank. The liquid argon tank is hooked up to a pressure regulator set to supply approximately 110 psi pressure to the shop. The high pressure argon tank is hooked up to a different regulator that is set to supply 100 psi pressure. When the liquid argon tank is empty, the high pressure tank automatically maintains a continuous flow of argon until the liquid tank is changed.

3. **Carbon Dioxide**

   Carbon dioxide is supplied from high pressure tanks, typically from a three-tank manifold. The manifold is hooked to a pressure regulator that is set to supply 140 psi gas to the shop. Carbon dioxide is used in a mixture with argon as a shield gas. A gas mixer is used to supply the gas in the required proportions. The mixture is usually 75 percent argon and 25 percent carbon dioxide.

4. **Mixed Gas**

   Another shield gas used in the welding process is a mixture of 90 percent helium, 7.5 percent argon and 2.5 percent carbon dioxide. This gas is furnished in high pressure tanks. Additionally, an argon/CO2 mix is needed for MIG pulse spray transfer, which is a process currently being utilized.

5. **Propylene Base Gas**

   The gas used for cutting is liquefied petroleum gas. A three-tank manifold is typical. The manifold is connected to a pressure regulator that supplies 120 psi to the fabrication shop. A flash-back arrester is used before the supply enters the shop.

6. **Compressed Air**

   Compressed air is needed for tools and machinery throughout the fabrication shop. The size of the air compressor needed will depend on the quantity and type of tools that use compressed air.

NOTE: ***Be sure to comply with all local safety and OSHA codes for tank storage and separation.***

PLANNING THE PREFABRICATION

One great advantage of prefabrication is that it allows the contractor to step back and consider the whole job and then decide how to proceed in a way that will allow as much cost control and leave as little to chance as possible. In effect, it encourages the contractor to plan and schedule the job in great detail. No matter how big or small the job, the contractor must approach it with one question in mind: what steps need to be taken so that material can be sent to the jobsite to minimize field installation costs?

Planning is typically the job of the foreman, project manager, and drafting department with adequate communication with the estimator who bid the job. At the very least, the estimator must advise how the job was conceptualized, what assumptions were made, what alternates are included, exactly what is in the contract, whose equipment and auxiliary accessories must be used, etc.

Several technologies can be used in preparing the work product. After planning and deciding what will be prefabricated, the job needs to be drawn. Below is a list of technologies to consider:

1. Laser Scanning/BIM/CAD-CAM

Deciding on what technology to use in a shop is a major decision that requires research and investment. Most fabrication shops use a combination of software to help get accurate product onto the shop floor.

a. **Laser scanning** is a good solution and has become an effective and accurate means of getting the model in the contractor's possession. Once scanned and implemented into the drawing software, the scanned model can be used in a variety of ways and will allow the following to happen:

- Begin drawing accurately to field conditions (it replaces field measuring);
- Periodic scanning to check that all trades are accurately installing according to signed-off coordination drawings;
- Field operations progress ensuring that the schedule is maintained; and
- Determine the value of work that has been installed for billing purposes.

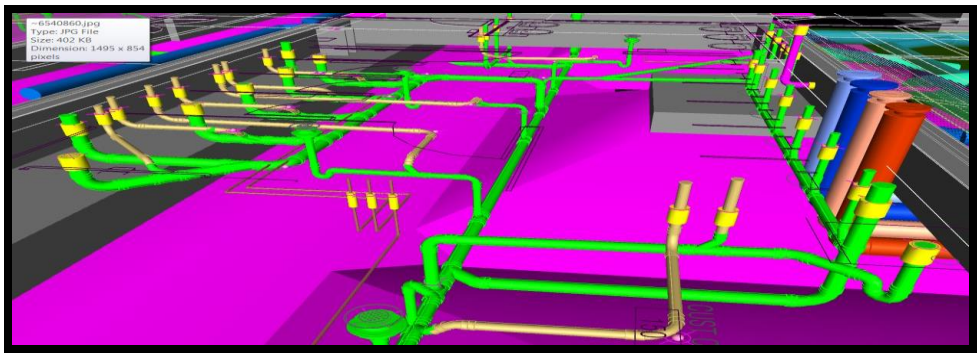
b. **BIM or Building Information Modeling** is another technology that when used in conjunction with CAD software allows for accurate fabrication drawings. The following should be considered when using BIM:

- Accuracy of the model (often the model provided by the Owner/Architect is not accurate;
- Accuracy of the various trades inputting into the model;
- Cost of having the model created; and
- The ability and benefit to viewing the pipe in a three dimensional format.

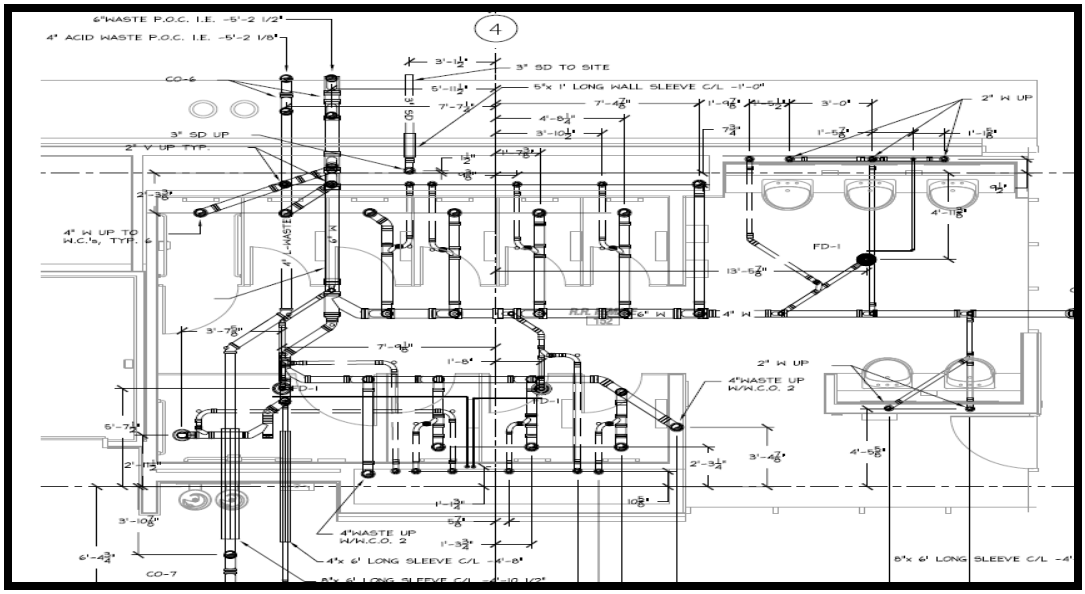
c. **CAD software** or design software is essential in producing detailed spool drawings for shop fabrication. We have included some examples in spool drawings for your reference.

Below is a step-by-step example of the shop fabrication process for an area of a Plumbing U/G Acid Waste System, and how the BIM Model and CAD Drawing are incorporated into the overall process leading to the site installation.

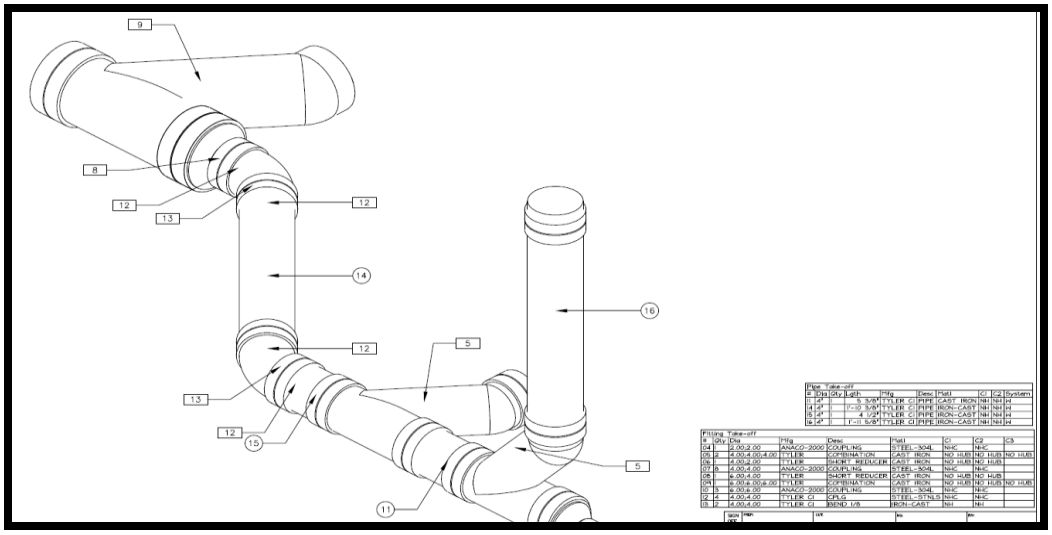
Step1 - Through the use of NavisWorks BIM Modeling software, model and coordinate all MEP scope until it is clash free. It is critical that all MEP trades take part of the coordination project and it not be limited to the mechanical/plumbing trades.



Step 2. - Once the BIM Model is signed off, generate shop drawings and submit to the Mechanical Engineer of Record or the owner/client for approval.



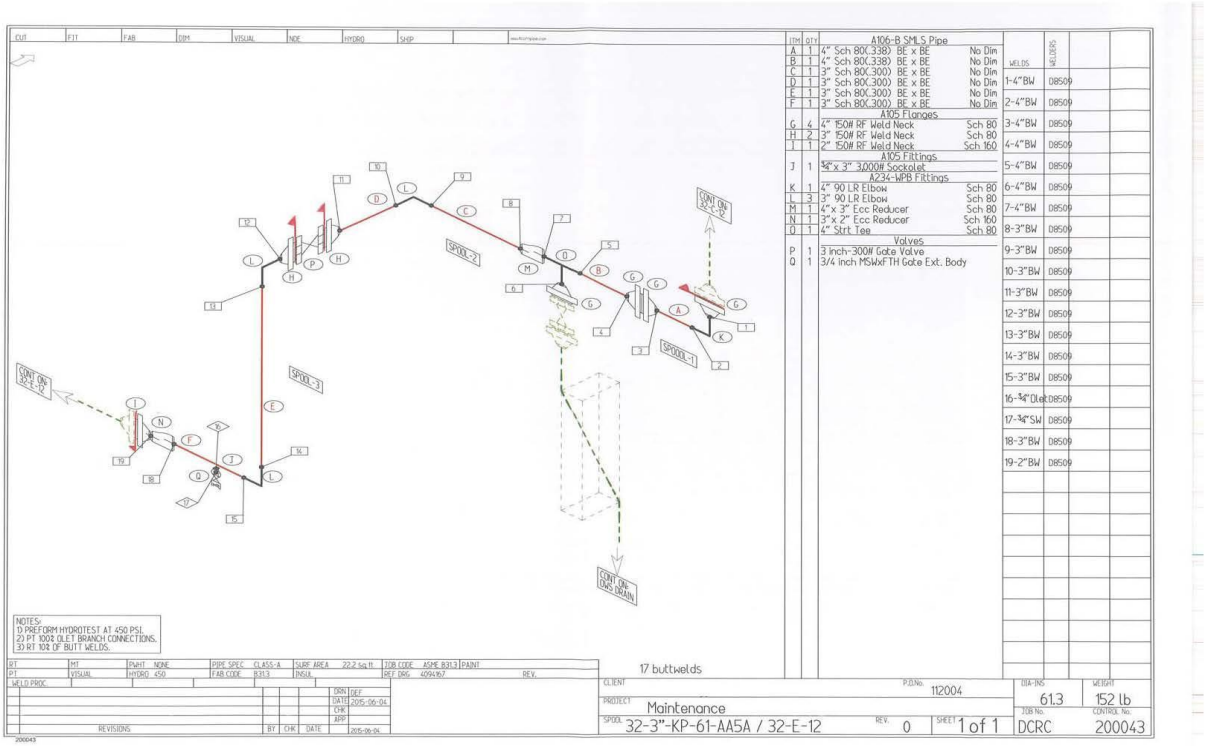
Step 3. - Once the shop drawings are approved, generate individual spool drawings and release them to the fabrication shop for production.



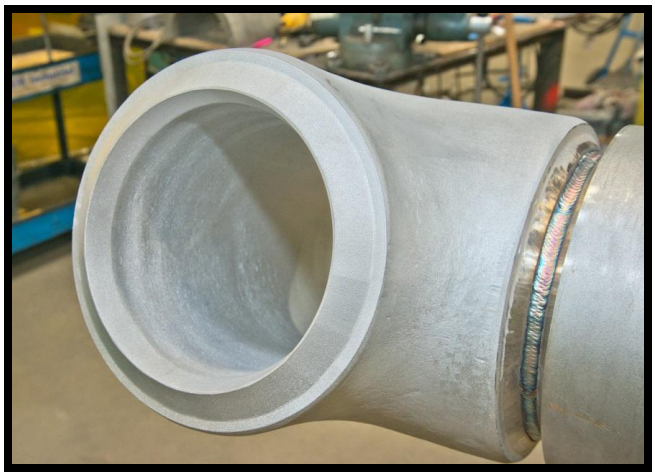
Step 4 - Once the spools are fabricated in the shop, bundle them together, label them by area and ship them to the jobsite.

Step 5 - Receive the spools at the jobsite and install them with minimal site field labor.

The shop fabrication drawing below is an example of a typical industrial shop fabrication drawing.



Below are some examples of industrial shop fabrication:



POTENTIAL QUALITY CONTROL DOCUMENTATION REQUIREMENTS

The following requirements should be incorporated into the planning of an industrial project:

- Positive Material Identification (PMI)
- Mill Test Reports (MTR's)
- Hydro-test Reports
- Pre/Post Weld Heat Treating
- Non-Destructive Testing (PT, UT, X-ray, etc.)
- Weld Maps

POTENTIAL SET-BACKS OF PRE-FABRICATION

Although there are many advantages to pre-fabrication, there are also some potential setbacks to consider prior to starting a project. In all, none of the following factors should discourage a company from pre-fabrication, but they need to be considered when deciding to open a fabrication shop, estimating a project that will utilize your fabrication shop, and/or starting a project within your fabrication shop.

1. **Buy-in or lack thereof from field personal**
   Field personal can feel threatened that their work (or field hours) is being taken from them by the use of a fabrication shop. Push-back could include:

   - "We can do it just as fast in the field."
   - "We will not have mistakes or re-work due to transferring information from the field to the shop."
   - "We will not have the double or triple handling of the material if you send it direct to the site."

2. **Material handling/freight**
   Pipe that is field fabricated and then installed is handled the minimum amount of times. In a pipe fabrication shop the material is off-loaded, put into the flow of the shop (cut/prep/weld), often times relocated within the shop for hydro-testing, loaded onto trucks for delivery to the site, and then received at the site to be moved into location to be installed.

   This additional handling needs to be considered when estimating a project with the use of a fabrication shop. Other considerations of added handling include:

   - Fabricated pipe should be sent to a paint shop to be blasted, primed and painted prior to being shipped to the site; and
   - Break-in or emergency work within the shop from another job.

3. **Storage/Space Requirements**
   To operate a fabrication shop, ample space is needed to stage areas for cutting/prepping, weld turntables and sub-arc machines and to hydro-test piping spools. Storage space is also required both inside and outside of the fabrication shop for pipe, fittings, valves and loose steel (flat stock, angle, I-beams, channel, etc…). Other factors that need to be considered for storage within a fabrication shop include:

   - Separation of material for different jobs:
   - Domestic material requirements
   - Material Specification (i.e. low-temp carbon steel, 304SS, 316SS, 321SS, Chrome-moly's, etc.)
   - QC Requirements (MTR's, Positive Material Identification (PMI's), or thickness measurements)
   - Carbon Steel and Stainless Steel materials and tools need to be separated to avoid cross

contamination

- The footprint required if you are pre-fabricating skids, modules or tanks
- Completing pre-fabrication prior to being needed on site could require off-site storage that would add rental costs to a project

4. Straight vs. Premium Time

It is important for the estimator and project manager to communicate with the fab shop supervisor concerning the required delivery date of the fabrication to field. Project schedule requirements could create situations where some jobs are on straight time while others are on overtime. When this occurs, communication to the craft workers is crucial to keep moral up and avoid conflicts and animosity.

5. Cash-Flow

If managed properly and incorporated in the contract documents, pre-fabrication can be invoiced as stored material on a project and therefore helping the cash-flow. Alternatively, many contracts don't allow for billing of pre-fabrication until it is physically installed in the field. The project manager along with the accounting department needs to be aware of this for large jobs so they can manage the overall company's cash-flow.

6. Work Flow

Work flow in a fabrication shop has to be established and followed for all types of work pushed through the shop. It is recommended to review the Lean Manufacturing Process to avoid becoming counterproductive when multiple jobs are being worked on at the same time.

CONCLUSION

A decision to set up a piping fabrication shop is a major one, requiring much thought and commitment. Before making the investment, a contractor should thoroughly explore local union agreements that may limit the type of fabricated product. It's also prudent to include trades people in the planning of the fabrication process, as they will undoubtedly have very constructive input.

The values, perceptions, and attitudes of management personnel will also have a strong influence upon what kind and size of fabrication shop is possible. Management decisions can establish limits on a shop faster than any other factor. If management attitudes are positive—that is, if managers believe that anything that can be measured can be dimensioned, and that anything that can be dimensioned can be fabricated—then a contracting firm interested in fabrication is off to a good start and will likely make good use of the shop.

Once labor and management are onboard and making collective decisions, there should be no limit to the capability of the shop and its potential to increase the bottom line. Fabrication must be considered at the estimating and job planning stage. The ability to prefabricate as well as pre plan the job will add to a contractor's overall profitability.

However, once the shop has been established, it is equally important to stay familiar with ever evolving construction technologies and re-invest when the time is right. The most efficient process today could be obsolete in the next few years due to the emergence of newer tools and equipment. New processes should be thoroughly evaluated before being

introduced to the fab shop not just delegated to the fabrication manager for implementation. The fabrication facility should be treated like a project with no end date but with endless possibility for increasing profit.

Resources provided by WGS, Inc.

