

## Coordinating the Design and Construction of FRP / GRP Chimney Liners



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### 1. Introduction

Over the past 6 years electric utilities in the United States have under taken a program of retrofitting Wet Flue Gas Desulphurization (WFGD) Systems at coal-fired power plants throughout the country. These projects have been initiated due to a variety of environmental regulations, settlement agreements and permitting conditions. These retrofit projects, along with the construction of several new coal-fired power plants, have resulted in the construction of over 70 new concrete chimneys with over 100 flues or liners. Because of the excellent corrosion resistance and relative cost advantage of Fiberglass Reinforced Plastic (FRP) Chimney Liners (also known as Glass Reinforced Plastic (GRP) Chimney Liners) the overwhelming majority (approximately 90%) of the chimney liners were constructed of FRP. (Figure 1)

The normal project delivery method for concrete chimneys in the United States is design-build, where the chimney contractor is responsible under a single contract for the complete design, supply and erection of the chimney. Usually, the only subcontracted work is electrical, elevator and coatings. Major material supplies are generally purchased to designs and specifications prepared by the chimney contractor. For most types of chimney liners, such as brick, steel and metal alloys, the chimney contractor preforms the design of the liner, procures the materials or fabricated components for the liner, and installs or erects the liner at the construction site. For FRP chimney liners, due to the specialized nature of the design and manufacturing methods, and the size of the components involved, it is normal practice to have a specialist FRP supplier design and supply the liners, with the filament winding performed on site. (Figure 2) Because of the interconnection of the FRP liner with the design and construction of the overall chimney, many challenges are presented to the chimney contractor and FRP fabricator while working together on a project. This paper discusses several of the major areas where coordinating the activities of the chimney contractor and FRP liner fabricator are critical to realize a well-executed project.



*Figure 1: Chimney with FRP Liners on WFGD System*

The discussion is presented in relation to the various phases of a project, namely:

- The Bid (Pre-contract) Phase
- The Design Phase
- The Fabrication Phase
- The Construction or Erection Phase

### 2. The bid (pre-contract) phase

In the design-build project delivery method, the bid stage presents a challenge to the chimney contractor, as for all design-build contractors, to perform enough of the design so that an accurate estimate can be developed without necessarily developing a final design with all required details needed for construction. For brick, steel and alloy liners, this design work is totally in the hands of the chimney contractor's design team and is typically handled by performing preliminary designs based on past projects. For FRP liners where the design will be included in the subcontract to the FRP supplier, the designers from the two companies must independently produce designs while ensuring the integration of the two into the one complete chimney. This integration is complicated by the fact that no



**Figure 2: On-site Fabrication of FRP Liners**

contractual relationship would typically exist between the companies for the project being considered and there are typically multiple FRP suppliers vying for the work. The chimney contractor must ensure that the FRP suppliers have the information required for performing and coordinating the design of the FRP liner. The major design coordination issues that must be addressed are shown in Table 1.

Subject	Recommendation
Specifications and Codes	Provide all Specifications and Codes that will be required for the design.
Arrangement	Provide a General Arrangement of the Liner showing the location of major features such as Breechings, Access Openings, Drains, etc.
Supports / Expansion Joints	Identify proposed locations for all supports and expansion joints.
Shell – Liner Interaction	Provide Shell deflections at points of contact with Liner or define process for analysis of interaction.
Support Loads	Agree on support loads from Liner and if they include overweight allowance per ASTM D 5364.
Erection Loads	Define how Liner will be erected and include design considerations.

**Table 1: Major Design Coordination Issues**

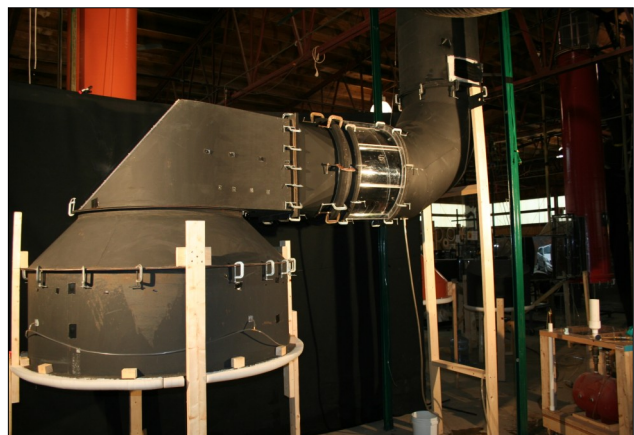
In addition to design issues, the detailed scope of work for each party must be established during the Bid Stage. This would include the scope for all accessories to be included with the FRP Liner, such as access doors, test ports, liquid collection system and drains, including where and when they will be installed, who will supply and who will install, and if final information is not available what is the basis for the bid and how will adjustments be made. For instance, typically the Liquid Collection System design will not be finalized until after award and a Wet Flow Model Study is performed. The chimney contractor should provide an initial configuration for the liquid collectors that would form the basis of the subcontract and define the basis for adjustment, such as unit price or lump sum, when the final arrangement is available. Also, the scope of work for the site facilities and activities must be agreed upon, including the area required for

manufacturing and storing the liner cans, transporting the cans from the manufacturing area to the base of the chimney, supply of material and labor for the field joints, and any support or assistance provided by the FRP supplier during erection. The FRP supplier should pay close attention to any Special Conditions and to the Specifications and assume that they will have to be followed explicitly, or take specific exceptions.

Finally, it must be emphasized that these issues in the Bid or Pre-contract Phase should be thoroughly addressed. Since the chimney contractor likely does not yet have a contract and the FRP supplier is probably quoting to multiple chimney contractors, there may be a tendency for the FRP supplier to treat their proposal as a “bid to a bid” which can be followed up with a formal proposal later. Likewise, the chimney contractor, in their haste to put together an estimate by the bid due date may treat their request for proposal as just “getting a price” and work out the details later. Either of these behaviors could be disastrous as much could change when the details of the design and scope of work are finalized. Considering that the FRP Liner subcontract could be 30 to 50% of the cost of the chimney contract, a lack of accuracy in this phase could result in losing the bid or losing money on the contract.

### 3. The design phase

At the beginning of the Design Phase the chimney contractor should finalize the chimney layout and location of the major features that affect the FRP liner design such as the breeching size and location, support and expansion joint locations and access provisions. Agreement on all of the design coordination issues should also be documented. This should all be incorporated into the final subcontract. The FRP supplier is then responsible for developing a Design Report and the design drawings for the FRP liner following the requirements of the specifications and ASTM D 5364. These design documents should be checked by the FRP supplier for accuracy prior to submittal and the chimney contractor should review them to ensure that all required interface information is included.



**Figure 3: Wet Flow Model Study – Model Setup**

The Wet Flow Model Study (Figure 3) to finalize the design of the Liquid Collectors and drains will be performed during the Design Phase by a consultant engaged by either the chimney contractor or the owner's engineer. When the results are available they should be compared carefully with the design used for the proposal and any differences documented and handled according to the basis established in the contract. Generally, contracts have time limits for submitting change orders requests and these should be followed diligently to avoid losing the opportunity to be compensated for the changes. The details of the liquid collection components should then be incorporated into the detailed fabrication drawings along with all other appurtenances such as test ports, access doors, drains and attachments for supporting items to be furnished by others.

Also, during the Design Phase the procedures to be used for the fabrication and erection, including safety plans, work plans, quality procedures and an inspection & test plan should be developed. The submittal and approval of these plans is important to ensure a smooth operation once work begins at the jobsite. If the responsibility for obtaining the air quality permit for operation of the on-site manufacturing facility (styrene emissions) is with the FRP supplier, the application for the permit should be submitted well in advance so that sufficient time is allowed to account for any administrative procedures required, such as public hearings, which can vary depending on the governmental authority having jurisdiction. Similarly, if a building permit or building inspections will be required; these should be arranged prior to mobilization. All of these plans, programs and permits need to be in place so that production is not held up waiting for approvals. A mobilization package should be prepared and submitted as required containing the plans, procedures and permits prior mobilization at the jobsite.

#### 4. The fabrication phase

The Fabrication Phase usually coincides with the construction of the concrete chimney shell by the chimney contractor; however it may start prior to the start of shell construction in the case of multi-flue chimneys where the shell is constructed by slipforming and the FRP fabrication time is much longer than the shell construction duration. In either event, care should be taken in scheduling the fabrication of the FRP liner so that all of the cans are completed with accessories installed prior to the start of FRP liner erection. Some overlap of the fabrication and erection can be utilized on multi-flue chimneys, however since FRP liner cans are erected in much less time that it takes to fabricated them, this should be carefully planned to avoid running out of liner cans to erect. (Figure 4)

Quality Control during fabrication is critical. Although the FRP supplier is responsible for QA/QC for their work, it is normal practice to have third party inspection and oversight of



*Figure 4: FRP Liner Cans in Storage at Jobsite*

the fabrication, usually on a full-time basis. We recommend that this third party inspection be organized and provided by the owner or their agent. The benefits of third party inspection by the owner are:

- Facilitates owner acceptance by having their inspector intimately familiar with the fabrication process and QC measures.
- Facilitates the resolution of NCRs (Nonconformance Reports) as the owner usually will have them reviewed by a third party.
- Reduced total project cost due to less duplication of inspectors and consultants.
- Avoids potential delays caused by waiting on follow-up inspections or resolution of issues.

All procedures and test plans should have been established prior to mobilization at the jobsite. QC records should be produced and maintained during the fabrication of each can and be available to all parties. All non-conformances and fabrication issues should be addressed as they occur while the can is still in the process of being fabricated. Inspection and acceptance of cans should be performed prior to the can being placed in the storage yard.

All accessories which are to be attached to the can should be installed in the yard prior to erecting the can. (Figure 5) This will avoid increasing the erection time to perform this work



*Figure 5: Liquid Collectors Pre-installed in Liner Can*



**Figure 6: FRP Liner Cans Being Erected in Chimney**

inside the chimney. This work should also be scheduled to be completed well in advance of the date the can is needed for erection to avoid delays. Particular care should be taken in planning the assembly of the breeching or elbow entry sections as these items can take considerable time to fabricate and their dimensional accuracy is important to the erection and fit-up of the completed FRP liner (1).

Jobsite safety and construction related operations should be carefully monitored. Lift plans should be prepared in advance for all operations involving the handling of the cans, including extraction from the mandrel, upending and transporting. Depending on the FRP supplier's experience working on construction sites, the chimney contractor may need to provide assistance in developing lift plans, especially for Critical Lifts. Hazardous material safety and chemicals storage should be coordinated with the plant's site safety department. Material Safety Data sheets and handling and storage plans should have previously been submitted as part of the mobilization package.

## 5. The erection phase

The Construction or Erection Phase (Figure 6) can be approached in one of three ways. First, the FRP supplier could perform the erection of the liner in the chimney including, lifting and joining. This is not common as most FRP suppliers do not have experience in this type of erection and it would require an even greater level of coordination in the design and erection of the concrete chimney shell, roof, support grillages and access provisions. The second method would be for the chimney contractor to perform the erection with the joining of the cans performed by the FRP supplier off of access provided by the chimney contractor. This method was fairly common in the early projects and has the advantage of each party performing the work that they are most experienced in.

However, it can be an inefficient use of field labor with one crew sometimes having little to do while waiting on the other crew. This of course can be overcome by using the third method where the chimney contractor performs all of the erection, including the joining of the cans, inside the chimney. As chimney contractors have become more familiar with working with FRP, this method has become more common.

The work within the chimney must be well planned as the erection will be on the critical path with little other activities which can be performed concurrently. The work area for making the joints between the cans must be safe and allow for efficient work flow. (Figure 7) Access to the area must be convenient for the workers and provide for emergency egress as required by regulations. Safety procedures within the chimney must be strictly enforced, especially regarding fire safety and respiratory protection. The handling and lifting of the FRP liner cans and the raising of the liner should all be thoroughly engineered and performed under a written erection plan.



**Figure 7: Field Joining of FRP Liner Cans**

## 6. Conclusions

Due to the specialized nature of the design and manufacturing methods involved in providing an FRP liner for a concrete chimney, it is normal practice to have a specialist FRP supplier design and supply the liners, with the filament winding performed on site. The coordination of the FRP liner with the design and construction of the overall chimney project presents many challenges to the chimney contractor and FRP fabricator. Each phase of the project requires close coordination of the activities of the FRP supplier and the chimney contractor. If the activities in each phase are properly planned and coordinated as discussed in this paper, the activities of the subsequent phases and the project as a whole should progress smoothly resulting in a well-executed project for all parties.

## 7. References

- [1] Bochicchio, V.: Rectangular Breechings vs. Round Elbows for Wet Stack Entries. CICIND Report, Vol. 25, No. 1, January 2009, pp. 57 – 59.