A Method for Estimating Cost Comparisons in Raising SIL Levels

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Key Words

Safety instrumented systems, safety loop configurations, engineering changes, life cycle costs

IEC 61508 Phases

Phase 14 – Overall Operations and Maintenance
Phase 15 – Overall Modification and Retrofit

Introduction

This paper has been prepared by the SIPI Project Manager as a result of consultations with and material provided by a UK chemicals company. It describes a method designed and implemented by the company to enable more accurate costs to be determined when modifications are made to existing safety functions. The site, a COMAH (Seveso II) Top Tier site, has undertaken an extensive exercise on SIL determination, the implementation of IEC 61508/IEC 61511 and also Risk Based Inspection. In addition they have standardised on one supplier of control and safety systems. These programmes of work resulted in engineering changes to some of the safety loops requiring specifications to be developed and cost estimates produced for sanction by works management. The organisation developed a method referred to as 'SIL Jump Costing' to ensure that the cost element of these modifications could be more accurate and less prone to cost deviations. The method does not include the cost implications of modifications to software, this is currently being developed by site engineering personnel.

The article is provided to the SIPI project as a suggested method that can be tailored by SIPI members to take account of their specific local circumstances.

SIL Jump Costing Method

To enable a base case to be established, the first step was to document a typical SIL 1 trip configuration for review and agreement as a basis for the development of the generic cost model. A sketched P&ID was developed (see Appendix 1) together with typical Instrument and Air Hook-up arrangements for the base case.

When this base case had been confirmed the Mechanical requirements were agreed along with any other assumptions so work could commence on the cost model.

The next stage was to move from the SIL 1 trip to SIL 2 trip situation addressing the incremental hardware costs. To establish this it was necessary to set out what information to base this progression on and any assumptions made. Options had to be clearly stated and the percentage adjustments up or down to the cost by inclusion and adjustment to the base case.

An additional factor considered for inclusion was the need to establish whether the safety loop was going to be based on level, flow, pressure or temperature for this exercise. The duty of the valve and application may have a big impact on the cost and costs based on a typical flow rate will increase the accuracy of the cost estimation model.

Basis for the SIL 1 trip situation:

In respect of the end user site under consideration a common site configuration was agreed for the wetted-end equipment consisting of 1-off Rosemount 3051 Pressure Transmitter piped from Monoflange manifold on 1" branch.
1-off Samson Plug type ESD Valve 2" Class 600 Stainless Steel.

Criteria and Assumptions - Actuator/Positioner

It was then necessary to establish a set of criteria and document all the assumptions made in respect of the all engineering disciplines required in order to establish site-specific costs. For each of these criteria costs were estimated based on time & materials as supplied and fitted, taking into account labour rates of local preferred suppliers and any contractual agreements in place covering material costs.

The list below relates to individual **instrument criteria** established for a typical site actuator/positioner:

- 1-off Thompson ICO4 type Solenoid valve 110/24v dc, mounted local to Plug valve
- 1-off Rosemount 3311 I/P converter on Instrument stand
- 2-off 0.75mm x 1pr IS Blue cables to existing field Analogue Junction Box for transmitter + I/P
- 1-off 2.5mm x 3c ***Xlpeswapvc*** cable to existing field Digital Junction Box for Solenoid valve
- 150mm tray/fittings – Analogue – 6mtrs
- 150mm tray/fittings – Digital – 6mtrs
- 41x41mm channel supports (Air/tray drops) - 9mtrs
- 41x41mm channel supports < 300mm – 10 off (3mtrs)
- Instrument 6-way Air manifold added to bottom of existing air manifold
- Bellofram filter/regulators/gauge – I/P and Valve – 2 off
- 10mm Cu/pvc pipe/fittings air to valve actuator + I/P – 5m+5m
- 6mm Cu/pvc pipe/fittings I/P to valve positioner/filter reg. to positioner/Shut Off Valve – 3m
- 10mm ball-o-top air isolation valves – 2 off
- 12mm St Process connections with HRTC type fittings for Pressure Transmitter – 3m
- Unclip/re-clip cables on existing cable routes – 3 x 30mtrs
- Control Room Panel modifications – allow ***Prov*** Sum £2k

For each of these criteria an individual cost was established.

The next stage of the method was to establish the specific **instrument engineering** changes and additional equipment required to reconfigure the safety loop from a SIL 1 to a SIL 2 rating in order to calculate the additional costs. These incremental costs are in addition to those detailed above and include:

- 1-off Rosemount 3051 Pressure Transmitters
- 1-off Shutoff Ball Valve 2” Class 600 with Actuator
- 1-off Thompson ICO4 type Solenoid valve 24v dc
- 1-off 0.75mm x 1pr IS Blue cables to existing field Analogue Junction Box for transmitter
- 1-off 2.5mm x 3c Xlpeswapvc cable to existing field Digital Junction Box for Solenoid valve
- 150mm tray/fittings – Analogue – 3mtrs
- 150mm tray/fittings – Digital – 3mtrs
- 41x41mm channel supports < 300mm – 4 off (1mtr)
- Bellofram filter/regulator/gauge – Valve – 1 off
- 10mm Cu/pvc pipe/fittings air to Shut Off Valve/actuator – 5m
- 10mm ball-o-top air isolation valve – 1 off
- 12mm St Process connection with HRTC type fittings for Pressure Transmitter – 3m
- Unclip/reclip cables on existing cable routes 2 x 30mtrs
- Control Room Panel modifications – allow ***Prov*** Sum £2k

At this stage options and alternatives were identified and documented, for example:

- Add two Transmitters as option for jump from SIL 1 to SIL 2 for 2oo3 Voting
- Carbon Steel Pipe work Class 600 with costs for 4” and 6” line sizes
- Hastelloy Pipe work Class 600 with costs for 4” and 6” line sizes

Other Considerations:

Other criteria were identified and incorporated into the model. For each of these criteria a decision was made as to whether or not it impacted on the method and if so a cost would have to be determined. These included:

- **Scaffold Access**
  - Cost to include 30mtrs @ 3.5m ***affl*** for Instrument field cables

- **Mechanical**
  - Mechanical piping modifications based on modifying a 5 metre spool piece with one elbow and inserting one additional branch for 1oo2 Voting. For 2oo3 voting this becomes two additional branches. A worst-case scenario of cutting a line at a remote location away from the instrument, in two places and welding new flanges in-situ for the Class V Shutoff ball valve has been allowed for each case. This will require hot work, which, assuming the work will be carried out during a normal Plant Outage, should not cause a problem. Costs are for pipe work and insulation only.

- **Crane Hire**
  - Crane Hire not required as work would be undertaken during plant shutdowns

- **Maintenance/Life Cycle costs**
  - Life cycle costs based on a 20 year period. Ideally the valve would be checked every 2 years but in effect this would not happen until Plant Shutdown every 4 years. Based on a 6" St valve, overhaul costs from the valve Database is £500. Add £100 transportation to/from Plant and £100 for soft spares. Assume this operation is carried out five times, total cost £3,500. Add valve replacement at 10 years based 4" St valve of £5,000 and cost of Instrument shop maintenance of £1,500. Add £2,000 for software issues over the life cycle. Average total Life Cycle cost then equates to £12,000 to add to each case.

    Other issues which needed to be considered included inflation costs affecting labour and materials along with changes in technology i.e. certified Single Critical Instruments. It was assumed sufficient provision had been made to cover these items.

    Instrument replacement was also considered, but with present pressure transmitters improved reliability and 12 year guarantee period, it was not thought necessary to make any cost provisions for these.

- **Engineering/Design and management**
  - Engineering/Design costs to be included

Other criteria:

- It will be necessary to modify grating on platforms for piping/Instrument stands/tray work
- As no 'Site Standard' Valve Data sheets exist it was difficult to consider valve performance and specification in order to get a meaningful cost. It depends on individual locations/duties. Therefore no specific cost was included.

Any other assumptions:

- Cable routing averages 40mtrs to existing Field Junction Box
- Assumed that Analogue/Digital Junction Boxes exist and have sufficient spare capacity
- Assumed that Field multicores have sufficient spare capacity
- No Major Scaffold Access routes necessary
- Spare way exists on Plant Air Manifolds to fit new extension air manifold
- Panel modifications include panel wire/terminals etc,
- No new Analogue/Digital ESD Cards required or inter panel wiring
- SIL 1 Valve – Actuated Plug type with positioner Class 600 type
- SIL 2 Valve – Add Class V Shutoff Ball Valve Class 600 type
- Assumed it is physically possible to modify existing pipe work without major construction or hot work to vessels etc

- Existing Instruments to be disconnected/removed/replaced during pipe work modifications.

Example:

Appendix 3 provides two configuration options for upgrading from SIL 1 to SIL 2. These cover 1002 and 2003 voting both based on 2" stainless class 600.

The Model

The 'SIL Jump Costing' model was developed using an Excel Spread Sheet. Examples appear in Appendix 4.

The s/sheet was constructed allowing for a number of scenarios:

- SIL 1 to SIL 2, 1002 instrument installation for:
  - 2", 4" and 6" stainless valves
  - 2", 4" and 6" Carbon Steel
  - 2", 4" and 6" Hastelloy
- SIL 1 to SIL 2, 2003 instrument installation
  - 2", 4" and 6" stainless
  - 2", 4" and 6" Carbon steel
  - 2", 4" and 6" Hastelloy

By taking all the individual costs for instruments, mechanical, scaffold, crane, Maintenance/life cycle and engineering/design/management as documented earlier in the paper and clustering, total costs can be calculated and inserted in the model for the following key criteria:

- Direct costs
  - instruments
  - mechanical
  - scaffold
  - crane
- Indirect costs
  - Maintenance/life cycle
  - Engineering/Design/Management

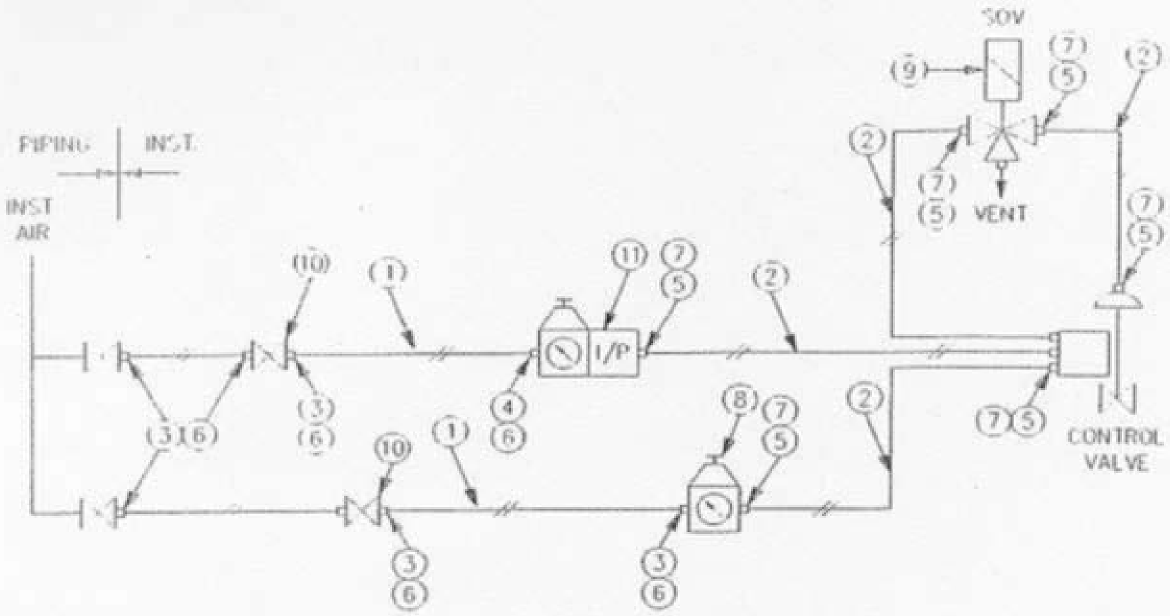
The s/sheet can be easily adapted to cover other criteria identified from experience of upgrading loops, requirements for shut-downs outside the planned shut-down window, revisions to local labour agreements and material pricing.

Conclusions

This article provides information on the development of a method and associated cost model to assist in calculating all related costs in upgrading safety loops from SIL 1 to SIL 2 ratings. The method was developed as a result of extensive site wide IEC 61508 implementation and SIL determination exercises resulting in some modifications to existing safety loops. The method is flexible and from operational experience has proved beneficial in estimating and controlling costs associated with the site operations and maintenance regimes.

Appendix 1 – specimen P&ID

Project Name Instrument Air Hookup Diagram	CONTROL VALVE & SOV Dwg. No. 4891-S51-460001_C1_SHT010



TAG LIST

TAG NUMBER	SERVICE / DESCRIPTION	MANUFACTURER	MODEL
FV-5140-S51	LP STEAM FLOW TO S522	<Unspecified>	CONTROL VALVE
FV-5236-S51	STEAM SUPPLY TO E587	<Unspecified>	CONTROL VALVE

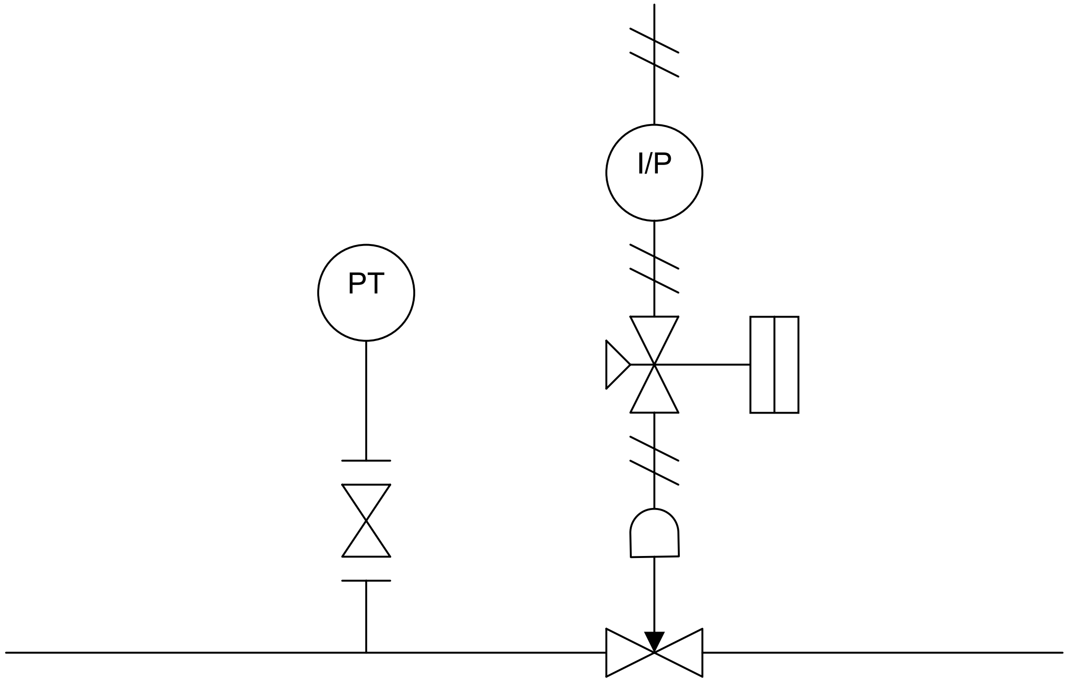
QUANTITY

ITEM NO	QUANTITY	DESCRIPTION	MATERIAL	PART No.
1	10m *	10mm OD PVC COVERED COPPER TUBE	PVC/COPPER	
2	3m	6mm OD PVC COVERED COPPER TUBE	PCV/COPPER	
3	5	1/2" NPT x 10mm Swagelock MALE STUD COUPLING	BRASS	B-10M0-1-8
4	2	1/4" NPT x 10mm Swagelock MALE STUD COUPLING	BRASS	B-10M0-1-4
5	8	1/4" NPT x 6mm Swagelock MALE STUD COUPLING	BRASS	B-6M0-1-4
6	7	10mm PV NUTS	BRASS	B-10M2-1PV
7	8	6mm PV NUTS	BRASS	B-6M2-1PV
8	1	BELLOFRAM FILTER REGULATOR		
9	1	MAXSEAL SOLENOID VALVE		IC04
10	2	BALL-O-TOP ISOLATION VALVE	BRASS	514-123
11	1	I/P CONVERTER WITH REGULATER. FOXBORO		E69F

* Note- The length of 10mm pipe is indicative, the length of tubing required for each installation is unique.

AUTH: PROCESS ENGINEER:
AUTH: PLANT ENGINEER :
AUTH: INSTRUMENT ENGINEER :

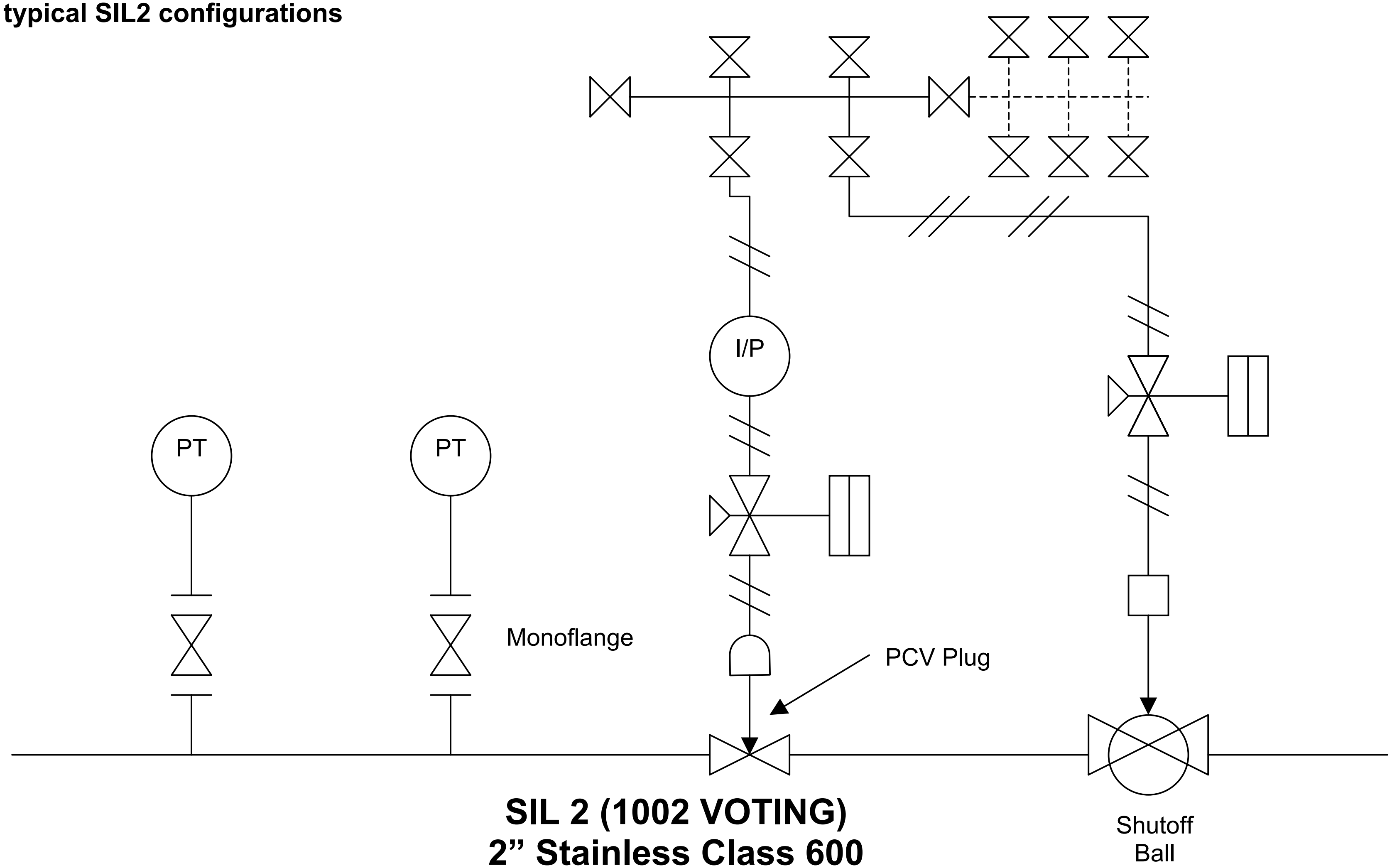
Appendix 2 Existing Base Case



SIL 1 EXISTING BASE CASE

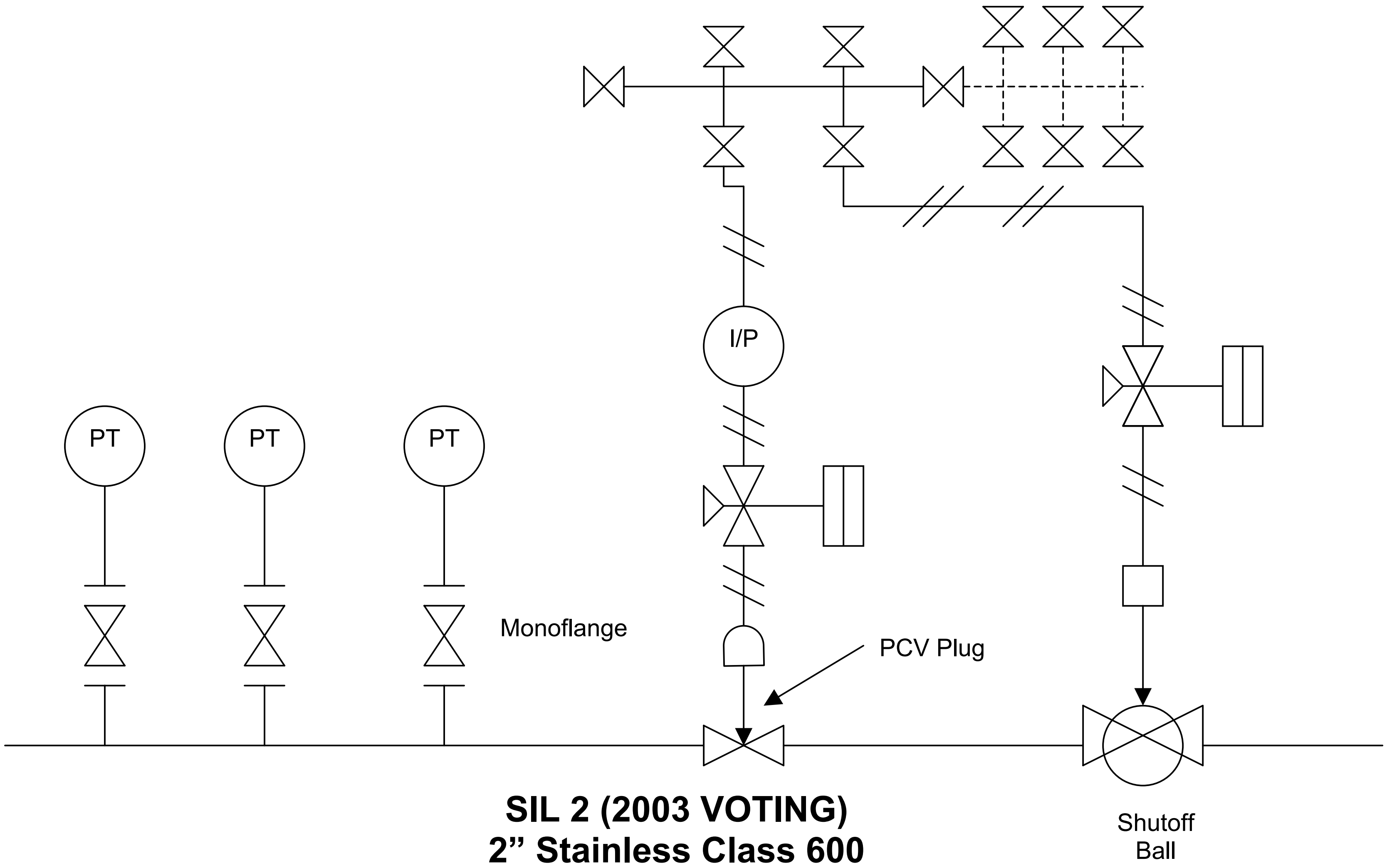
2" STAINLESS CLASS 600

Appendix 3 typical SIL2 configurations



SIL 2 (1002 VOTING)
2" Stainless Class 600

Options
1) 4" + 6" sizes
2) Carbon (2", 4" 6")
3) Hastelloy (2", 4", 6")



SIL 2 (2003 VOTING)
2” Stainless Class 600

Options
4) 4” + 6” sizes
5) Carbon (2”, 4” 6”)
6) Hastelloy (2”, 4”, 6”)

Appendix 4 SIL Jump Costing Model

Job Code	SIL Jump Costs / Work Order Number	Qty	Unit		Total Cost - £ Indirect	Total Cost - £ Direct		Total Cost - £ Indirect	Total Cost - £ Direct		Total Cost - £ Indirect	Total Cost - £ Direct
	SIL Jump Costing											
	SIL 1 to SIL 2 Situation				**2" Stainless**			**4" Stainless**			**6" Stainless**	
	1oo2 Instrument Installation				Indirect	Direct		Indirect	Direct		Indirect	Direct
	Instruments	1	sum			£10,300			£12,200			£16,700
	Mechanical	1	sum			£8,900			£14,100			£20,400
	Scaffold Access 30mtrs @ £50/mtr	1	sum			£1,500			£1,500			£1,500
	Crane Hire	1	sum			£0			£0			£0
	Direct Cost					£20,700			£27,800			£38,600
	Maintenance/Lifecycle costs	1	sum		£12,000			£12,000			£12,000	
	Engineering/Design/Mgmt	1	sum		£9,300			£12,500			£17,400	
	Indirect Cost				£21,300			£24,500			£29,400	
	Total Cost				**2" Stainless**	£42,000		**4" Stainless**	£52,300		**6" Stainless**	£68,000
	SIL 1 to SIL 2 Situation											
	1oo2 Instrument Installation				Indirect	Direct		Indirect	Direct		Indirect	Direct
					2" Carbon Steel			**4" Carbon**			**6" Carbon**	
	Instruments	1	sum			£9,450			£11,000			£12,000
	Mechanical	1	sum			£5,000			£7,100			£9,000
	Scaffold Access 30mtrs @ £50/mtr	1	sum			£1,500			£1,500			£1,500
	Crane Hire	1	sum			£0			£0			£0
	Direct Cost					£15,950			£19,600			£22,500
	Maintenance/Lifecycle costs	1	sum		£12,000			£12,000			£12,000	
	Engineering/Design/Mgmt	1	sum		£7,250			£8,900			£10,200	
	Indirect Cost				£19,250			£20,900			£22,200	
	Total Cost				**2" Carbon Steel**	£35,200		**4" Carbon**	£40,500		**6" Carbon**	£44,700

SIL 1 to SIL 2 Situation

1oo2 Instrument Installation

			Indirect	Direct	Indirect	Direct	Indirect	Direct
			2" Hastelloy		**4" Hastelloy**		**6" Hastelloy**	
Instruments	1	sum		£23,950		£30,100		£44,250
Mechanical	1	sum		£18,800		£35,400		£53,400
Scaffold Access 30mtrs @ £50/mtr	1	sum		£1,500		£1,500		£1,500
Crane Hire	1	sum		£0		£0		£0
Direct Cost				£44,250		£67,000		£99,150
Maintenance/Lifecycle costs	1	sum	£12,000		£12,000		£12,000	
Engineering/Design/Mgmt	1	sum	£19,950		£30,200		£44,650	
Indirect Cost			£31,950		£42,200		£56,650	
Total Cost			**2" Hastelloy**	£76,200	**4" Hastelloy**	£109,200	**6" Hastelloy**	£155, 800

SIL 1 to SIL 2 Situation

2oo3 Instrument Installation

			Indirect	Directs	Indirect	Directs	Indirect	Directs
			2" Stainless		**4" Stainless**		**6" Stainless**	
Instruments	1	sum		£13,100		£14,950		£19,450
Mechanical	1	sum		£11,300		£16,500		£22,800
Scaffold Access 30mtrs @ £50/mtr	1	sum		£1,500		£1,500		£1,500
Crane Hire	1	sum		£0		£0		£0
Direct Cost				£25,900		£32,950		£43,750
Maintenance/Lifecycle costs	1	sum	£12,000		£12,000		£12,000	
Engineering/Design/Mgmt	1	sum	£11,700		£14,850		£19,750	
Indirect Cost			£23,700		£26,850		£31,750	
Total Cost			**2" Stainless**	£49,600	**4" Stainless**	£59,800	**6" Stainless**	£75,500

SIL 1 to SIL 2 Situation

			Indirect	Direct	Indirect	Direct	Indirect	Direct
	2oo3 Instrument Installation		**2" Carbon Steel**		**4" Carbon**		**6" Carbon**	
	Instruments	1 sum		£12,200		£13,700		£14,700
	Mechanical	1 sum		£6,000		£8,100		£10,100
	Scaffold Access 30mtrs @ £50/mtr	1 sum		£1,500		£1,500		£1,500
Z360	Crane Hire	1 sum		£0		£0		£0
	Direct Cost			£19,700		£23,300		£26,300
	Maintenance/Lifecycle costs	1 sum	£12,000		£12,000		£12,000	
	Engineering/Design/Mgmt	1 sum	£8,900		£10,500		£11,900	
	Indirect Cost		£20,900		£22,500		£23,900	
	Total Cost		**2" Carbon Steel**	£40,600	**4" Carbon**	£45,800	**6" Carbon**	£50,200

SIL 1 to SIL 2 Situation

		Indirect	Direct	Indirect	Direct	Indirect	Direct
2oo3 Instrument Installation		**2" Hastelloy**		**4" Hastelloy**		**6" Hastelloy**	
Instruments	1 sum		£34,600		£40,800		£55,000
Mechanical	1 sum		£23,900		£40,500		£58,500
Scaffold Access 30mtrs @ £50/mtr	1 sum		£1,500		£1,500		£1,500
Crane Hire	1 sum		£0		£0		£0
Direct Cost			£60,000		£82,800		£115,000
Maintenance/Lifecycle costs	1 sum	£12,000		£12,000		£12,000	
Engineering/Design/Mgmt	1 sum	£27,000		£37,300		£51,800	
Indirect Cost		£39,000		£49,300		£63,800	
Total Cost		**2" Hastelloy**	£99,000	**4" Hastelloy**	£132,100	**6" Hastelloy**	£178,800

SIL Jump Costing