FIBERGLASS REINFORCED PLASTIC (FRP) PIPING SYSTEMS
A DESCRIPTION OF ENGINEERING SERVICES

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Enclosed on the following pages is one in a series of papers written by the Engineering Department of Specialty Plastics, Inc. on fiberglass reinforced plastic (FRP) piping systems. This paper, which describes the different types of engineering services applicable to FRP piping systems, is one in a line of papers written on the basic principles involved in the selection, specification, and design of the components involved in fiberglass piping systems.

Specialty Plastics, Inc., as a designer, manufacturer, and installer of fiberglass piping systems with two decades experience in the advanced composites industry, provides this paper as a service to its customers involved in the design and selection of fiberglass reinforced plastic piping systems.

The intention of this report is to provide a complete and thorough description of the various engineering services that can be employed on projects involving fiberglass piping. The information is presented as independent data, thus allowing the user to make his own independent conclusions and to determine which engineering services are required.

The guidelines drawn in the report are based on the history and experience of Specialty Plastics in the fiberglass composite pipe industry. These guidelines, however, are intended to be just that - guidelines. Each application of an FRP piping system is unique and must be treated as such. Furthermore, because of certain intangibles involved with FRP piping systems, a "pre-engineered" system is not recommended. A detailed design of each piping system is necessary to achieve the full potential of the FRP piping system. By doing so, the customer is ensured of a "custom-designed," "custom-manufactured," and "custom-installed" system to his specifications and needs.

Introduction:

When investigating the use of fiberglass reinforced plastic (FRP) pipe in the chemical, petrochemical, marine, and other industries, several decisions have to be made early on in the design of the piping system. These include the pipe fabrication technique, the method of installation (flanged pipe vs plain end pipe, and field-fabricated vs shop-fabricated spools), and the joining system (adhesive-bonded vs butt and strap, for example), to name a few.

The engineering that must be performed in the design stage of the project is critical to all future phases of the project. Engineering services include design calculations, piping stress analyses, piping surge analysis, piping support drawings, piping orthographic drawings, piping isometrics, and shop fabrication spool drawings. Each type of service offers different information to different parties. Engineering information is of value to designers, draftsmen, project engineers, purchasing agents, mechanical contractors, manufacturers, and subcontractors. Each party requires different types of engineering services depending upon their role in the project. This report will give a description of each type of the various engineering services available and where these services are typically employed.

The purpose of this report is to provide the interested reader with independent information on the engineering services typically employed on projects with FRP. This is but one of the many aspects of FRP piping systems that must be investigated before a successful design can be completed. Fabrication materials, pipe flexibility, and pipe strength, are but a few of the additional aspects that should be considered. By reading and understanding the information in this report, one step of many is taken toward the successful design of a fiberglass piping system.

A Description of Engineering Services

Design Calculations

Design calculations are the design of either piping components only or of very simple piping systems. C alculations may include hoop stress due to internal pressure, axial stress due to thermal expansion, allowable external collapse pressure, recommended support spacing, etc.

These general calculations will often inform the designer as to whether or not fiberglass will be suitable for a particular application. Design calculations are also excellent for simple systems, such as column pipe applications, where basic engineering theories can be used to calculate stresses and deflections in the system. Also, in piping systems where pressures and temperatures are low, simple design calculations may be all that need be employed.

Design calculations will provide the designer and engineers with the following pieces of information:

- The design conditions and any relevant codes and standards
- A complete listing of piping component stresses, deflections, etc.
- Safety factors or allowables for stresses, deflections, etc.

Piping Stress or "Flexibility" Analysis

A piping stress analysis is a detailed "flexibility" analysis performed on an entire piping system. A piping stress analysis is performed to determine the deflections, rotations, forces, and moments acting on a piping system. The piping stress analysis also calculates stresses, such as hoop, axial, bending, and torsional stresses, due to the design conditions.

The piping stress analysis is a much more detailed engineering service that can be performed on fiberglass piping systems. Due to the many unique features of FRP, this type of service is not uncommon. When FRP piping is exposed to relatively high pressures and temperatures, or when special external loads are present, such as wind loads, ship motions, or seismic conditions, a piping system stress analysis is often undertaken to ensure adequate design.

The piping stress analysis will provide information to the designers and project engineers. It will also provide valuable information to the installation contractors for locating supports, guides, and anchors. This information includes the following:

An isometric of the piping system identifying all parts of the system
A complete listing of deflections and stress on the piping system
A restraint summary of all of the supports in the piping system

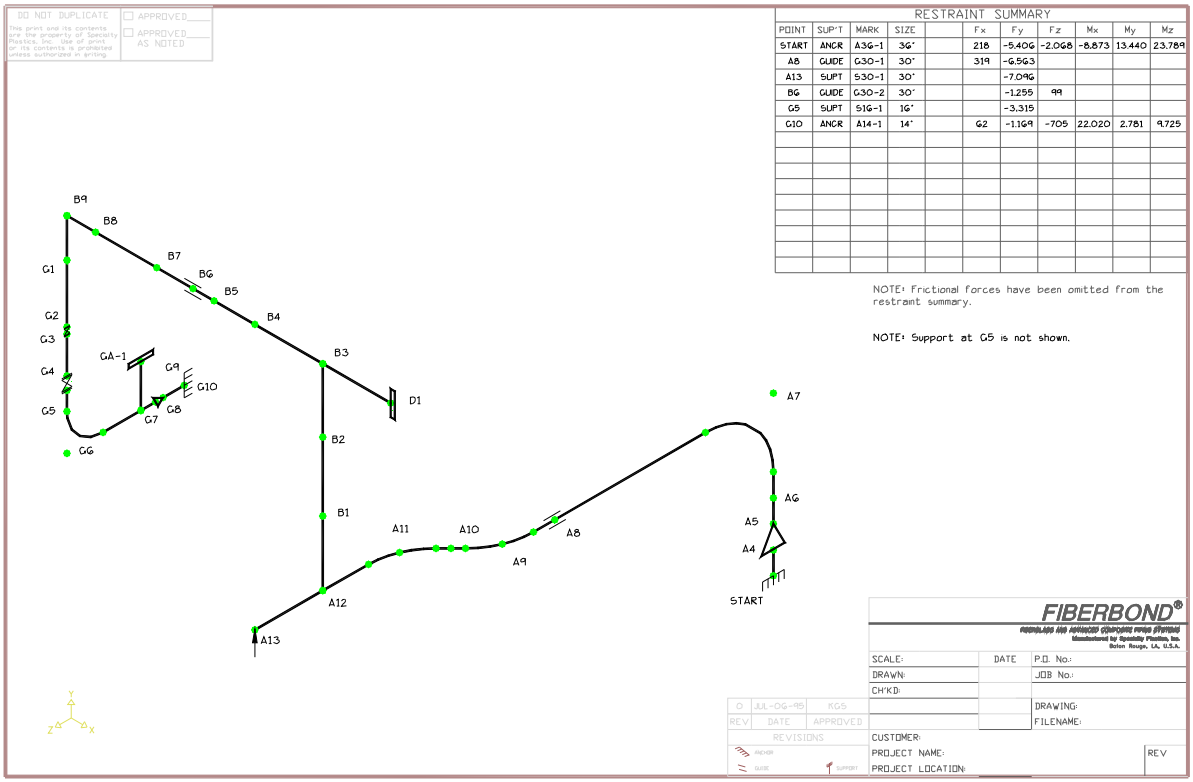

Figure 1. Example of a stress isometric from a flexibility analysis.

Piping Support Drawings

A piping support drawing is a two-dimensional drawing providing detailed dimensions for each type of pipe support. The piping support drawing also provides design information, such as allowable vertical load, allowable anchor load, etc.

Piping support drawings are often utilized on fiberglass piping systems since most FRP piping is custom manufactured with O.D.s different from standard carbon steel. The piping support drawings are normally produced for each project with the exact dimensions necessary for fabrication.

Piping support drawings are used by the designer to ensure that the pipe supports can withstand the design loads. Piping support drawings are also used by the manufacturer for fabrication. A piping support drawing includes the following:

A 2-D view of the pipe support to provide enough detail for manufacturing. Sections are provided where necessary
Bill of materials for fabrication

Piping Orthographic Drawings

Piping orthographic drawings are two-dimensional drawings, such as plans, elevations, and sections. These drawings provide detailed information for the entire piping system, including T.O.S. elevations, B.O.P. elevations, structural steel locations, tank and vessel locations, routing dimensions, valve takeout, gasket locations, flange orientations, etc.

Piping orthographic drawings are essential engineering documents used throughout all phases of a piping project. Designers, project engineers, draftsmen, contractors, and manufacturers all use orthographic drawings.

Piping orthographic drawings are often used by project engineers and by installation contractors during the installation phase of the project. When isometric drawings are not available, orthographic drawings are used by draftsmen to produce shop fabrication spool drawings.

Piping Surge Analysis

A piping surge analysis is a complex, transient analysis of a piping system. It is used to evaluate the integrity of the piping system when subject to transient hydraulic surges. Due to the complexity of the analysis, the model of the piping system often needs to be simplified so that it can be evaluated properly with suitable software. Various scenarios can be evaluated, with the model possibly changing depending on what is required to be evaluated in each scenario.

A piping surge analysis is used by the designer to ensure that the piping system can withstand the transient hydraulic loads that are imposed on the system. Specifically, a surge analysis will be evaluating:

Pressure surges due to pump startup, shutdown and other scenarios
Formation of air cavities and vacuum conditions
Sizing of any air release valves
Suitability of opening and closing times of valves

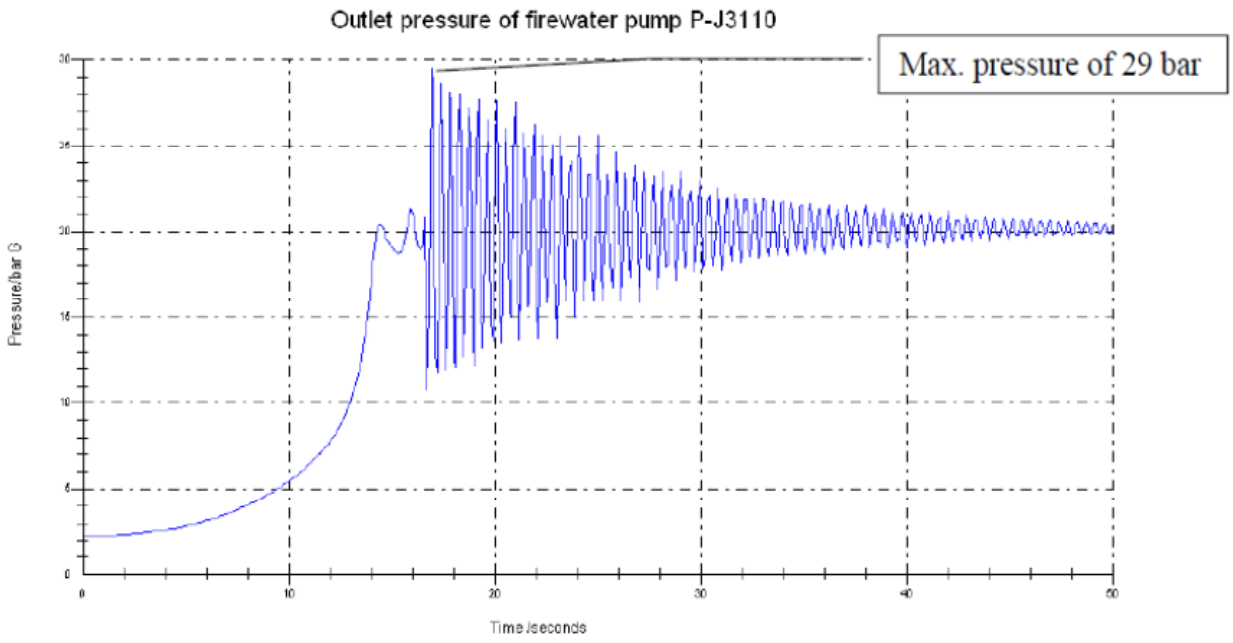

Figure 2. An example of a graph of pressure surge versus time from a transient surge analysis.

Piping Isometrics

Piping isometrics are isometric drawings which provide detailed dimensions for each individual piping run. Piping isometrics include centerline elevations, routing dimensions, valve takeouts, gasket locations, flange orientations, etc. Piping isometrics differ from orthographic drawings in that the isometrics provide detailed information for each individual piping run whereas orthographic drawings provide detailed information for the entire project site.

Piping isometrics are generally produced from orthographic drawings and are important pieces of information to engineers. In very complex or large piping systems, piping isometrics are essential to the design and manufacturing phases of a project.

Piping isometrics are often used by designers prior to a stress analysis and are also used by draftsmen to produce shop fabrication spool drawings. Isometric drawings are also helpful to installation contractors during the field portion of the project. Some of the information on piping isometrics includes:

An isometric view of each individual piping system
Reference points to orthographic views from which the isometrics were generated
The location of all field welds and pipe supports

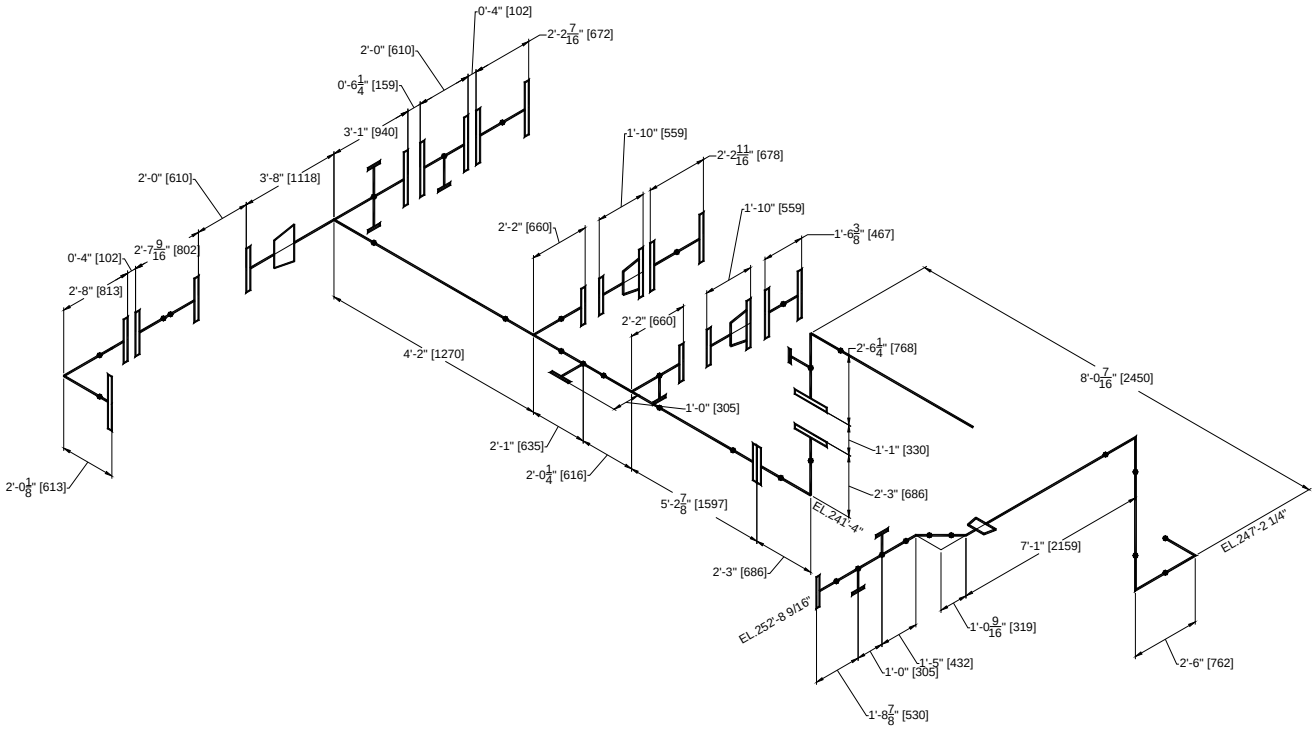

Figure 3. An example of part of an isometric.

Shop Fabrication Drawings

Shop fabrication spool drawings (also referred to as spool drawings or spool assembly drawings) are assembly drawings providing detailed manufacturing and fabrication information for each unique "spool" piece. Spool drawings include dimensions and angles, a bill of materials, and manufacturing information.

On prefabricated piping projects, shop fabrication drawings are essential pieces of information. Shop fabrication drawings are normally produced from piping isometrics or, when these are not available, orthographic drawings.

Spool fabrication drawings are used extensively by the fabricator doing the shop assembly work. Shop fabrication drawings provide the following pieces of information:

A 2-D or isometric view of the spool piece to provide enough detail for fabrication
A bill of materials for fabrication
Field reference information, such as a line tag number and/or isometric line number

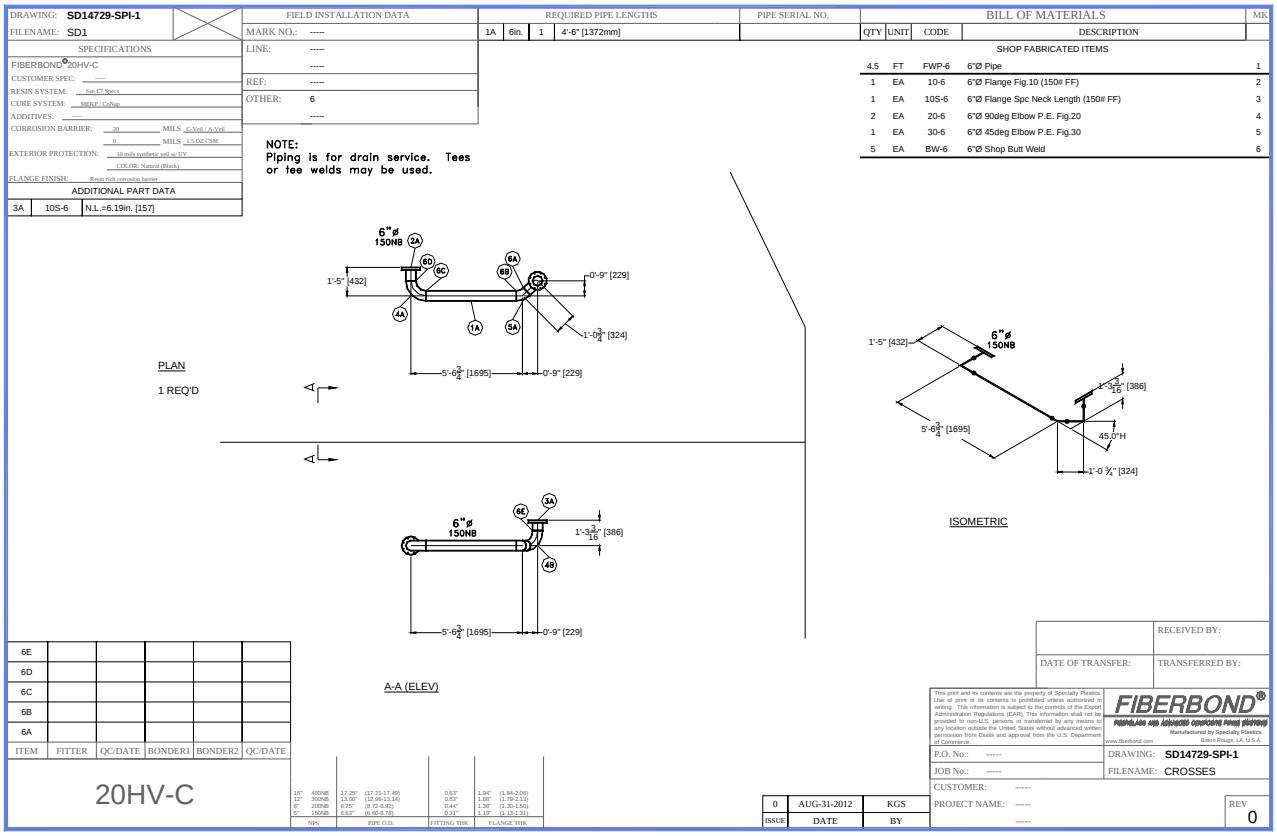

Figure 4. An example of an assembly "spool" drawing.

Applications for Each Engineering Service

It is not the intent of this report to draw conclusions from the information presented above. Rather, the decision on which engineering service is to be employed is left up to the user. There are, however, certain parts of the design process and certain applications that merit the use of one or more of the above described engineering services. This has been summarized in the tables below.

Summary of Engineering Services

	Design Calculations	Stress Analysis	Surge Analysis
Who Performs This Function?	Normally performed by the engineering firm responsible for the design of the piping system. Manufacturers with independent engineering departments, such as Specialty Plastics, are also capable of performing this service.	Normally performed by the engineering firm responsible for the design of the piping system. Manufacturers with independent engineering departments, such as Specialty Plastics, are also capable of performing this service.	Normally performed by the engineering firm responsible for the design of the piping system. Manufacturers with independent engineering departments, such as Specialty Plastics, are also capable of performing this service.
When Is This Service Performed?	Usually performed during the preliminary design phase and during feasibility studies.	Always performed during the detailed design phase.	Usually performed during the detailed design phase.
Why Is This Service Performed?	To determine the feasibility of whether or not an intended product can meet the minimum requirements of the design.	For detailed design work on critical or essential services where unique loading conditions justify this type of service.	For detailed design work on critical or essential services subjected to hydraulic surge conditions, such as the firewater ringmain.
Unique Characteristics	Valuable tool during preliminary design to determine whether or not the intended product is adequate for the design service.	An excellent engineering tool which is becoming more and more common because of its reliability and its lower cost.	

Summary of Engineering Services (continued)

	Orthographic Drawings	Isometrics	Assembly "Spool" Drawings
Who Performs This Function?	Normally performed by the engineering firm responsible for the layout of the piping system.	Normally performed by the engineering firm responsible for the layout of the piping system.	Manufacturers providing the shop fabrication services normally perform this function.
When Is This Service Performed?	Always released during the detailed design phase of the project. These drawings may also be released during the bid stages of a project for purchasing purposes.	On small piping systems, this service is not always performed. On large and complex piping systems, isometrics are normally required and generated using 3D modeling software.	Normally completed once the ortho or isometric drawings are released to the manufacturer for fabrication.
Why Is This Service Performed?	This service provides scaled plan and elevation views of the piping system, support and equipment.	These drawings provide detailed information in a much more compact format for use in the manufacture and fabrication of specific piping systems.	Almost always used on shop fabrication projects.
Unique Characteristics	One of the most valuable tools during the installation phase of the project. Usually drawn to scale.	Isometrics drawings provide very specific information in a clean and easy to read format. Usually not drawn to scale.	A strongly recommended tool for projects utilizing FRP. Shop fabrication greatly reduces the time dedicated to field installation and often proves more economical.

Selection Process Guidelines:

To summarize the information presented in this report, a set of questions have been summarized below. These criteria make up many, but not all of the considerations that need to be taken into account during the selection process. By answering each of the questions, the user can have a better idea of which engineering service to employ.

Is the piping system part of an essential or critical service?
It is becoming more and more common to require a piping stress or "flexibility" analysis of fiberglass piping systems. This is even more so when the system is deemed critical or essential or in relatively severe services. Piping systems that operate above 200 psig and above 150°F are commonly subject to a flexibility analysis.

Is fiberglass simply being considered as an alternative material to existing standards?
Detailed calculations are often very easy to perform and provide very valuable pieces of information during a feasibility study. These calculations can often give some information to the designer as to whether or not FRP is suitable for the design conditions.

Is field installation of the project going to be time critical?
Where field installation needs to be minimized or where conditions are adverse, shop fabrication spool drawings should be produced and the piping system should be shop fabricated to the greatest extent possible. This will greatly minimize field installation time.

Is shop fabrication or field installation going to be considered during the purchasing phase of the project?
Piping isometrics or orthographic drawings should be used by the Purchasing Department of the end user to obtain not only bids for the supply of pipe and fittings, but also bids for the performance of shop fabrication and field installation. It is often an economic advantage to the end user to purchase FRP with these considerations in mind.

One aspect of the selection process that should be seen as an advantage is the wide variety of custom products that can be offered in the fiberglass pipe industry. This is an advantage in the sense that it allows the designer to specify a product that best fits its purpose. Among the variables open to the designer is pipe construction (including resin, reinforcement type, helix angle (for filament winding), liner reinforcement, liner thickness, and exterior corrosion barrier.), pipe manufacturing method, joining method, and installation method.

These variables, however, are often seen as a disadvantage to the selection process due to the non- standardization of the products. This is true only to those unfamiliar with the fiberglass industry. As one becomes more and more familiar with the composites industry and sees the advantages of fiberglass, it becomes apparent that flexibility in design is one of its greatest advantages.