Piping & Instrumentation Interface Optimization

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Abstract

Interface Management is a critical requirement for any huge project, and it becomes more critical when it comes to an EPC contractor. Each stage/phase of an EPC project has numerous stakeholders across various disciplines. Interface items are all those elements, within the scope of work under the responsibility of one stakeholder (Discipline/Department, Contractor, Supplier, Fabricator, etc.) which may be impacted by the scope of work of the other stake holder/s. The lump-sum type of projects has further increased the importance as ineffective interface management is generally one of the main factors of project cost over-run and schedule delays.

This paper will mainly be focusing on the Piping / Mechanical / Instrumentation interfaces in a large EPC lump sum project. It is important to establish the communication/procedure promptly at every stage of an EPC project so that the proper information is exchanged through close collaboration between these disciplines (along with their contracts/vendors/suppliers) so that each one can perform their scope of work efficiently. Each discipline shall understand the importance of the information exchange and shall also be able to appreciate the criticality of their respective data/information concerning cost and schedule aspects.

This paper will highlight the importance of the collaboration between these departments/disciplines while covering the interfaces at each phase of the project. This will also identify the critical requirements at each stage and will highlight the advantages of a good interface while also highlighting the concerns if the interface management is inefficient.

The paper will cover the Consideration of piping and instrumentations interface during:

1. Study of Feed Documentation & Conceptual Development
2. Critical Stages / Milestones of Engineering (like 30%, 60% Model Review)
3. Finalization of the Mechanical Packages Vendors.
4. Construction and Commissioning Phase.

The paper will also discuss some typical issues/concerns along with the mitigation of these concerns with practical examples.

The paper will conclude some important findings from the project experience of the Authors related to this interface along with the most appropriate mitigation ways and means to correct &/or prevent these at an appropriate stage of the project.

Interface; Instrumentation; Control System; Piping; Engineering interface;

1. Problem Description, Possible Mitigations & Precautions to Prevent:

1.1. Introduction

Piping and Instrumentation is one of the most critical interfaces in an EPC contract. Following are the main stages of an EPC project where the Piping & Instrumentation discipline interface is critical and can result in serious concerns if not handled properly at the appropriate time.

- Study of Feed Documentation & Conceptual Development
- Early Stage of Engineering
- Critical Stages / Milestones of Engineering (like 30%, 60% Model Review)
- Finalization of the Mechanical Packages Vendors.
- Construction / Commissioning Phase

The Piping & Instrumentation Interface is a Critical and appropriate alignment is necessary among the two disciplines and their associated stakeholders like Mechanical Package Vendors, Piping/Mechanical Contractors, Fabricators, Bulk Suppliers, etc.

As described above that the Piping & Instrumentation interface creates major issues for any EPC project. This must be considered as one of the main interface risks on the project. The earlier we identify this risk, the cheaper & easier will be the mitigation. If we take appropriate checks and precautions at each stage of the project, then we can prevent most of these issues. The authors have described these issues, possible mitigation, and precautions to prevent these. All these are described below against each stage of the project.

1.2. Conceptual Development from Feed Documentation

Problems:

- Each discipline has its own specific requirements and there can be conflict within these specifications complicating the interface between the two disciplines.
- There can be incomplete information which leaves respective disciplines to consider their own assumptions which can risk the interface conflict. This problem is amplified further if more EPC contractors are involved.

Possible Mitigations & Precautions to Prevent:

- FEED documentation & contract specifications/requirements shall be studied properly to understand the discipline interface as well as any interface with other EPC contracts.
- Identifying the Interface Gap between two disciplines.
- Raising of appropriate TQs for respective disciplines considering Interface points between Piping & Instrumentation. Tapping & hook-up alignment concerns must be clarified as a combined effort by both disciplines.
- Scope Split for Piping & Instrument Interface with Other EPC Contractors/Company must be clarified before starting the detailed engineering so that any gap for the scope concerning Interface can be clarified to avoid later rework/cost/schedule impact.

1.3. Early Stage of Engineering:

Problems:

- Flow element Selection by Instrumentation impacts the Piping layout in general and it can have a drastic impact if the upstream/downstream lengths are going beyond the module size.
- Control Valve Sizing is another major interface that impacts this interface. Typical must be agreed to ensure bypass line requirements, drain vent, criticality/maintenance access of the valves
- Preferred valve orientation, as well as additional accessories like handwheels, positioners, and volume tank requirements, can cause significant layout issues later.
- Instrument Tapping size, rating, orientation, and service is another point of an interface that can be a showstopper in some cases due to the lead time and limitations on the piping.
- Instrument Air requirements for control valves/ on-off valves can cause a problem, particularly for vendor skid instrumentation.
- Flushing, Drain/Vent requirements for the diaphragm seal instruments and Level gauges.
- Optimization of process assemblies at pressure instrument tapings.
- Analyzer requirement, it's sizing, utility connection, or any other related connections to finalize the layout and piping interface requirement.
- Anything impacting the plot plan finalization such as number and size of Analyzer shelters, instrument shelter or MCC/sub-station, etc.

Possible Mitigations & Precautions to Prevent:

- Flow element selection for compact layout:

Authors observed that sometimes due to plot size constraints it's very difficult to fit flow meter which justifies the upstream and downstream requirement of the flow meter which may result in an improper installation of the flow meter and this will impact the precision of reading, thus proper thought process to be given for altering the type of flow meter which will fit into the available option of layout and pipe routing.

In general, Instrument discipline consideration is always focused on flow measurement type, service fluid properties like phase (liquid/ gases/ vapor), process conditions, flow range, accuracy, etc. Authors recommend this to be a joint consideration as a critical interface point as flow meter installation matters equally to both disciplines, on one side Instrumentation needs to check the accuracy & process conditions whereas Piping needs to take care of the considerations for proper installation of flow meter like upstream and downstream lengths with relation to valves, strainer, pipe fitting like elbows, reducers and tees and other tapings as it has a direct impact on the flow profile and hence the accuracy.

Hence this must be a joint exercise with the following considerations:

- Process and Accuracy
- Plot Plan & other Piping Constrains
- Addressing the Piping Constraints by changing the flowmeter type.
- Cost optimization concerning the cost of the meter and Pining change cost

- Sizing and orientation of control valves and it's the actuator for critical pipes:

The piping design engineer finalized the pipe routing for the critical line before the 30% model review, with assumptions to finalize these critical lines. One of the major assumptions which are related to piping and instrumentation interface is the sizing and orientation of the actuator of the control valve. If instrumentation provides appropriate data on sizing and orientation of control valve to piping, there will be no changes or negligible changes in a later stage of engineering.

- Instrument Tapping Size, Rating & Service:

Instrument Tapping Size/Type: Authors observed in multiple projects that instrument tapping requires modification during construction due to mismatch in the supplied instrument type &/or the BOQ for the isolation valves (Normal Vs Block & Bleed Isolation). Some instruments may not have isolation (like extended diaphragm seal instruments) or need special isolation like lap joint or diaphragm seal purging requirements or special analyzer tapping or extraction type instrument tapping etc. These are non-routine instrumentation that should be taken care of during initial engineering itself and hook-ups shall be taken care of accordingly.
Rating/Schedule: Authors also experienced many issues at the site where the rating and schedule of the tap/weldolets caused the problem for instrument installation. This was due to either last-minute changes which were not passed on to piping or the pipe ID and instrument OD (like thermowell) were not properly matched.
Service: Process service in many cases require special requirements like Sour service, hydrogen service, Sulphur, or Steam. Sometimes there are specific requirements for heat tracing of instrument lines. Authors faced this problem in H2 production units and in Sulphur handling units of the refinery which do have special requirements.
Instrument-Piping interface matrix development can ensure consistency across the scope.

- Instrument Air requirements for Valves:

Depending upon the size of the unit & project specifications, instrument manifolds are used for air distribution. These manifolds come in various combinations like 6, 12, 18, or 24 air taps. Each type may require a different inlet pipe size due to air volume. Many valves also require two independent tapping. Authors faced this problem in some projects with a typical project specification that required volume boosters to have an independent air supply connection which was missed in some units causing major rework in units. In some cases, client specification suggests direct tapping from the header. Appropriate understanding/clarification in such cases shall be taken in advance to avoid any future confusion/rework.

- Compactness of process block isolation at instrumentation connection for optimization:

Instrument tapping isolation requirements have many aspects like process service, specific project requirements in the project for specific units/process, instrument type, online/shutdown maintenance requirements, etc. There are many readymade & highly optimized isolation solutions are available these days from standard manufacturers. These can reduce the time, effort, space, and cost while also helping in ease of maintenance and future replacements. The conventional isolation valve assemblies have disadvantages like higher leak points due to a greater number of joints, bulky in design requiring more space, and additional supporting requirements. As these isolation valve assemblies have more items, it requires more fabrication/installation cost/ & time. However, with proper consideration of these disadvantages and the study of available solutions in the market concerning the project requirements, significant optimization opportunities can be explored. Hence this must be a joint exercise with the following considerations:

- Typical isolation requirements to be checked as per project requirements and not as per previous project experience.
- The impact of isolation cost concerning Instrument selection must be taken care of.
- Available/Possible solutions available in the market must be explored in advance within the project requirements.
- If required queries and value creation must be suggested to the Client.

The authors would like to specifically point out the double block and bleed assemblies to be explored due to their significant cost/time optimization. The authors also highly recommend exploring the use of mono flanges for diaphragm-type instruments.

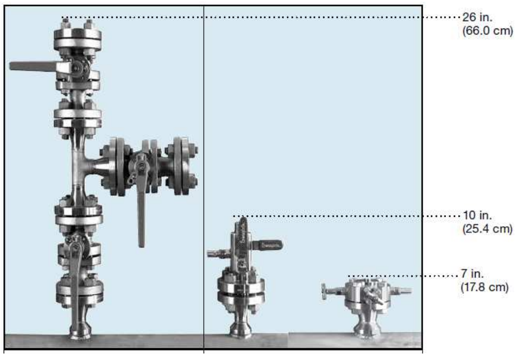

Fig. 1: Illustration for compactness of mono flange and integrated block and bleed assembly over conventional process isolation configuration

- Analyzer Shelter location in layout with considering appropriate dimensions of analyzer:

Finalizing the requirement of the analyzer shelter and its appropriate size consideration and location in layout during the early stage of design will be helpful for the project to finalize the layout which will be having negligible changes during detail engineering execution.
The analyzer is always a critical entity, which has a long lead time to deliver at the site; generally, the construction schedule is getting impacted due to the late engineering of the analyzer. So, performing engineering related to the analyzer in the early stage will support the construction site to mitigate on the schedule.

1.4. Critical Stages / Milestones of Engineering (like 30%, 60% Model Review)

Problems:

- Cable Trench and Cable duct bank sizes, routing, and requirement of the separate route for redundant cables can cause a major rework if not adequately sized and any modification not communicated at the right time.

- Home run cable tray sizes, particularly for the main pipe racks, module entries, building entries, etc. can cause major rework or significant increase in cable sizes if not planned properly.
- Vent & Drain Requirements for each type of instrument can cause major rework if any typicals are not agreed upon or a proper alignment is not reached between the two disciplines.
- Piping Vibration and impact on instrumentation for performance
- Support requirements for instruments & Instrument tapping like Gusset Supports are missed.
- Consideration of Process and utility connection to Analyzer and space for cable tray and tubing connection
- Steam trace and contra tracing requirements for instruments or instrument impulse tubes are missed
- Drain for Pressure Relief Valve for bonnet plugs were missed to engineer
- Primary cable instrument tray & instrument junction box supports not taken care of, specifically on fireproofed structures.

Possible Mitigations & Precautions to Prevent:

- Cable tranches and duct bank sizing:

This impacts the layout but also involves multiple disciplines like electrical and civil structural teams. Due to the involvement of multiple disciplines, this can have significant repercussions as any miscommunication or gap may impact the rework for multiple disciplines. Spare requirements are often missed or not calculated properly causing concerns at the time of construction /mechanical completion handover to the Client. Adequate spare volume to be considered based on a good industry basis and keeping margin from the actual spare space to be handed over. The must be a checklist that takes care of the timely feedback to the other disciplines/stakeholders. Direct buried trenches can be easy to handle, however, concrete trenches and duct banks must be created with sufficient margins.

- Cable tray sizing and routing and freezing space in the layout:

This is sometimes becoming a major cause of rework at the time of fabrication/construction. Authors observed this problem mainly in the battery limit modules/utility units as it’s not just the interface between two disciplines BUT also an additional interface between two teams and happens mainly due to communication gaps. Many times, instrument teams route the trays in advance and release the drawings. These drawings are not revised after any piping changes due to model comments causing a major rework at the module yard or site.

- Vent and drains for instrumentation:

Finalization of philosophy for venting and draining at every appropriate stage of the project will be useful for finalization of underground piping network with accuracy and eliminate the necessity of the additional pipe rework at the construction site.

- Piping Vibration and impact on instrumentation for performance.

Some instruments are impacted due to small vibrations like ultrasonic flowmeters and at the same time, some instruments can create vibration due to excessive noise or pulsation if proper calculations are not done by either discipline. Authors faced this concern at the site, adequate modifications were done by either adding new supports or strengthening or changing from stiff to spring supports.

- Gusset support for instrument tapings:

There are various configurations for gusset supports, selection of the configuration of appropriate type plays a major role for the cost-effective selection of proper gusset support, if gusset requirements are appropriately considered during the design phase. Welded type gussets are simple in design, easy to fabricate, require less material, and are economical to install over the clamp type gusset design. The added advantage of the welded type gusset selection in design is that welding work will be completed before hydro testing of pipe network which ensures appropriate installation of gusset support before the test. This will support the construction site to reflect correct progress completion.
Each line has instruments tapping with small-bore piping. Appropriate gusset support if not selected at the design phase will lead to bulky clamp-type gusset supports which look bigger than the process isolation assembly of instrument connection.

- Process and utility connection to Analyzer and space for cable tray and tubing connection:

Freezing the requirement of process and utility connection to the analyzer and handling the interface for the analyzer connections promptly will support the site to do not have rework or additional work which causes schedule and cost impact at a later stage.
Proper space considerations for the cable tray and impulse/utility tube routing must be captured so that the site contractor doesn't face any problem after house installation. Proper utility space for piping connections must also be taken care of within the Analyzer house/shelter boundaries. Any changes during the analyzer-package engineering must be properly fed back to piping. The author's faced multiple issues of mismatch in several projects during their site experience, specifically to the utility connections for the analyzer/analyzer shelters.

- Drain requirement for Pressure Relief Valve for bonnet plug:

During engineering, according to the type of pressure relief valve requirement of bonnet vent plug or bonnet vent to a safe location to be finalized at appropriate design time as this requirement are getting realized at the pre-commissioning stage of project execution which causes a substantial delay in schedule and increases in cost due to site routing of these vent pipes.

- Interface for steam tracer and contra tracing for instrumentation connection:

Steam tracing requires routing of steam lines to specific instruments. Depending upon the service, impulse tube tracing requirements may be different from pipeline tracing requirements. The general understanding is that if the pipeline has stream tracing then instrument impulse lines will also be having tracing, but this is not always true. Authors experienced multiple issues on this, specifically on the steam service lines. Steam impulse tubes have condensate pots and hence the impulse tubes will not require any steam tracing. If not taken care this results in unnecessary rework and material procurement. The authors also experienced several services where the specific temperature is to be maintained at impulse tubes and LP steam was not available in the unit. This resulted in a major rework to route the LP steam line to the units for impulse tube steam tracing.

- Fireproofing/Insulation Requirements of Instruments and impulse lines:

Primary cable instrument tray & instrument junction box supports must be interfaced properly with the understanding of the steel, concrete, or fireproofed locations.
Proper coordination is critical concerning where and what type of fireproofing/insulation is required. Proper inputs must be taken from the process engineers and vendors. Care also must be taken where frequent maintenance is required so that fireproof jacketing can be done rather than fixed mass. The same is true for insulation also so that adequate opening/box is provided for maintenance.

1.5. With Mechanical Packages Vendors:

Problems:

- Vessel Instrumentation Piping designed by vendor, but instruments are loose supplied. This type of arrangement can have major gaps in the tapping requirements unless it's coordinated well between the two discipline responsible engineers. The same problem can be there if the instrument for the package is procured by EPC contractors themselves for vendor piping skids.
- All issues discussed in Section 3.3 are also applicable to the vendor package skids/modules.
- Supporting of instrumentation tapping, long length level instrumentation

Possible Mitigations & Precautions to Prevent:

- Vessel Instrumentation & Piping

Level instrumentation and equipment mounted pressure and temperature interface is not limited between instrumentation and piping, here mechanical is also involved for the elevation and orientation of the nozzle for level instrument connection. The civil-structural team is also involved in the related platforms and ladders engineering for accessibility instruments and related isolation, drain, and vent valves.
To facilitate the appropriate communication between instrumentation, piping, civil-structural and mechanical, an instrumentation engineer prepares level sketches to communicate level device nozzle and tap elevation, connection type and size, and other requirements with Piping and Mechanical engineer. These level sketches can also provide information about the closed vent and drain requirement of level gauges, indicate the requirement of visibility and an elevation for the visible range of level gauge so accordingly piping can generate platform requirements.

- Issues discussed in Section 3.3 are also applicable to Mechanical Packages:

All the Points Considered in the above Engineering Stage are also applicable to Mechanical Packages. In most cases model review of packages doesn't include complete instrumentation reviews with DDP as it comes generally under vendor responsibility. In many cases, documentation issued is also incomplete which results in missing these concerns even at the time of vessel/package inspection.
Authors experienced several issues where package RE agrees to certain aspects or even the scope changes for fabrication/erection at site and the same is neither captured in site BOM nor any hook-ups are assigned. This results in significant rework as well as schedule delays at the site.

- Loose Supplied instruments with Mechanical Packages:

Many instruments are loose supplied by mechanical package vendors. BOQ for all loose supplied instruments needs to be coordinated either with the packaged vendor or internally with piping. The authors experienced quite some issues where the material is neither considered by piping, nor by the vendor for some of the loose supplied items and there were also cases where BOM was considered by both parties. Both parties worked on different lists, the internal piping department used the old list of loose supplied items whereas the loose supplied item list got changed and the vendor updated BOM accordingly, but internal communication was missed between the two disciplines. Hence a checklist must be followed every time there is a change and not just in the start-up.

- Supporting instrumentation tapping, long length level instrumentation.

Instrument Supports like Gusset supports etc. are often decided at a late stage and mostly missed to be communicated to the Package vendor. This is not even considered at the time of package scope agreement resulting in site rework and additional scope for site Subcon which also lasts in last-minute material procurement as well as schedule delays to mechanical completion.

1.6. Construction / Commissioning Phase

Problems:

- Damage of Inline instrumentation while an installation by Piping Contractor
- Construction Sequence can be a major concern if not coordinated well between Piping & Instrument construction engineers and contractors.
- Instrument's removal & re-installation coordination/planning for Hydrotest
- Instrument's removal & re-installation coordination/planning for Steam/Air blowing
- Preservation of Valves & Instruments by Piping Contractor

Possible Mitigations & Precautions to Prevent:

- Damage of Inline instrumentation while installation of inline instruments by Piping Contractor

Inline instruments are generally in the piping contractor scope. This installation must be supervised by instrument engineers otherwise there can be unnecessary damage to the critical electronic or pneumatic components which can even delay the construction schedule if the damage is not identified in time. All instruments shall be reviewed before starting the inline installation for removal of delicate electronic or pneumatic parts like positioners or small gauges which are more prone to damage.

- Sequence of Work at Site:

The sequence of work for both disciplines must be coordinated and planned carefully to avoid rework. The authors observed at the site that in many cases instrument contractor laid branch cable trays in advance which blocked the space for interface piping from other modules or package skids. In some cases, the piping contractor routed the steam tracing tubes blocking instrument access. Lack of coordination between the two discipline construction engineers and contractors caused major

rework for E&I contractors at the site and unnecessary schedule delays. In some cases, the location of the utility stations was completely covered by the secondary tray work which caused significant rework/schedule impact.
Sequencing coordination is critical for the fireproofing, insulation, tracing requirements so that rework, as well as multiple mobilizations of required craft, is avoided.

- Instrument Removal/Installation before the hydro test:

Inline instruments are required to be removed for hydro tests. Many of the instruments are necessary for piping loop completion to ensure proper alignment of piping but there are many instruments for which the installation can be avoided till hydro test. This must be agreed upon and coordinated well in advance between the two discipline engineers to avoid rework. Similarly, many of the online instrument installations can be avoided by instrument contractors till the hydro test is completed.
The authors observed many cases at the site that instrumentation was installed by the instrument contractor but was required to be removed. In some cases, electronic parts were loosely shipped for safety but were installed before the hydro test whereas the instrument was to be removed once again which resulted in damage to some of these electronics parts. There were also cases where piping engineers removed the cable/pneumatic connections themselves which also resulted in some damage and missing parts.

- Instrument Removal/Installation for Steam Blowing/line cleaning etc.:

Inline instruments are also required to be removed for steam blowing/air blowing or chemical cleaning. The instrument team was not involved at the time of developing the steam blowing procedure and hence the instrument removal was not included in the scope of the contract. It was also observed that some instrumentation was planned to be in line to observe steam blowing. Authors experienced instrument damage during this work which caused rework as well as procurement actions. Function check planning was also impacted as the proper coordination was not there between the two teams. Some instruments were not removed which resulted in dirt deposition, like in some of the thermowell, which resulted in lower temperature reading during start-up.

- Preservation of Valves by Piping Contractor while removal/installation for construction/commissioning:

Inline instruments specifically control valves and on-off valves require proper preservation after these are removed from the lines or before the first installation. This neither is done properly by the Piping contractor nor was noticed by the instrument engineers. This resulted in the depositing of dust and rainwater on the valve discs, seats, and gland area leading to stuck valves and damage to the seat. This in turn impacted the schedule of commissioning as many of the valves were required to be removed for repair and cleaning. Apart from the schedule delay, this also resulted in a significant cost impact as many of the valve removal and installation required the use of big cranes. This ~~is~~ had an impact on the warranty issues also as many of these valves are not working post-PTOP and the vendor was not accepting warranty claims as proper preservation was not done.

2. Conclusion:

- Layout related issues can cause major upset, rework & delays. Extra care & Adequate margins can be used to avoid last-minute layout changes which will impact all disciplines and affect the overall cost and schedule of the project.
- Instrument tapping size, rating/schedule, and service-related interfaces are one of the most critical interfaces between Piping & Instrumentation. Additional care and the final audit for this must be done by senior engineers and specific points mentioned by the Authors can be used as a checklist.
- Usage of readymade & highly optimized isolation solutions in the market must be explored in advance. Subsequently, these must also be added to the typical & model library.
- Specific interface checklist shall be developed for mechanical package and each point modified for main plant units must be carefully communicated to the Package vendors.
- Mechanical Package RE and Discipline Package RE must communicate each deviation or scope change to the appropriate interface management team and do adequate changes or revisions to the hook-ups, IFC drawings, and the material procurement including the scope changes for the site contractor.
- Finally, all the interface issues faced by the Authors must be added to the interface practice as well as the checklist for the discipline interface procedure. Gate reviews must be used for each audit of the above-discussed interface issues.

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