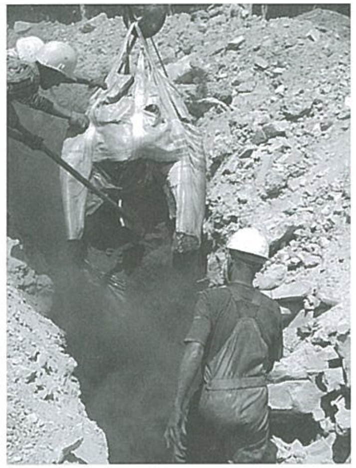
Electrodes used to monitor pipe potential

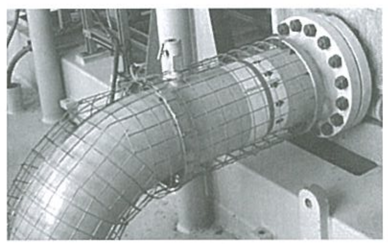
Cathodic protection



Coke breeze

Laying of flexible anode

The **Insulation specification** covers the different types of insulation installed on equipment and piping: insulation for heat conservation, personnel protection as shown here and acoustic insulation. It specifies the insulation materials (such as mineral wool), thickness and provides detailed requirements for proper installation, ensuring in particular an adequate protection from the weather.



Chapter 9

Piping

Based on the Process Fluid list obtained from Process, and the material selection having been made, Piping discipline defines different groups (called classes) of piping material.

For instance:

- piping for all low pressure non corrosive fluids will be class A,
- piping for low pressure low corrosive service will be class B (extra thickness – called corrosion allowance – added compared to class A),
- piping material for low pressure highly corrosive service will be class C (material changed from carbon steel used in class A and B to stainless steel), etc.

Definition of the **Piping Material Classes** allows to standardize the piping material by using the same for several services. In this way, material will be interchangeable at Site. Any excess material for any lines of a given class can be used for any other line of the same class. Should there be a change at Site on one of these lines, it will be easier to find available material.

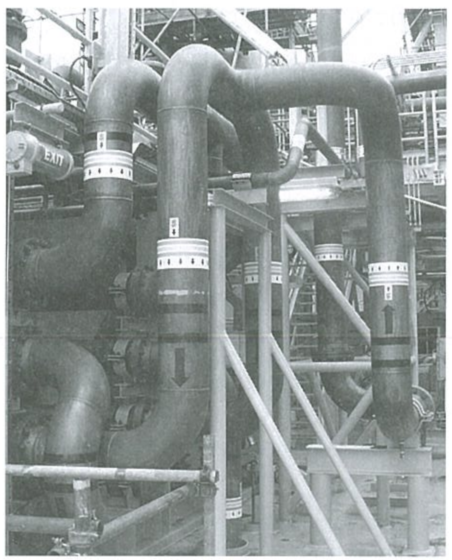
Process Fluids list

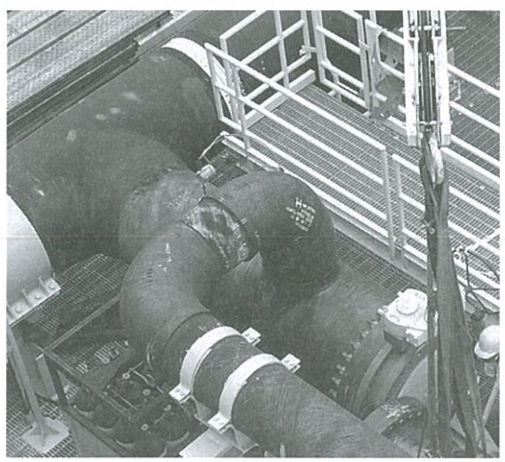
FLUID	SYMBOL	OPERATING CONDITIONS T (°C) MAXI/DESIGN		MPa(abs) MAXI/DESIGN		MATERIAL
Drain	BD	30	50	atm	2	CS
Drain	BD	30	50	atm	9.95	CS
Drain	BD	50	70	atm	26.6	CS
Fuel Gas	FG	30	50	0.8	1.0	SS
Fuel Gas	FG	40	60	4.5	5.0	SS
Fuel Gas	FG	55	75	9.8	9.95	CS
Diesel fuel	FO	amb	50	0.2	0.4	CS
Fire Water	FW	amb	50	1.1	1.3	HDPE
Fire Water	FW	amb	50	1.1	1.3	CS
Lube Oil	LO	30	80	0.42	0.6	GALVAN
Methanol	ME	20	50	atm	0.4	SS
Methanol	ME	20	50	25.45	26.6	SS
Open drain	OY	amb	50	atm	0.4	CS
Hydrocarbon Gas	P	30	50	atm	2	CS
Hydrocarbon Gas	P	30	50	9.8	9.95	CS
Hydrocarbon Gas	P	-40/30	-46/50	atm	0.3	LTCS
Hydrocarbon Gas	P	-40/30	-46/50	9.8	9.95	LTCS
Hydrocarbon Gas	P	138	160	25.35	26.6	CS
Hydrocarbon Gas	P	50	70	25.35	26.6	CS
Hydrocarbon Gas	P	138	160	25.35	29.2	CS
Hydrocarbon Gas	P	-40/138	-46/160	25.35	29.2	LTCS
Hydrocarbon Gas	P	-40/50	-46/70	25.35	26.6	LTCS
Utility Air	UA	30	50	1.1	1.3	CS
Utility Water	UW	amb	50	0.3	0.5	GALVAN

Piping material classes

PIPING CLASS	RATING #	MATERIAL	COR. (mm)	TEMPERATURE MAX OPER °C	TEMPERATURE DESIGN °C	PRESSURE MAX OPER Barg	PRESSURE DESIGN Barg
11A	150	CS	0	30	50	atm	19
15A	600	CS	0	30	50	97	98,5
18A	2500	CS	0	138	160	253	265
21A	150	LTCS	0	-40/30	-46/50	atm	2
25A	600	LTCS	0	-40/30	-46/50	97	98,5
28A	2500	LTCS	0	-40/50	-46/70	253	265
28B	2500	LTCS	0	-40/138	-46/160	253	291
31A	150	SS	0	30	50	7	9
31U	150	SS	0	20	50	atm	3
35A	600	SS	0	40	60	44	49
38A	2500	SS	0	20	50	253	280
91A	150	CS-GALVA	0	30	80	3.2	5
91A	150	CS-GALVA	0	amb	50	2	4
10P	150	HDPE	0	amb	50	10	12

The pictures below show two types of "exotic" materials: Cu-Ni (Copper-Nickel alloy) and GRE (Glass Re-inforced Epoxy) used for high (fresh water) and very high (sea water) corrosive services.





Piping involves a large variety of components: straight runs, elbows, tees, flanges, reducers, valves, etc. Each of these components must be specified in order to be purchased. This is done in the **Piping Material Classes specification**.

Piping material classes

PIPING CLASS	RATING #	MATERIAL	COR. (mm)	TEMPERATURE MAX OPER °C	TEMPERATURE DESIGN °C	PRESSURE MAX OPER Barg	PRESSURE DESIGN Barg	ASME DESIGN CODE
11A	150	CS	0	30	50	atm	19	B31-8
15A	600	CS	0	30	50	97	98,5	B31-8
18A	2500	CS	0	138	160	253	265	B31-8
21A	150	LTCS	0	-40/30	-46/50	atm	2	B31-8
25A	600	LTCS	0	-40/30	-46/50	97	98,5	B31-8
28A	2500	LTCS	0	-40/50	-46/70	253	265	B31-8
28B	2500	LTCS	0	-40/138	-46/160	253	291	B31-8
31A	150	SS	0	30	50	7	9	B31-8
31U	150	SS	0	20	50	atm	3	B31-3
35A	600	SS	0	40	60	44	49	B31-8
38A	2500	SS	0	20	50	253	280	B31-8
91A	150	CS-GALVA	0	30	80	3,2	5	B31-3
91A	150	CS-GALVA	0	amb	50	2	4	B31-3
10P	150	HDPE	0	amb	50	10	12	B31-3

Piping material class specification

SERVICE : DRAIN (BD) HYDROCARBON GAS (P)	GENERAL MATERIAL : CARBON STEEL API 5L Gr. B, X52, X65 — Corrosion Allowance = 0	RATING : 2500# RTJ	PIPING CLASS : 18A — Page : 1/3

Limits — CODE: ASME B31-8

T °C	-29	38	121	160
P Barg	265	278	278	265

	DIA from	DIA to	Sched./ WT(mm) Rating	End	Material standard	Dimensions standard	DESIGNATION	NOTES
PIPE	1/2"	3/4"	160	BE	API 5L Gr B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	1"	1"½	XXS	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	2"	2"	160	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	4
	3"	3"	80	BE	API 5L Gr X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	4
	4"	14"	120	BE	API 5L Gr.X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	4
	16"	24"	(*)	BE	API 5L Gr.X65-MDS-CS06	ASME B36 10	S.A.W. WELDED PIPE (*) 16" thk = 25.4, 18" thk = 28.58 20" thk = 31.75 , 24" thk =38.1	4
FORGED STEEL FITTING B.W	1/2"	2"		BW	ASTM A105-MDS CS01	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
	3"	14"		BW	A694- F52-MDS CS03	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
	16"	24"		BW	A694- F65-MDS CS05	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
FORGED STEEL FITTING BUTT WELDING	1/2"	3/4"	160	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	1"	1"½	XXS	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	2"	2"	160	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	3"	3"	80	BW	MSS SP-75 WPHY 52-MDS CS03	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	4"	14"	120	BW	MSS SP-75 WPHY 52-MDS CS03	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	16"	24"	pipe thk	BW	MSS SP-75 WPHY 65-MDS CS05	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	1
FLANGES	1/2"	2"	2500# RTJ	BW	ASTM A105-MDS CS01	ASME B16.5	WELDING NECK FLANGE	1
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS03	ASME B16.5	WELDING NECK FLANGE	1
	14"	14"		BW	A694-F52-MDS CS03		HUB CONNECTOR (BW AS PER ASME B16-25)	1-2-3
	16"	24"		BW	A694-F65-MDS CS05		HUB CONNECTOR (BW AS PER ASME B16-25)	1-2-3
	2"	2"	2500# RTJ	BW	ASTM A105-MDS CS01	ASME B16.36	2 ORIFICE WN FLANGE + 1/2"PLUG+JACK SCREW	1
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS03	ASME B16.36	2 ORIFICE WN FLANGE + 1/2"PLUG+JACK SCREW	1
	1/2"	12"	2500# RTJ	-	ASTM A105-MDS CS01	ASME B16.5	BLIND FLANGE	
	14"	24"		-	A694-F52-MDS CS03		BLIND HUB CONNECTOR	2-3
GASKET	1/2"	12"	2500#		SOFT IRON (90 HB max)	ASME B16.5,B16.20	OCTAGONAL RING- JOINT GASKET	
	14"	24"			AISI 4140		SEAL RING FOR HUB CONNECTOR (FOR CLAMP-TYPE DEVICE)	2-3
BOLTING					A193Gr.B7+ Zn Bichr. A194Gr.2H+ Zn Bichr.	ASME B16.5 ASME B1.1	STUD BOLT & 2 HEAVY HEX. NUTS DIA≤1"COARSE Series, DIA >1" 8 THREADS series	
						ASME B1.1	SPECIAL BOLTING FOR CLAMP-TYPE DEVICE	3

Such specification defines:

- the metallurgy, specified by reference to an international material standard, e.g., API-5L,

SERVICE : DRAIN (BD) HYDROCARBON GAS (P)	GENERAL MATERIAL : CARBON STEEL API 5L Gr. B, X52, X65	RATING : 2500# RTJ	PIPING CLASS : 18A
	Corrosion Allowance = 0		Page : 1/3

Limits					CODE: ASME B31-8
T °C	-29	38	121	160	
P Barg	265	278	278	265	

	DIA from	DIA to	Sched./ WT(mm) Rating	End	Material standard	Dimensions standard	DESIGNATION	NOTES
PIPE	1/2"	3/4"	160	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	1"	1"½	XXS	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	2"	2"	160	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	4
	3"	3"	80	BE	API 5L Gr.X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	4
	4"	14"	120	BE	API 5L Gr.X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	4
	16"	24"	(*)	BE	API 5L Gr.X65-MDS-CS06	ASME B36.10	S.A.W. WELDED PIPE : (*) 16" thk = 25.4, 18" thk = 28.58 20" thk = 31.75 , 24" thk =38.	4
FORGED STEEL FITTING B.W.	1/2"	2"		BW	ASTM A105-MDS CS01	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
	3"	14"		BW	A694- F52-MDS CS0			
	16"	24"		BW	A694- F65-MDS CS0			
FORGED STEEL FITTING BUTT WELDING	1/2"	3/4"	160	BW	A234-WPB-MDS SC			
	1"	1"½	XXS	BW	A234-WPB-MDS SC			
	2"	2"	160	BW	A234-WPB-MDS SC			
	3"	3"	80	BW	MSS SP-75 WPHY 52-MD			
	4"	14"	120	BW	MSS SP-75 WPHY 52-MD			
	16"	24"	pipe thk	BW	MSS SP-75 WPHY 65-MD			
FLANGES	1/2"	2"	2500# RTJ	BW	ASTM A105-MDS CS			
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS0			
	14"	14"		BW	A694-F52-MDS CS0			
	16"	24"		BW	A694-F65-MDS CS0			
	2"	2"	2500# RTJ	BW	ASTM A105-MDS CS			
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS0			
	1/2"	12"	2500# RTJ	-	ASTM A105-MDS CS			
	14"	24"		-	A694-F52-MDS CS0			
GASKET	1/2"	12"	2500#		SOFT IRON (90 HB n			
	14"	24"			AISI 4140			
BOLTING					A193Gr B7+ Zn Bichr			
					A194Gr.2H+ Zn Bichr			

CHEMICAL REQUIREMENTS FOR HEAT ANALYSES (Section 6)

Type of pipe	Grade	Carbon maxi % (1)	Manganese maxi % (1)	Phosphorus maxi %	Sulfur maxi %
seamless					
Non-expanded or cold expanded	A	0.22	0.90	0.030	0.030
	B(6)	0.27	1.15	0.030	0.030
Non-expanded	X42	0.29	1.25	0.030	0.030
	X46(4), X52(4),	0.31	1.35	0.030	0.030
Cold expanded	X42(4), X46(4), X52(4),	0.29(2)	1.25	0.030	0.030
Non-expanded or cold expanded	X56(3,4), X60(3,4)	0.26	1.35	0.030	0.030
	X65, X70, X80	(by agreement)			

TENSILE REQUIREMENTS (Section 6)

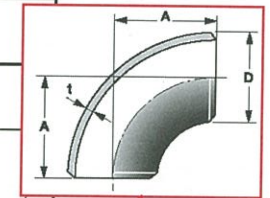
Grade	Yield strength minimum ksi	Yield strength minimum MPa	Ultimate tensile strength minimum ksi	Ultimate tensile strength minimum MPa	Ultimate tensile strength maximum ksi	Ultimate tensile strength maximum MPa	Elongation minimum percent in 2 in. (50.8 mm)
A	30.0	207	48.0	331			See note (1)
B	35.0	241	60.0	413			
X42	42.0	289	60.0	413			
X46	46.0	317	63.0	434			
X52	52.0	358	66.0	455			
X56	56.0	386	71.0	489			
X60	60.0	413	75.0	517			

- the geometry/dimensions, by reference to international dimensional standard, e.g., ASME B16.9 for the elbows (defining the length, etc.),

SERVICE : DRAIN (BD) HYDROCARBON GAS (P)	GENERAL MATERIAL : CARBON STEEL API 5L Gr. B, X52, X65	RATING : 2500# RTJ	PIPING CLASS : 18A
	Corrosion Allowance = 0		Page : 1/3

Limits					CODE: ASME B31-8
T °C	-29	38	121	160	
P Barg	265	278	278	265	

	DIA from	DIA to	Sched./ WT(mm) Rating	End	Material standard	Dimensions standard	DESIGNATION	NOTES
PIPE	1/2"	3/4"	160	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	1"	1"½	XXS	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	2"	2"	160	BE	API 5L Gr.B-MDS-CS01	ASME B36.10	SEAMLESS PIPE	
	3"	3"	80	BE	API 5L Gr.X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	
	4"	14"	120	BE	API 5L Gr.X52-MDS-CS04	ASME B36.10	SEAMLESS PIPE	4
	16"	24"	(*)	BE	API 5L Gr.X65-MDS-CS06	ASME B36.10	S.A.W. WELDED PIPE : (*) 16" thk = 25.4, 18" thk = 28,58 20" thk = 31.75 , 24" thk =38.1	4
FORGED STEEL FITTING B.W.	1/2"	2"		BW	ASTM A105-MDS CS01	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
	3"	14"		BW	A694- F52-MDS CS03	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
	16"	24"		BW	A694- F65-MDS CS05	MSS SP-97	WELDOLET (BW AS PER ASME B16-25)	1
FORGED STEEL FITTING BUTT WELDING	1/2"	3/4"	160	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	1"	1"½	XXS	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	2"	2"	160	BW	A234-WPB-MDS SC01	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	3"	3"	80	BW	MSS SP-75 WPHY 52-MDS CS03	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	4"	14"	120	BW	MSS SP-75 WPHY 52-MDS CS03	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	
	16"	24"	pipe thk	BW	MSS SP-75 WPHY 65-MDS CS05	ASME B16.9	45°, 90°ELBOW, TEE, RED. TEE, CAP, REDUCER	1
FLANGES	1/2"	2"	2500# RTJ	BW	ASTM A105-MDS CS01	ASME B16.5	WELDING NECK FLANGE	1
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS03	ASME B16.5	WELDING NECK FLANGE	1
	14"	14"		BW	A694-F52-MDS CS03		HUB CONNECTOR (BW AS PER ASME B16-25)	1-2-3
	16"	24"		BW	A694-F65-MDS CS05		HUB CONNECTOR (BW AS PER ASME B16-25)	1-2-3
	2"	2"	2500# RTJ	BW	ASTM A105-MDS CS01	ASME B16.36	2 ORIFICE WN FLANGE + 1/2"PLUG+JACK SCREW	1
	3"	12"	2500# RTJ	BW	A694-F52-MDS CS03	ASME B16.36	2 ORIFICE WN FLANGE + 1/2"PLUG+JACK SCREW	1
	1/2"	12"	2500# RTJ	-	ASTM A105-MDS CS01	ASME B16.5	BLIND FLANGE	
	14"	24"		-	A694-F52-MDS CS03		BLIND HUB CONNECTOR	2-3
GASKET	1/2"	12"	2500#		SOFT IRON (90 HB max)	ASME B16.5,B16.20	OCTAGONAL RING- JOINT GASKET	
	14"	24"			AISI 4140		SEAL RING FOR HUB CONNECTOR (FOR CLAMP-TYPE DEVICE)	2-3
BOLTING					A193Gr.B7+ Zn Bichr.	ASME B16.5	STUD BOLT & 2 HEAVY HEX. NUTS	
					A194Gr.2H+ Zn Bichr.	ASME B1.1	DIA≤1"COARSE Series, DIA >1" 8 THREADS series	
						ASME B1.1	SPECIAL BOLTING FOR CLAMP-TYPE DEVICE	3



- the wall thickness (by steps, called schedules, for standardization reasons), for each diameter, which is calculated as per the applicable design code, pressure, temperature, material properties and allowance for corrosion.

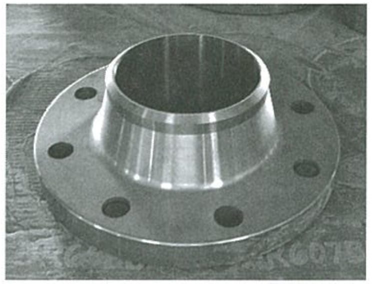
Piping wall thickness calculation

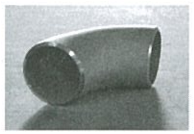
CLASS 18A : DIA ≥ 16" (CS 2500#)

CODE :		ASME B31-8
CLASS:		**18A : DIA ≥ 16" (CS 2500#)**
MATERIAL:		**API 5L Gr. X65 SAW : Ø ≥ 16"**
DESIGN PRESSURE:	bar	265
P	MPa	26,5
DESIGN TEMPERATURE:	°C	160
SPECIFIED TENSILE:	PSI	77000
	MPa	531,03
SPECIFIED YIELD:	PSI	65000
S	MPa	448,28
DESIGN FACTOR F		0,5
LONG. JOINT FACTOR E		1
CORROSION ALLOWANCE:		0
TEMP DERATING FACTOR T		0,9534

$$P = \frac{2St}{D} FET$$

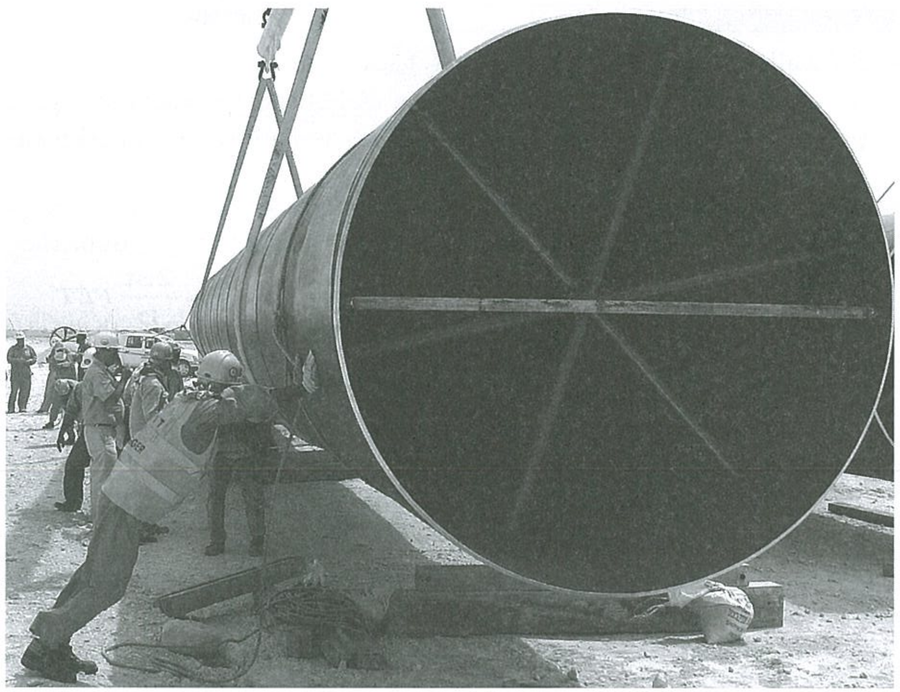
DIA DN	DIA D (mm)	thickness (mm) Min.	thickness (mm) selected
16"	406,4	25,20	**25,40**
18"	457	28,34	**28,58**
20"	508	31,50	**31,75**
24"	610	37,82	**38,10**
30"	762	47,25	**48,00**





Every piping item, besides straight lengths, must be counted in order to be purchased: elbows, tees, flanges, etc.

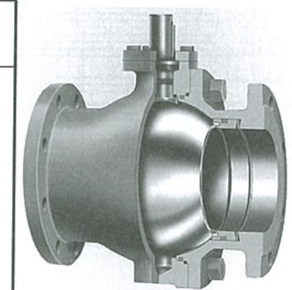
Using the P&IDs (for item count) and the Piping Layout drawings (for lengths), a preliminary list of the required piping material, called first **Piping Material Take-Off (MTO)**, is prepared. Typically, the first MTO will focus on long lead time items (large diameter, unusual materials) rather than standard off-the shelf ones (ordinary carbon steel, usual diameter). The first purchase order of piping material is placed for typically 70% of the quantities of the first MTO. This allows to start procuring piping material to ensure first supply to Site at an early date, while avoiding wastage: as only 70% is ordered, no excess material will have been ordered even if quantities decrease by up to 30% during detailed design.



Subsequent revisions of the piping Material Take-Off will be automatically generated by the 3D design software (see corresponding section). The designer will route each line in the 3D model, by selecting items (straight runs, elbows) from a catalog, for the corresponding piping class. The software will then produce the consolidated list of items, for all lines.

The specification of valves is a major task of the Piping engineer. It includes very detailed material requirements for valve internals, i.e., type of alloy required for trim, material of gaskets, etc. Indeed, these moving parts are subject to severe operating conditions (erosion, compression) and require specific material selection.

SERVICE : HYDROCARBON GAS (P)					GENERAL MATERIAL : ASTM A333 Gr. 6	RATING : 2500# RTJ	PIPING CLASS : 28A
					Corrosion Allowance = 0		
	DIA						
	from	to	Rating	End	DESIGNATION	Standard	Valve data sheet / Comments
BALL VALVE	1/2"	1"1/2	2500#	BW	Full bore with BW Nippples, Trunnion ball, 3-piece body Body:LTC Steel Trim: 17/4 PH impact tested at -46°C Seats/Seals: PEEK / Viton or equal	API 6D ASME B16-34	VB 01-1-28A
	2"	20"	2500#	BW	Full bore, welded body with BW pup pieces Trunnion ball Body:LTC Steel Trim: 17/4 PH impact tested at -46°C Seats / Seals PEEK or PTFCE / PTFE	API 6D ASME B16-34	VBF 01-2-28A
	2"	20"	2500#	BW	Reduced bore, welded body with BW pup pieces Trunnion ball Materials: Same as above	API 6D ASME B16-34	VB 01-2-28A

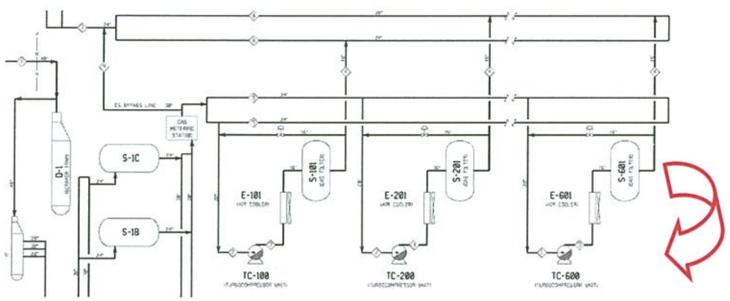


The Piping material specialist will review the valve vendors drawings and check that the material offered for the valve body, trim, gaskets, etc. are compliant or equivalent to the ones specified in the specification and valves data sheets.

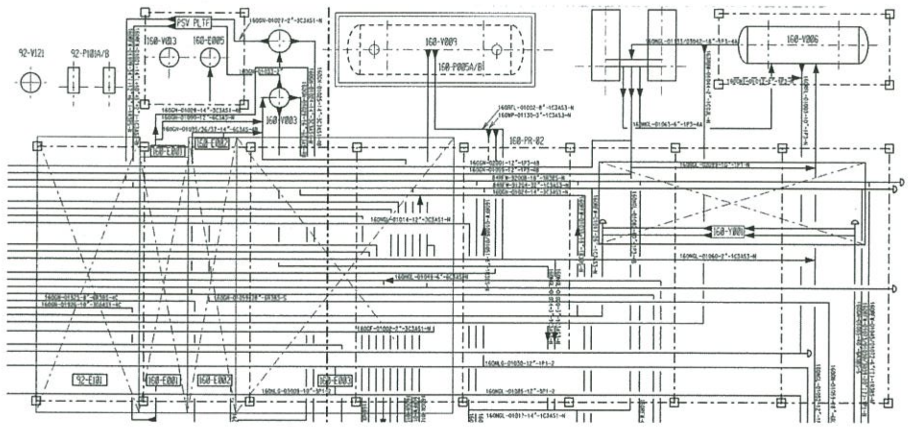
Piping routing studies starts from the Process Flow Diagrams, which show which interconnections are to be made between equipment, and the Plot Plan, which shows the location of these equipment.

Line Diagrams, also called "line shoot diagrams", are produced from Process and Utility flow diagrams, showing all pipes going from a particular plant area to another, regardless of the pipe services. These are geographical drawings, compared to Process and Utility flow Diagrams which are functional diagrams.

They allow to identify the required location and width of the main pipe ways/racks.



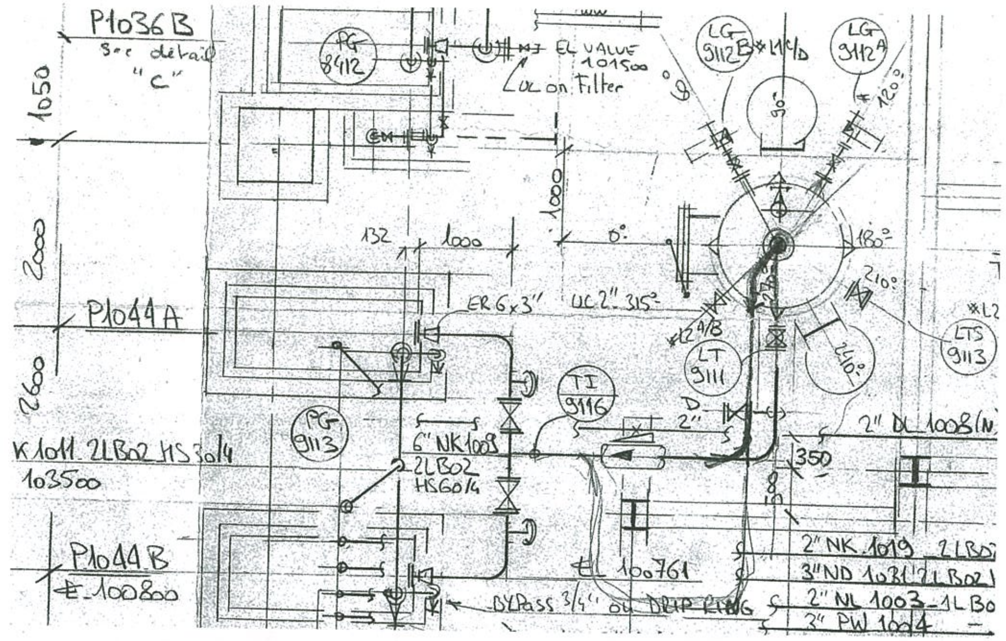
Line Diagram



Piping installation studies are then done to precisely define the routing of pipes, e.g., from pipe-rack to equipment, etc.

The installation specialist needs to have a general view encompassing a large number of requirements:

- Process requirements: a fluid in gravity flow, for instance, will require a sloped line routing, very low pressure drop allowance will require a very short routing, etc.
- Equipment details: elevation of nozzles for pressure vessels, dictated by process and shown on equipment guide drawings.



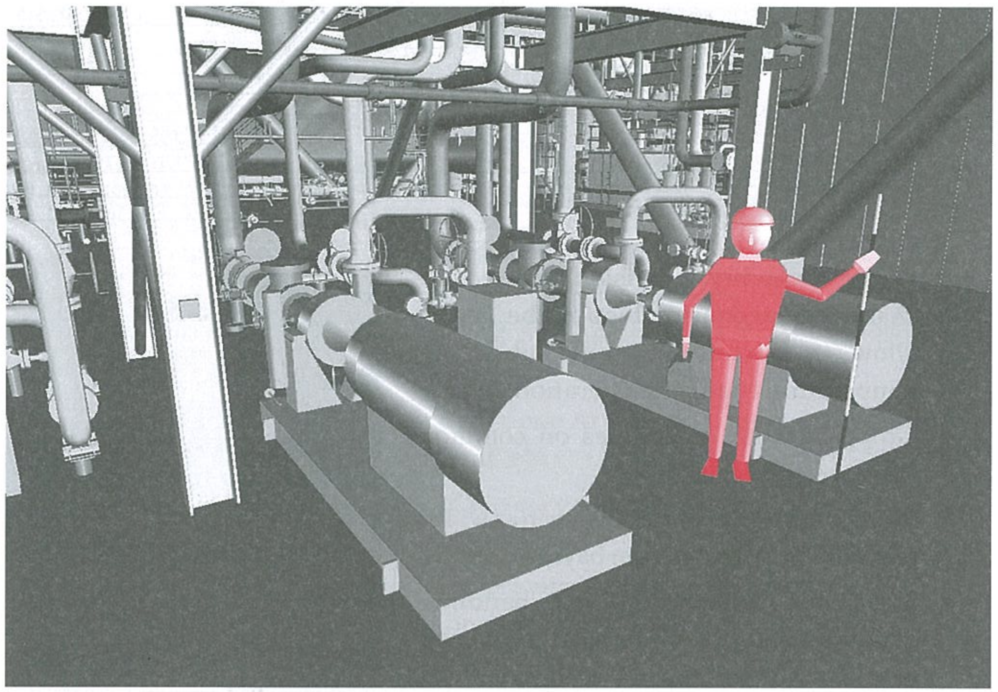
- Piping flexibility: provision of direction changes or expansion loop in the line to allow its expansion while subject to temperature change in operation[1],
- Grouping with other lines on common support/pipe-rack,
- Structural design constraints, such as width of piperack, span between bays, etc.,
- Space for dismantling and handling of equipment for maintenance: provision of clearance on top of equipment for

1. The straight routing of a line between two vessels would cause excessive forces on the vessels when the line temperature increases due to thermal expansion. Instead, a routing with a number of direction changes, or even a purpose-made expansion loop, must be adopted to allow the line to expand.
Detailed stress calculations are performed at a later stage in the design, to confirm that the routing of critical lines (high temperature, etc.) provides enough flexibility. The key is to be able to guess a correct routing, before these calculations are done. Indeed, they go into many details (location of supports, etc.) so that it would not be feasible to test a number of possible routings. The calculations will then simply validate the guessed routing.

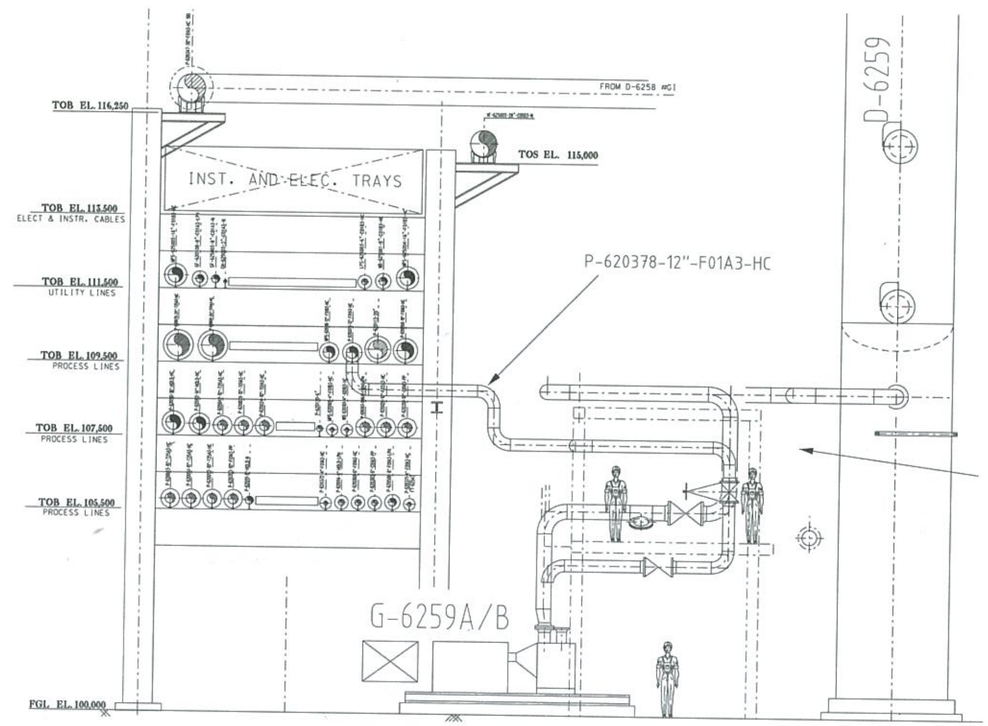
hoisting equipment, clearance for heat exchanger bundle pull-out, lay down area for dismantled parts, vehicle/forklift access where required, etc.

- Operator access: hand wheels of valves, instruments must be accessible to operators and therefore be placed at a suitable elevation. These ergonomics consideration are essential for the plant safe operation and are called Human Factor Engineering.

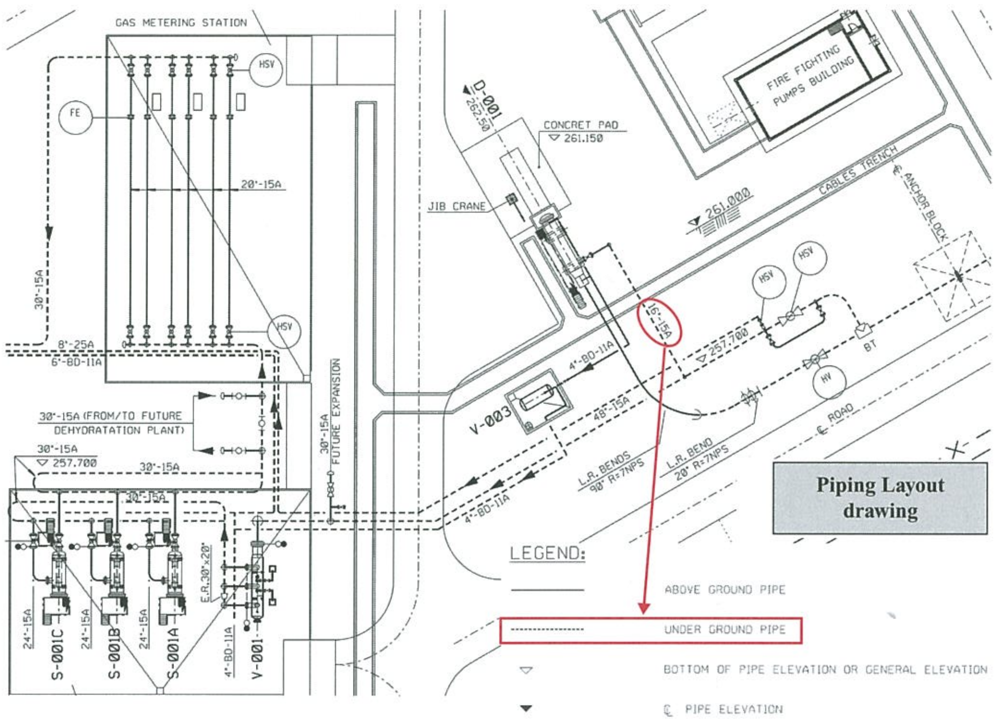
The above requirements translate into typical piping arrangements around control valves, pumps, which ensure sufficient working area for operational and maintenance tasks. For a pump, it would for instance include easy access to drain valves, space to remove the inlet strainer, etc.



Piping studies set the widths of pipe ways, the requirements for piping and equipment support structures, such as the elevation of concrete support structures for equipment, the width and number of levels of pipe-racks, etc.

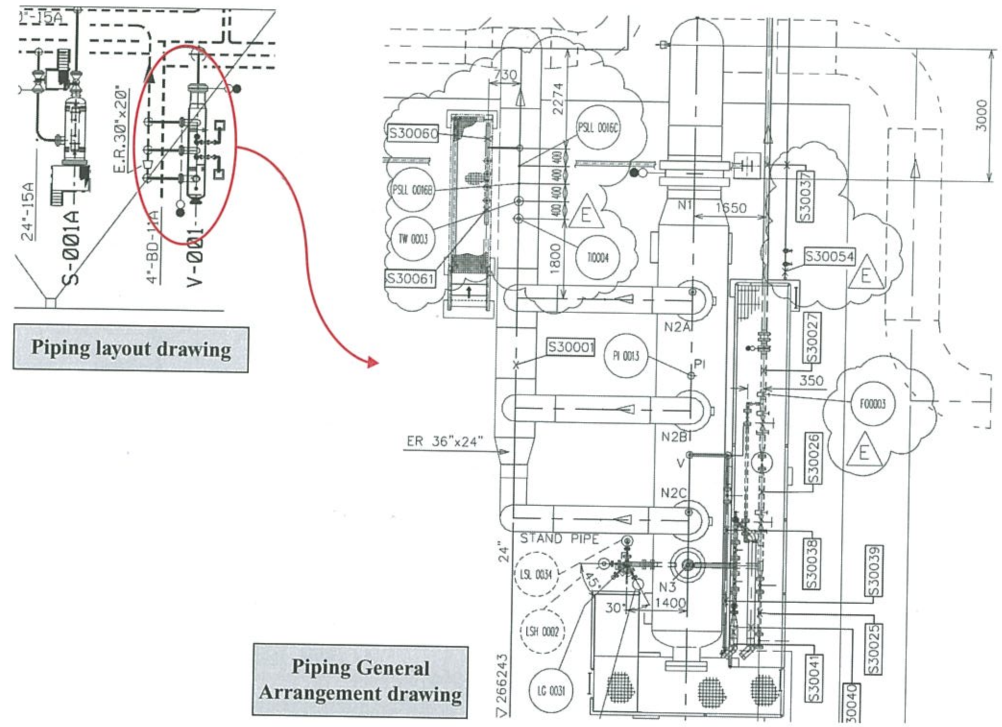


The 2D routing of the main lines is drawn on the **Piping Layout drawings**.



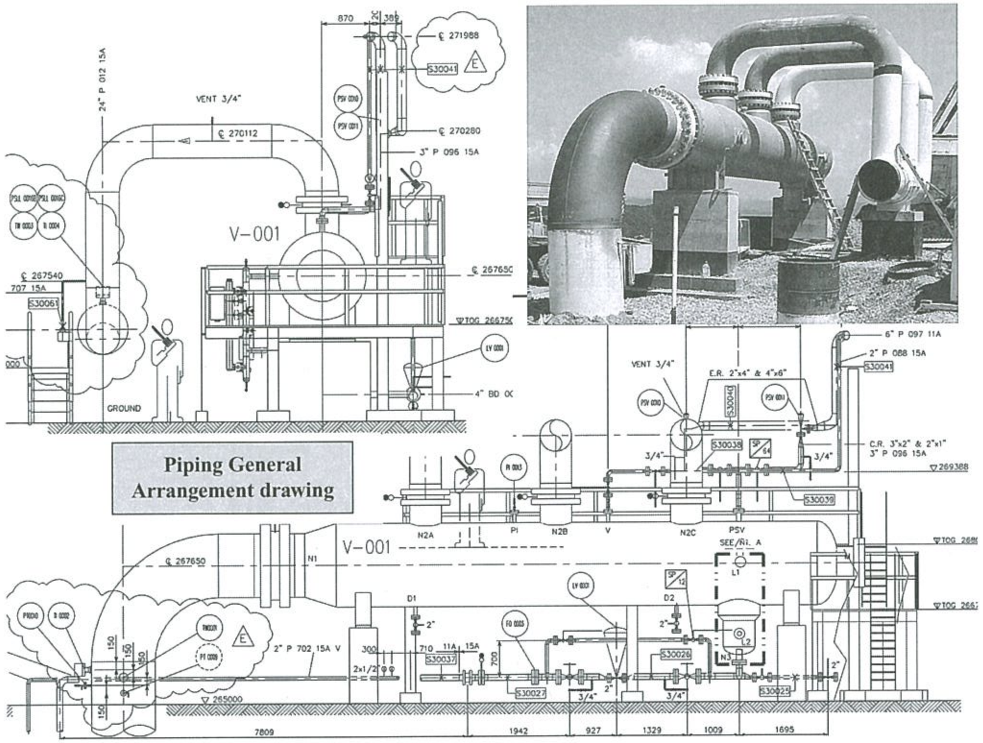
As explained above, the Piping Layout drawings allow to determine pipe lengths and to produce the first Piping Material take-off.

Besides layout drawings, Piping issues construction drawings, which are of two types: the **General Arrangement Drawings**, which are used for piping erection, and the **Isometric Drawings**, which are used for piping pre-fabrication.



The **Piping General Arrangement drawings** are very detailed. They contain all information necessary for erection of piping: all dimensions, elevations, position of in-line items, etc. They were originally produced to allow the production of Isometric drawings, when the latter was a manual task. As a the 3D model software is now used to produce Isometrics, Piping General Arrangement drawings are no longer systematically produced.

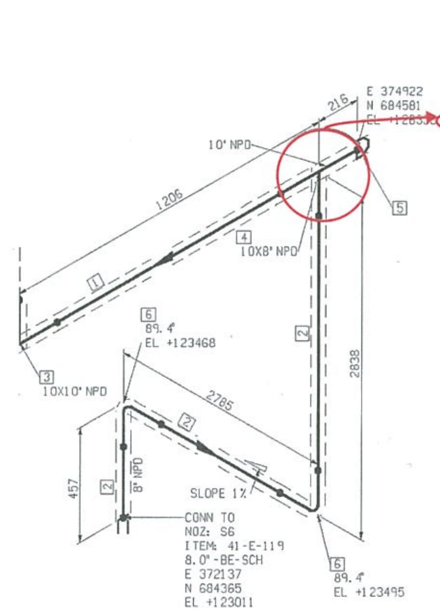
They were also used to give a view of the complete environment within an area, showing all equipment, pipes, valves, structures, etc. They tend nowdays to be replaced by snapshots taken from the 3D model.



Piping General Arrangement drawing

Piping Isometric Drawings show a 3D view of an individual line, with all the dimensions defining its geometry and the list of all its components (straight length, elbows, etc.).

Piping isometric drawing

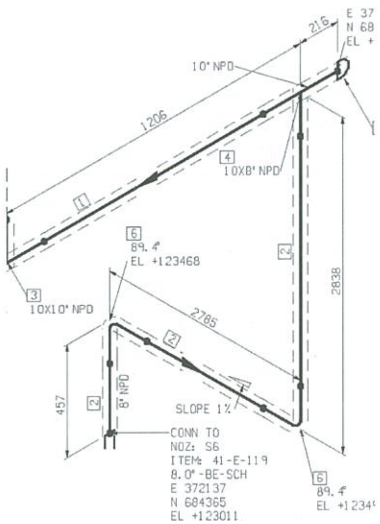


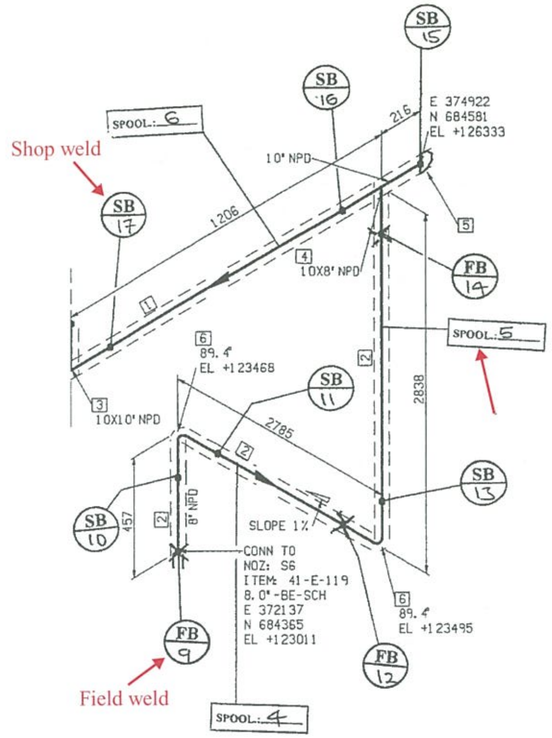
SHOP MATERIAL

PT NO	COMPONENT DESCRIPTION	DIAM (NS)	IDENT CODE	STOCK CODE	QTY
	PIPE				
1	PIPE, ASME B36.10, , ASME SA106 GR. B, BE, SEAMLESS, IN 10 X S-120	10	C1GABM1	PP2C1FHM1P0000	1956 MM
2	PIPE, ASME B36.10, , ASME SA106 GR. B, BE, SEAMLESS, IN 8 X S-120	8	C6D8E9	PP2C1FHM1P0000	9338 MM
	FITTINGS				
3	EQUAL TEE, ASME B16-9, ASME SA234 GR. WPB, BW, SEAMLESS, IN 10 X S-120	10X10	[illegible]	DTE2CORAM10000	1
4	REDUCING TEE, ASME B16-9, ASME SA234 GR. WPB, BW, SEAMLESS, IN 10 X S-120 / IN 8 X S-120	10X8	C1SNPEB	DTR2CORAM10000	2
5	CAP, ASME B16-9, ASME SA234 GR. WPB, BW, SEAMLESS, IN 10 X S-120	10	C1UCOJA	DCP2CORAM10000	1
6	90 DEG ELBOW LR, ASME B16-9, ASME SA234 GR. WPB, BW, SEAMLESS, IN 8 X S-120	8	C8GAW1	DE92CORAM10000	4

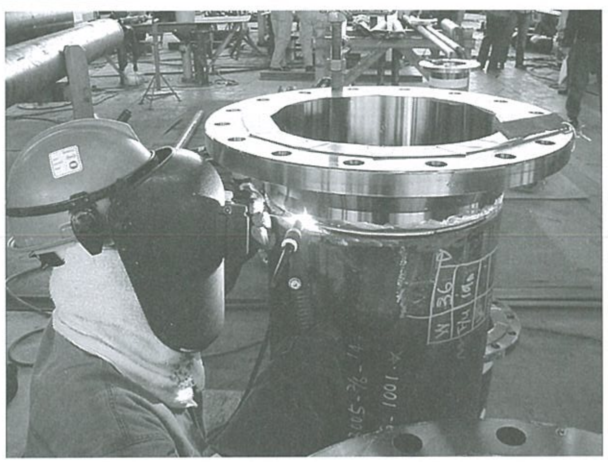
As piping materials are very numerous and resemble each other, e.g., it is not easy to identify one steel alloy from another, identifiers are stamped by the piping material supplier on each item and the identifiers are shown on the Isometric drawings.

The Isometric drawing produced by Engineering is not directly used for construction. Indeed, as the line will be pre-fabricated in parts, called spools, drawings must be issued showing how the line is divided into spools. Shop isometric drawings are issued to this end by the Construction contractor. They are also used to identify welds, each of which will be associated with inspection and test records.

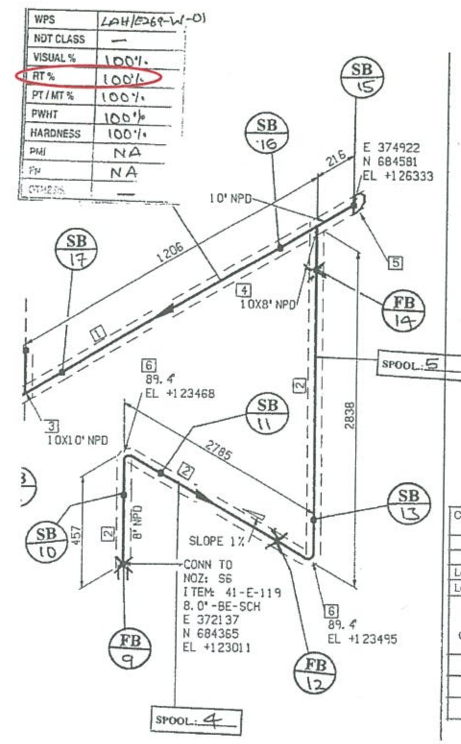




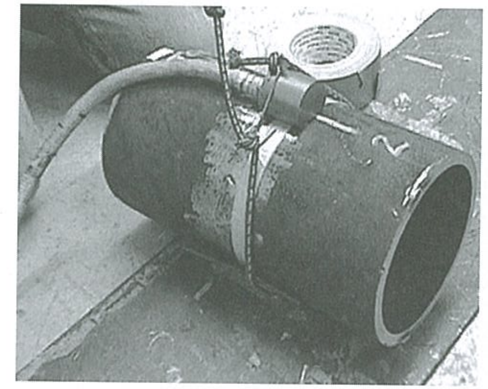
Piping Pre-fabrication:Gas cutting, welding



The fabrication workshop (shop) Isometrics also specify all fabrication requirements, such as the welding procedure to be used, the required inspection (surface of weld or in-depth inspection by means of radiography for instance), special operation such as heat treatment of welds, etc.



Piping Inspection and testing



RADIOGRAPHY REPORT

Customer :

Radiographic Technique			Pb Screen Thickness (mm)	Source Isotope
~~SWSI~~	DWSI	~~DWDI~~	Front & Back : 0·125	Source Strength
Location of Penetrameter	~~Source Side~~ / Film Side		Film Density : 2-3	Ug : 0·28
Location of Markers	~~Source Side~~ / Film Side		Sensitivity : 2%	

Ht/treat Condition	Film Location	Crack	Burn Through	Concave Root	Excess Penetration	Lack of Fusion	Lack of Root Pen.	Slag or El. Defect	Undercut	Porosity	Surface Concavity	Other	Result
N/A	0-12							✓		✓			Acc
	12-24											✓	Acc
	24-0				✓							✓	Acc

The **Line List** produced by Process is completed by Piping, with construction requirements, such as:

- specific non-standard fabrication requirements, such as heat treatment of welds, for high thickness pipes or pipes in corrosive service,
- specific testing requirements of piping material (for alloy steel, to ensure that the material used is the right alloy),
- inspection requirements (also called NDE: Non Destructive Examination) for welds: type, e.g., radiographic examination for gas services or surface defect control only for less critical services, extent of the inspection, e.g., 100% of welds to be tested for gas service, 10% only for non-critical service, etc.

POST WELD HEAT TREATMENT REPORT

Report No: P/HT/97/52
Date: 02 - 04 - 2009

Unit / Area No.: UTILITY
Material: P4 (A.S)

Recorder Sl. No. C-5002
Calibration Date: 10 - 03 - 2009

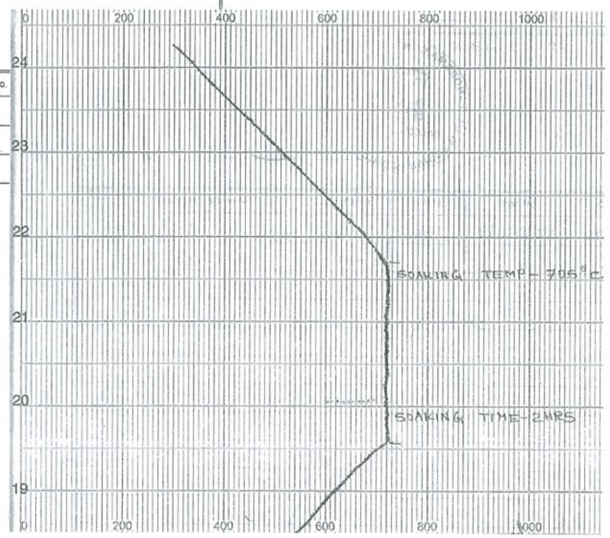
Post Weld Heat Treatment

PWHT CYCLE CONDITION

HRSG-E0-97

1 Heating Rate : 180°c / HR MAX
2 Holding Temperature : 705°c to 745°c
3 Holding Time : 2 HRS MIN
4 Cooling Rate : 180°c / HR MAX
5 Chart Speed : 25 mm / HR

Sr. No.	Drawing No. & Line No.	Size of Joint	Joint No.
1	893 - M - 320ɸ	10"	06
	92SHH - 69003 - 12" -	(12.7mm)	
	- M02 - 1 (SHT-09)		



- pressure test requirements including type (hydraulic, pneumatic test or service test only), depending on criticality of the line service, and pressure,
- type of coating,
- type of insulation (heat conservation, personnel protection, cold insulation) and thickness, etc.

Line Number			Line Size	Class	Line Connection		Paint Code	Insulation		PWHT	Hardness	NDE Requirement		Pressure Test		PMI
Fluid Code	Unit Code	Seq No.			From	To		Code	Thk.			Butt Welds	Fillet Welds	Medium	Press (barg)	
GN	71	61106	22	3C3AS1	LNG STORAGE	UNIT 93	1C	N	NO	YES	YES	A,B	A	H	51,80	0%
GN	71	61106	20	3C3AS1	LNG STORAGE	UNIT 93	1C	N	NO	YES	YES	A,B	A	H	51,80	0%
GN	71	61106	12	3C3AS1	LNG STORAGE	UNIT 93	1C	N	NO	YES	YES	A,B	A	H	51,80	0%
LNG	71	60001	32	3R0JLL	668-P001 A/B/C	LNG RUNDOWN HEADER	7S	6	180	NO	NO	A,D,F	A,F	P	33,00	100%
LNG	71	60001	22	3R0JLL	668-P001 A/B/C	LNG RUNDOWN HEADER	7S	6	170	NO	NO	A,D,F	A,F	P	33,00	100%
DOW	72	63000	0,75	1P1	72-P061A	DOW	1C	N	NO	NO	NO	A,B	A	H	3,00	0%
DOW	72	63001	0,75	1P1	72-P061B	DOW	1C	N	NO	NO	NO	A,B	A	H	3,00	0%
DOW	72	63002	0,75	1P1	72-P062A	DOW	1C	N	NO	NO	NO	A,B	A	H	3,00	0%
DOW	72	63003	0,75	1P1	72-P062B	DOW	1C	N	NO	NO	NO	A,B	A	H	3,00	0%

These inspection and testing requirements are shown on the Piping Isometric drawing in order to make it a document encompassing all information required for construction.

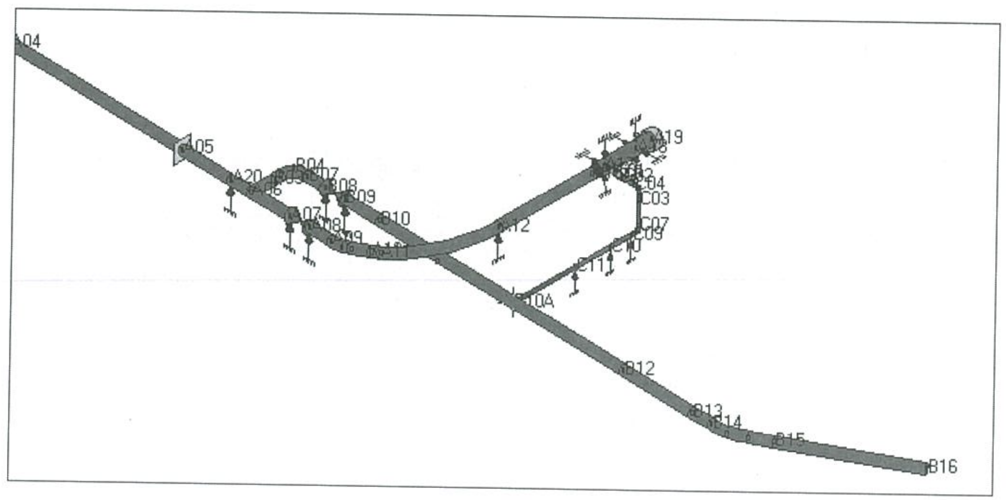
SERVICE CLASS	INSULATION CODE	PAINTING CODE	TEST FLUID	RT (%)	PT or MT (%)	PMI (%)	PWHT	INTERNAL CLEANING	TEMP. DGN. (°C)	TEMP. OPE. (°C)	PRESS. DGN. (Bar.)	PRESS. OPE. (Bar.)	P&ID NO.
151	1	50	H	5	0 0		NO		195	155	7.0	4.1	

It is a very tedious exercise to prepare the numerous piping isometrics (several thousands on a typical size job). Therefore this process is automated using the computer aided 3D design software, in which all the plant pipework is modelled.

The routing of lines done by the Piping designer takes into account good engineering practise and provides for flexibility in the line.

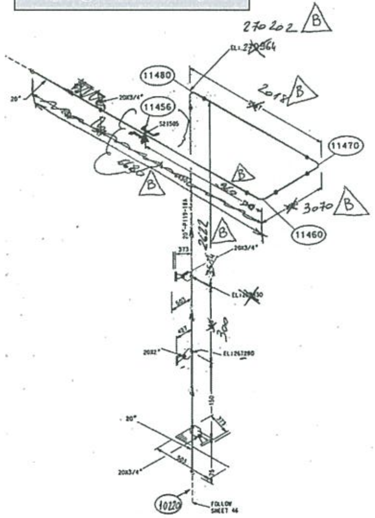
Nevertheless, this routing must be checked by the **Piping Stress Analysis & Supports** group. This is done by calculation of the stress in the line during operation (due to thermal expansion, pressure, etc.) and checking that the stress is within the maximum allowable for the concerned material and at the connection to equipment nozzles. The line installation temperature, i.e., the outside temperature prevailing at Site during the installation of the line, is one input of the calculation. The line thermal expansion is indeed due to the difference between this temperature and the line operating temperature.

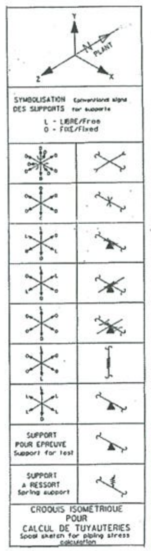
A computer model allowing finite element analysis is used for this purpose.



The results, which confirm that the routing is acceptable, are recorded in **Stress Calculation Note**.

Piping Stress Analysis





2.6. RESULTS

2.6.1. *Stresses*

a) Maximum operating calculated stress is 336.1 MPa < 448 MPa at node 10940,

b) Maximum primary calculated stress is 125.7 MPa < 310 MPa at node 6440,

c) Maximum secondary calculated stress is 206.7 MPa < 323 MPa at node 10940.

2.6.2. *Loads on nozzles*

W+D1+T1+P1+F1+F2 DESIGN CONDITIONS

NODE	EQUIPMENT	NOZZLE ITEM	FX (N)	FY (N)	FZ (N)	MX (Nm)	MY (Nm)	MZ (Nm)
1690	D-002	N3 8" 2500#	2940	-19397	-2174	-8514	-10186	141
1730	D-002	N3 AT THE SHELL	2940	-22579	-2174	-9332	-10186	-1217
550	D-002	N1	-44534	14341	-1885	12567	9766	49525
10580	S-101	N3 16" 2500# AT THE SHELL	-13412	-29622	-19325	49581	-21324	8078
ALLOWABLE LOADS FOR S-101			65526	65526	65526	105151	105151	105151

(W+D1+T1+P1+F1+F2)-(W+P1+F1+F2) THERMAL EXPANSION

NODE	EQUIPMENT	NOZZLE ITEM	FX (N)	FY (N)	FZ (N)	MX (Nm)	MY (Nm)	MZ (Nm)
1690	D-002	N3 8" 2500#	-447	-6026	-2832	-5349	-2422	2937
1730	D-002	N3 AT THE SHELL	-447	-6026	-2832	-6438	-2422	2957
550	D-002	N1	5759	19513	-1371	10044	7562	24947
10580	S-101	N3 16" 2500# AT THE SHELL	-14494	3929	-15772	-1455	-23046	5685

2.6.3. *Loads on restraints*

W+D1+T1+P1+F1+F2 DESIGN CONDITIONS

NODE	RESTRAINT	FRICT.FACTOR	FX (N)	FY (N)	FZ (N)	DX (mm)	DY (mm)	DZ (mm)
1435	REST SUPPORT	0.3	-649	2186	94	-26,4	0,0	4,0
1930	THREE WAY RESTRAINT	/	19090	-38179	-397	0,0	0,0	0,0
2120	REST + LINE STOP	0.3	4175	-13918	1146	1,4	0,0	0,0
2225	REST SUPPORT	0.3	-2958	-13961	2965	-1,1	0,0	1,1

3. CONCLUSIONS

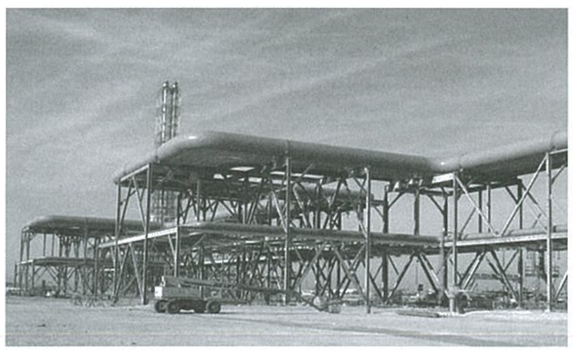
a) Stresses

The stresses in the line are acceptable, lower than allowable values.

b) Loads

The loads on the equipment nozzles are acceptable (lower than allowable values).

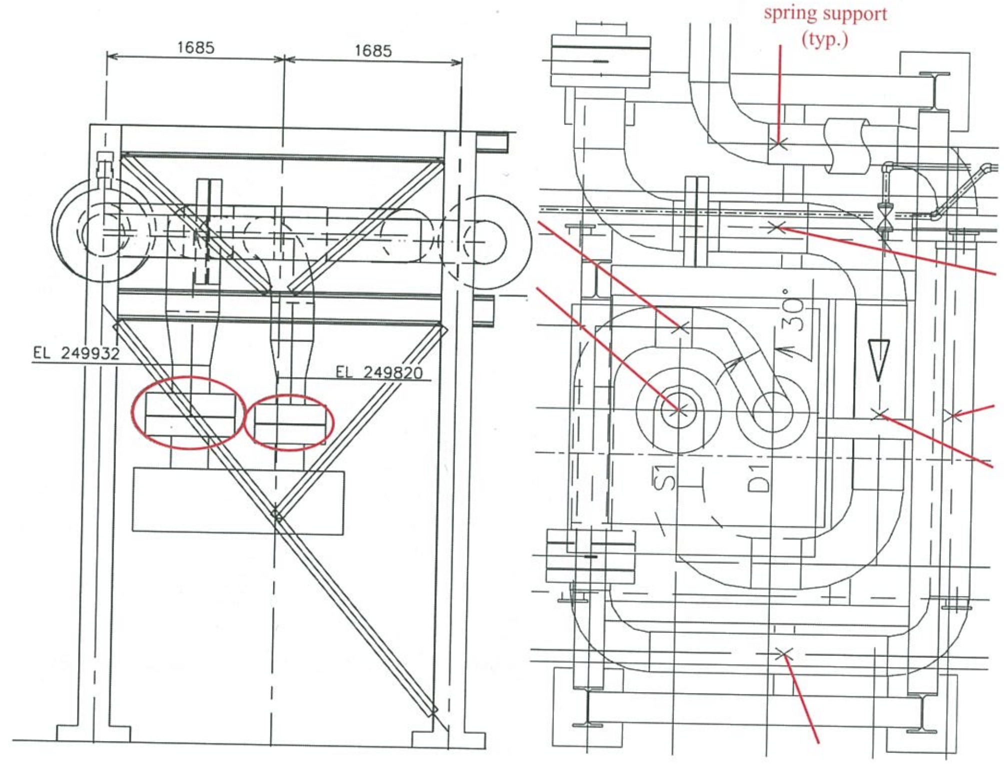
Once the routing is confirmed to be acceptable, the piping Isometric drawings are issued for construction.



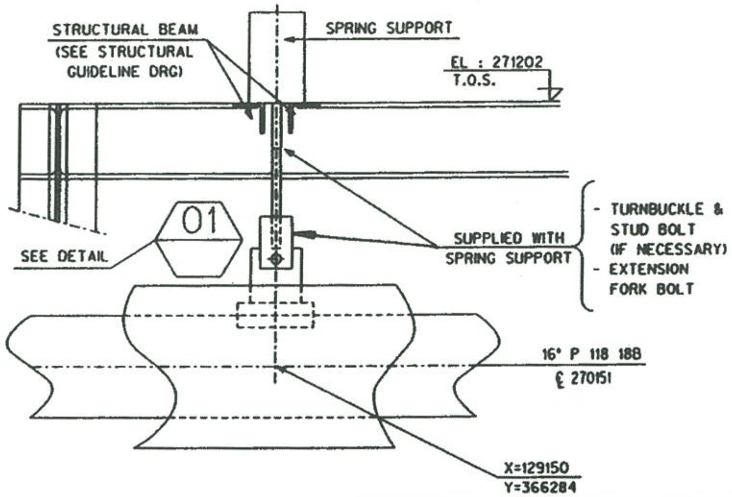
Piping Stress Analysis is systematic for high temperature/ high pressure service and large diameter lines. When such a line comes into service, if it cannot expand, because it is constrained, it will be subject to internal stress, which could exceed the strength of the steel or make the line come off its position and even fall from its supports. Allowance for displacement of the line must be provided in the design, by means of expansion loop and guiding supports. Typically, an expansion loop, such as the one depicted here, is provided to absorb the expansion of the line between two anchor (fixed) points.

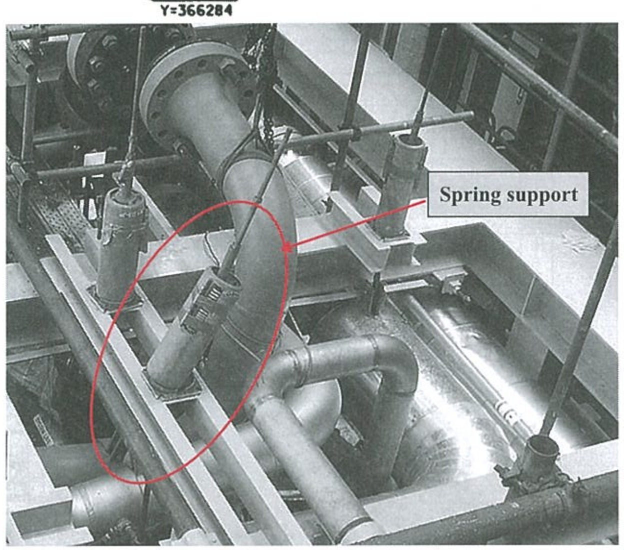
Special attention is paid at connections to rotating equipment, where the flexibility of the inlet & outlet lines must ensure that minimum loads are transferred to equipment nozzles.

Indeed, excessive forces on the connected equipment could result in its displacement. Typically, the driven equipment, a pump, for instance, will be displaced, resulting in its misalignment with the driver (motor). A special pipe routing, such as the one depicted below, is implemented to reduce the loads on the machinery flanges to prevent this.



Spring supports are provided to minimize the connecting lines loads on equipment nozzles.

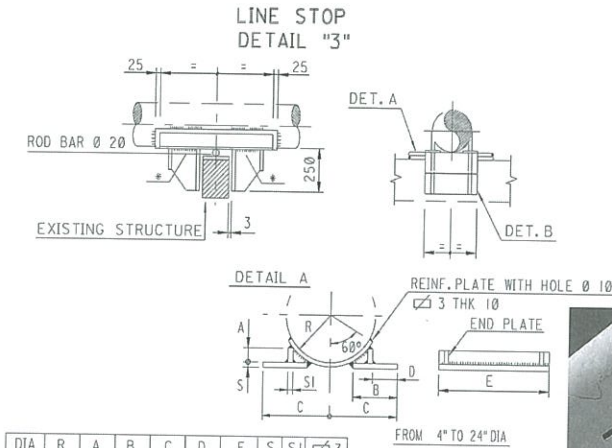




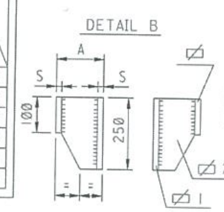
Positions of supports must also allow, during installation of the pipe work, effortless fitting of the pipes connecting to nozzles of rotating machinery. Very stringent tolerances are imposed by vendors in terms of parallelism between pipe flanges and rotating machinery nozzles. Forced connection of piping flanges to machine nozzles using hydraulic tools can generate forces and moments on nozzles and induce shaft misalignment. This can create serious problems to the machine.

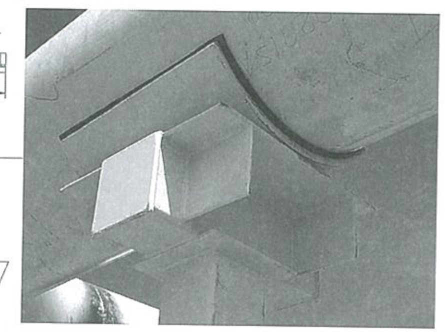
Pipe supports are otherwise standardized to the maximum extent, in order to allow their mass pre-fabrication.

Standard Pipe Support drawings

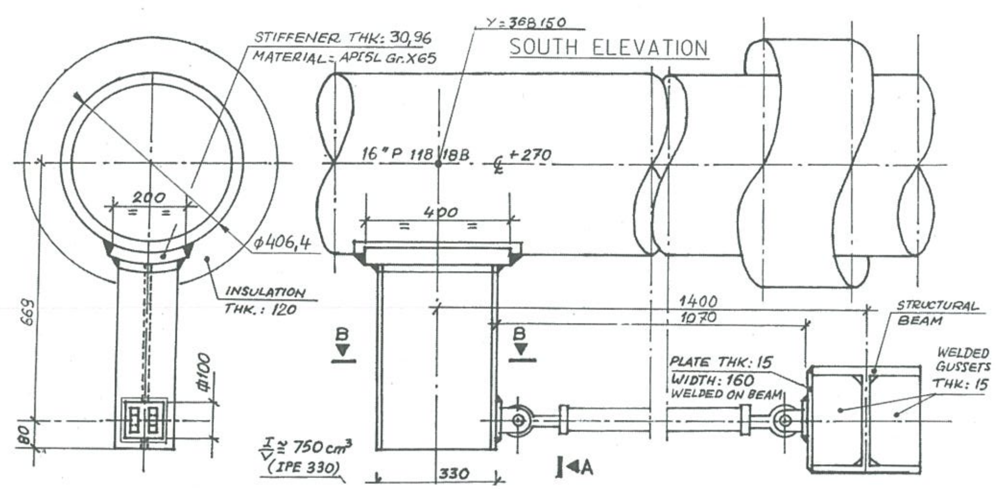


DIA	R	A	B	C	D	E	S	S1	3
4"	57	22	55	80	24	1000	6	6	
6"	84	36	72	103	24				
8"	110	47	87	128	24	1100	8	8	
10"	136	60	104	150	24				
12"	162	71	119	175	26	1200	10		
14"	178	79	131	200	27				380
16"	203	91	147	220	25				420
18"	228	58	144	220	41	1300			480
20"	254	64	155	235	37				530
22"	279	72	168	252	37	1400			580
24"	305	79	184	271	37				640





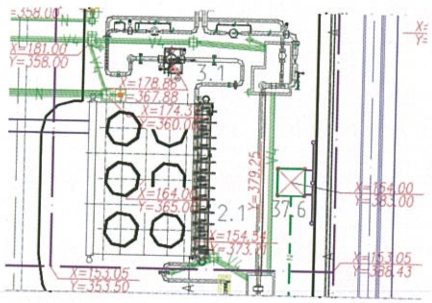
A few pipe supports, called **Special Pipe Supports**, are non standard, for which individual drawings are issued by the Piping Support group.



Chapter 10

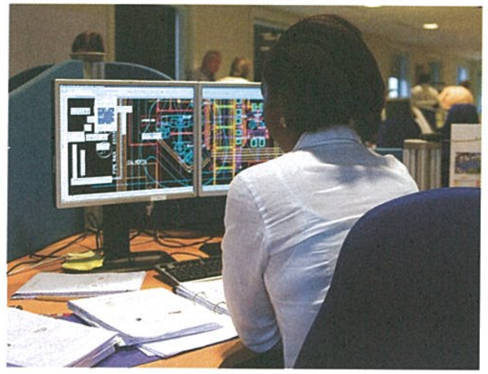
Plant model

Plants, specially Off-Shore platforms, are usually congested due to the limited space available. Several disciplines install their equipment in the same limited space: equipment, pipes, supports, structural steel, cables, etc. This must be coordinated in order to avoid interferences, e.g., pipe and structural steel members installed at the same place, etc.



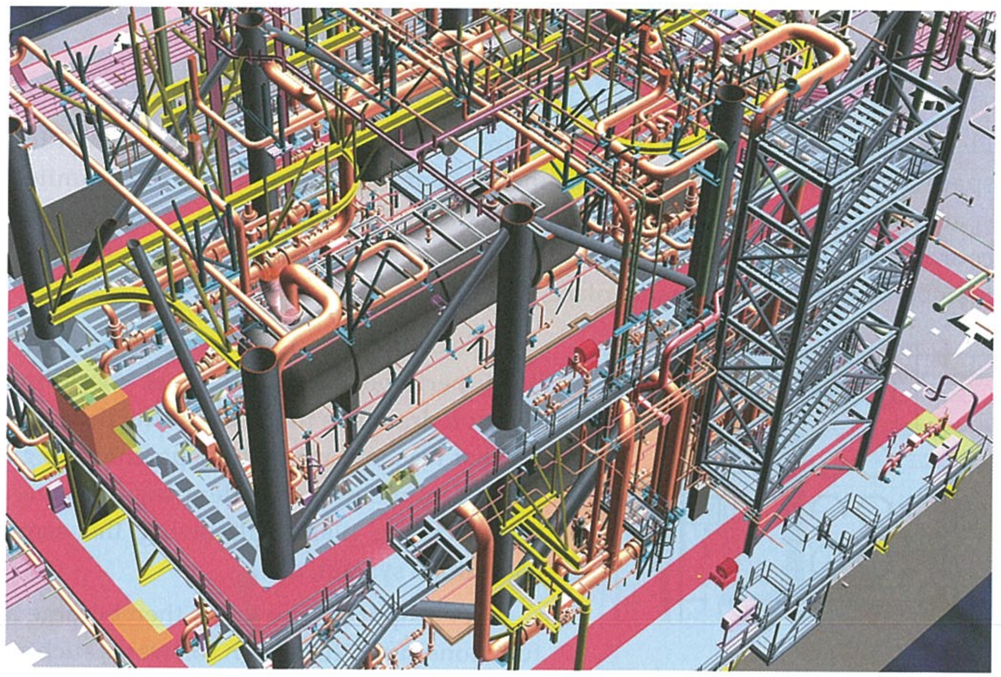
This coordination used to be done in 2D, by superimposing the various discipline location drawings that were at the time and for that reason done on transparencies, e.g., piping, foundations, underground piping, cable routing plans, all having the same coordinate system, etc.

Superimposing drawings then became a functionality of 2D design softwares such as AutoCAD, which allow the various disciplines to work in independent, yet superimposed, layers identified by different colors on the screen, e.g., cable sleeves in green, pipes in black... At any time in its design, the piping engineer can display the civil layout in order to check for civil interference with its own design.



Computer Aided Design systems are now in 3 dimensions, allowing to build a **3D model** of the plant. Models of plants used to be made using glue and plastic parts. This is now replaced by virtual (digital) 3D models, which are stored on a server and can be accessed by many users at the same time and from different locations.

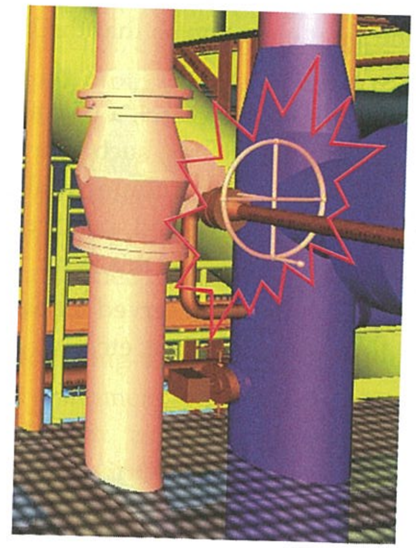
All significant materials are modelled to scale. The model reflects exactly what the plant will be. All buildings, roads, escape ways, structures, equipment, pipes, valves, cable trays, junction boxes, etc. are modelled in details by each engineering discipline.

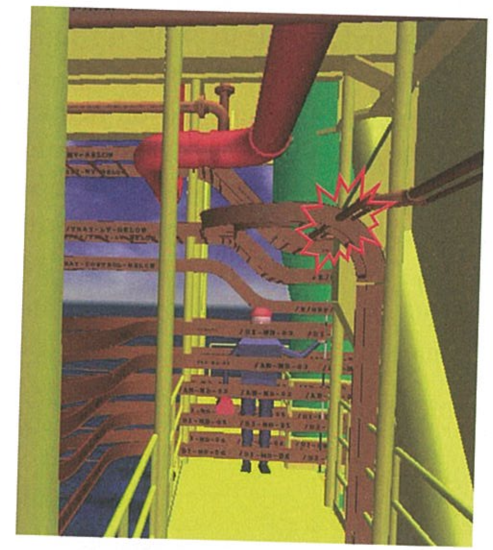


The use of a 3D model is particularly useful for Off-Shore platforms, where space is limited and its use shall be optimized.

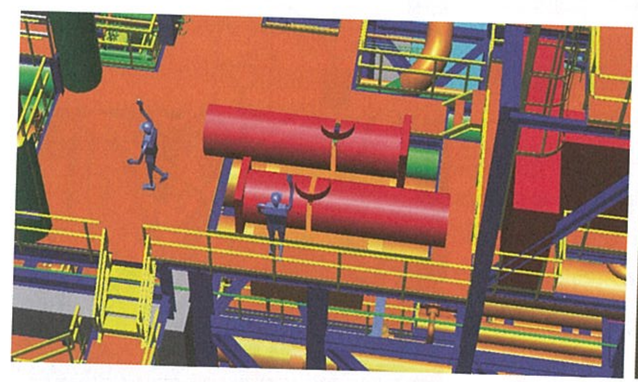
Using such a system allows to identify and clear interferences between disciplines in congested areas. Besides manual visual review of possible interferences in the

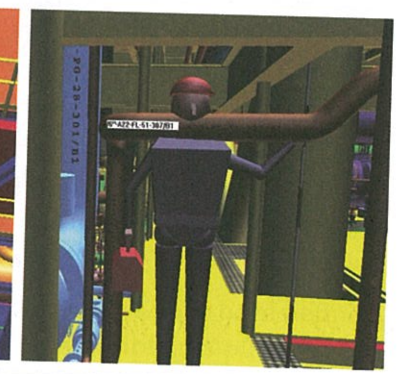
model, the system can perform automatic **clash checks**, in order to pinpoint the interferences left unnoticed.





Model reviews of the virtual plant are carried out at various stages in the design (typically 30%, 60% and 90% progress).



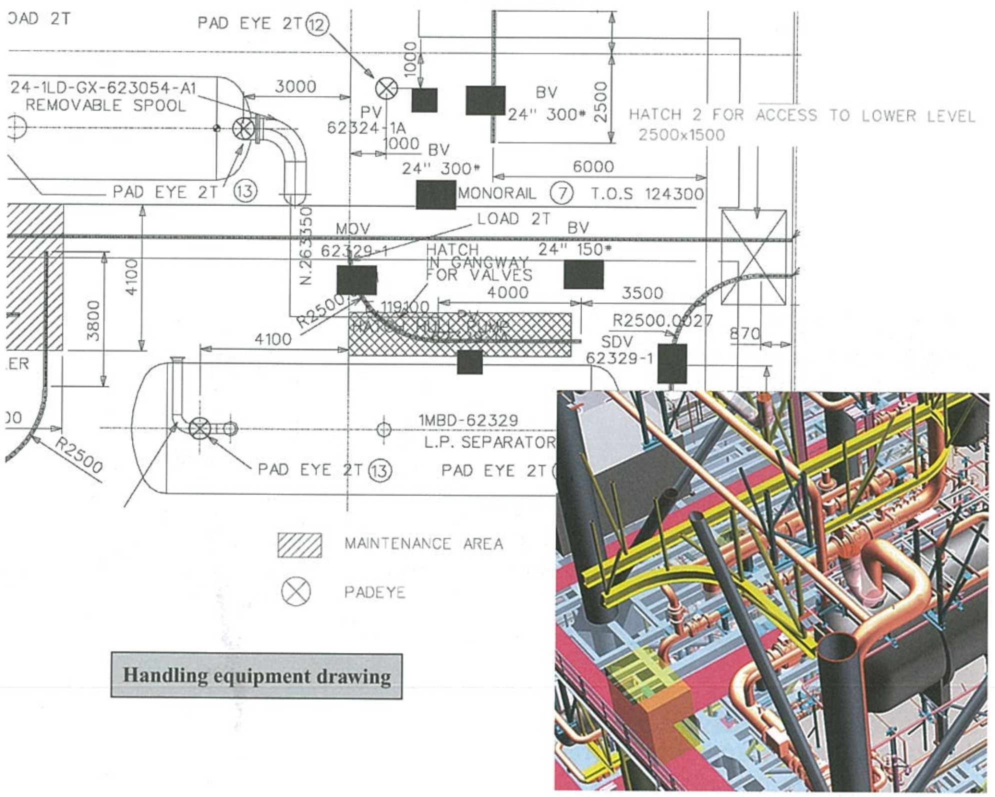


Such reviews allow to check operator accesses, overhead clearances, non-obstruction of escape ways, free space for equipment dismantling during maintenance, etc.

Ideally all disciplines, e.g., structural steel, piping, etc. not only inputs its design objects (steel structure beams and columns, pipework, valves, etc.) in the model but also performs its design in the model itself, rather than on specific discipline models, and issues directly its construction drawings from the model. This ensures that the latest information is in the model, e.g., if a steel beam depth has been recently changed from 1,000mm to 1,200mm, the pipe router will see it immediatly and be able to locate its pipe at the right elevation so that the latter will not clash with the steel beam.

Items modelled include one-off items, such as a pressure vessel, a package, a motorized/control valve, an in-line strainer, and standard items, such as a steel section, a piping elbow, etc. which are part of a catalogue. Using a catalogue allows to define each standard item, complete with detailed dimensions and specification, only once. This information will then appear on all occurrences of this item.

Modelling of virtual objects is also done, such as volumes reserved for escape ways, travel of dismantled equipment/parts during maintenance, etc.



Handling equipment drawing

Modelling of equipment is first done with estimates of equipment dimensions. Indeed, actual dimensions of equipment, which are sized by vendors, are not known initially.

Once vendor information becomes available, the equipment model is up-dated based on vendor drawings: exact dimensions, shapes, nozzle orientation, etc.

When modelling vendor packages, it is very important to model all items of the package, e.g., not only the main equipment, but also structural steel, package internal piping, etc. and to up-date these models with revisions of vendor drawings.

A register of items modelled, complete with indication of reference and revision of the vendor drawing, is maintained in each discipline to this end.

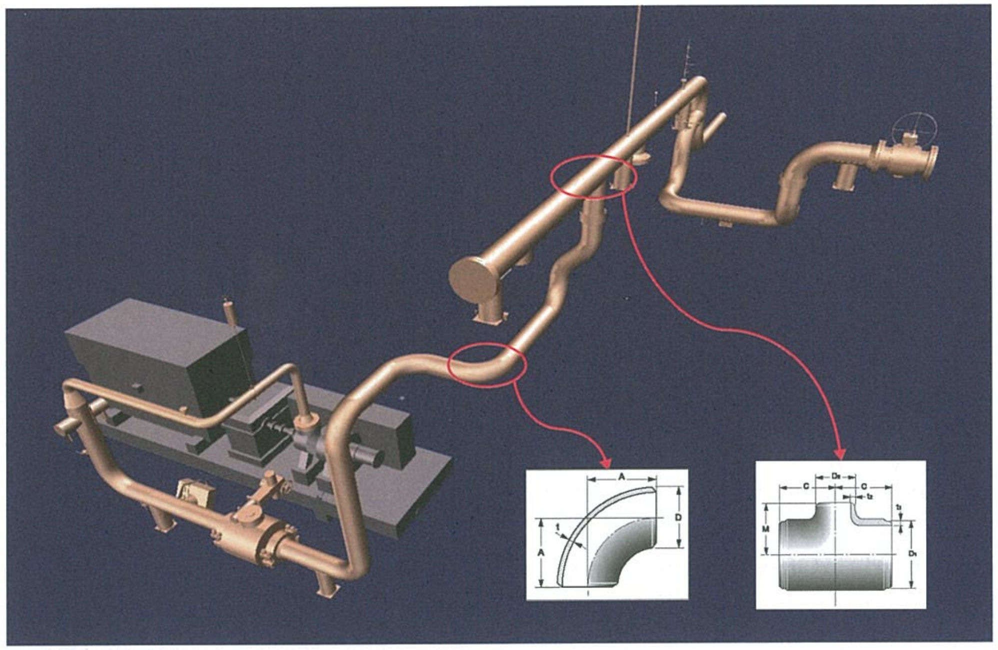
Modelling is not only done for large equipment, but also for smaller ones, such as motorized valves, particularly in Off-Shore environment where space is limited. Dimensions of motorized valves, including their actuators which can be very big, are non standard. Those dimensions will not be known before sizing has been done by the valve vendor.

As engineering progresses, each discipline adds its own objects and networks to the model, e.g., secondary structure, access platforms, stairways, ladders, piping supports, cable trays, instruments, junction boxes, lighting, etc.

In such a way, each designer finds the best location/routing for its items, according to required access, available free space, etc. It also allows to minimize the cost by finding the shortest routes for pipes, cables, etc.

Once equipment have been modelled and main pipe ways have been defined, lines are modelled in the 3D model. As discussed above, piping is purchased in individual components: straight pipes, elbows, tees, reducers, flanges. Each of these components must be modelled. This could be a very lengthy exercise. Fortunately, it is made easy by standardization of piping material and creation of a catalogue of items in the 3D model.

Lines are modelled using the items from the catalogue for the corresponding piping class. This allows a very fast "just pick and place" modelling, provided one has populated the catalogue with all items before hand.



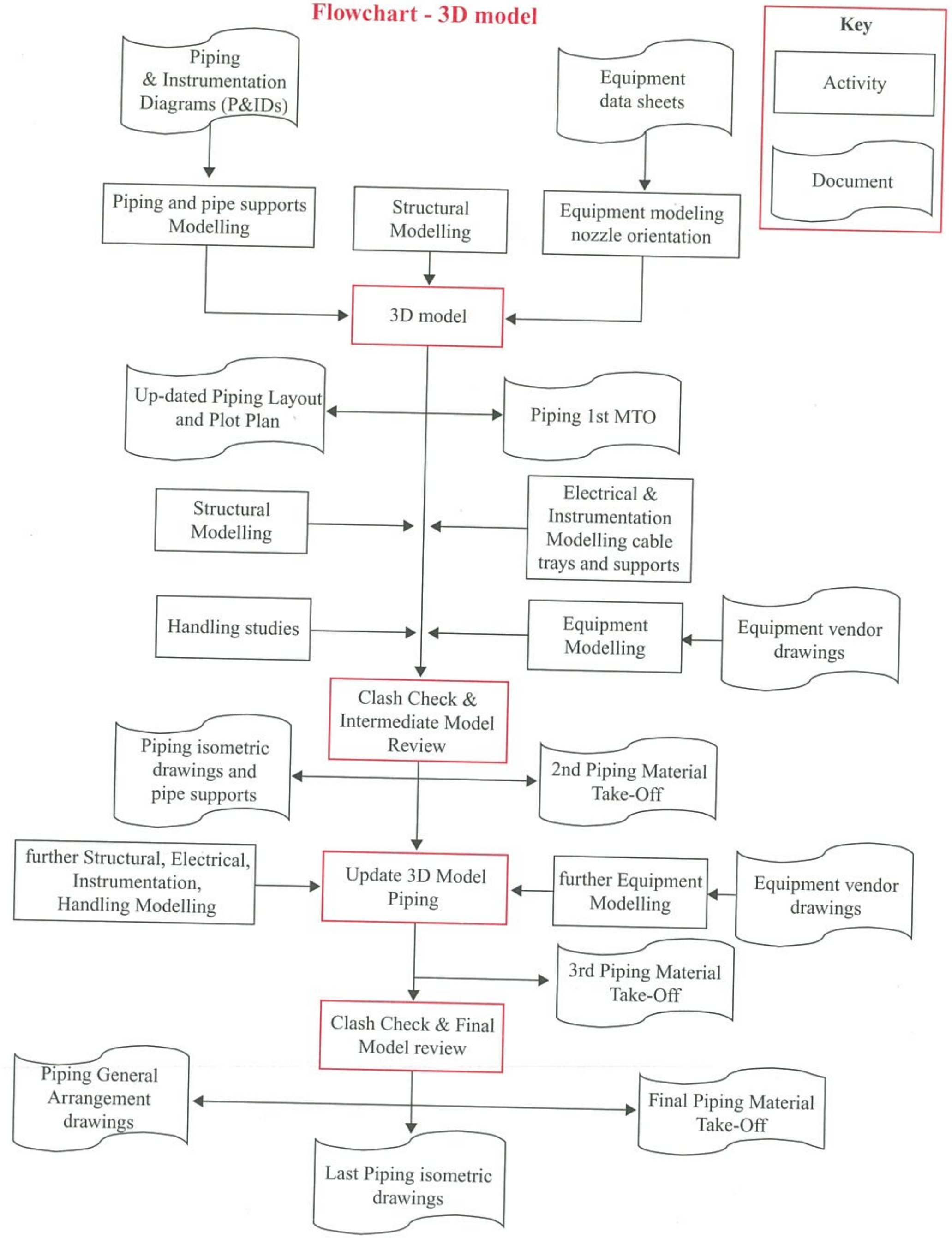
When extracting the piping Isometric drawing from the 3D model, dimensions and specifications of all items will come automatically from the catalogue.

REV	Item	SIGMA CODE CLIENT CODE	large diam.	small diam. /length	QUANTITIES TO BE SUPPLIED New A	Old B	BALANCE TO BE SUPP. A - B
SEAMLESS PIPE							
		TE04170	API5LGRB -ANSIB36-10 -BW -SCH40 -				
005	34		P 2		1248	1212	36
		TE04900	API5LGRB -ANSIB36-10 -PLAIN END -SCH80 -				
004	37		P 3/4		6	6	0
004	36		P 1		6	6	0
004	42		P 11/2		6	6	0
		TE14795	API5LGRB -ANSIB36-10 -PLAIN END -SCH80 -MDS CS01 -				
005	44		P 1/2		138	0	138
005	25		P 3/4		12	6	6
004	24		P 1		6	6	0
004	43		P 11/2		6	6	0

Once piping modelling is advanced enough, a revision of the **Piping Material Take-Off (MTO)** can be extracted from the 3D model. Balance is made between this latest bill of required material and the material already ordered on the basis of the first MTO. Shortage material is purchased through an amendment to the purchase order. The MTO will in fact be extracted several times from the model, in order to purchase piping material as early as possible. Routing of large diameters lines and lines in exotic materials will be prioritized as corresponding material has long lead time. As soon as the corresponding lines are routed in the model, their MTO will be extracted and the material ordered. The piping MTO will therefore undergo several revisions.

The modelling activities of the various engineering disciplines take place, and associated documents are issued, as depicted on the flowchart that follows.

Flowchart - 3D model

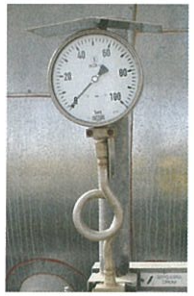


Similarly to Piping, other disciplines extract bill of quantities from the 3D model, such as steel structures, cable trays, etc.

On Off-Shore projects, the model is also used to determine the global module/ platform weight and centre of gravity, from the individual components weight and centre of gravity.

Chapter 11

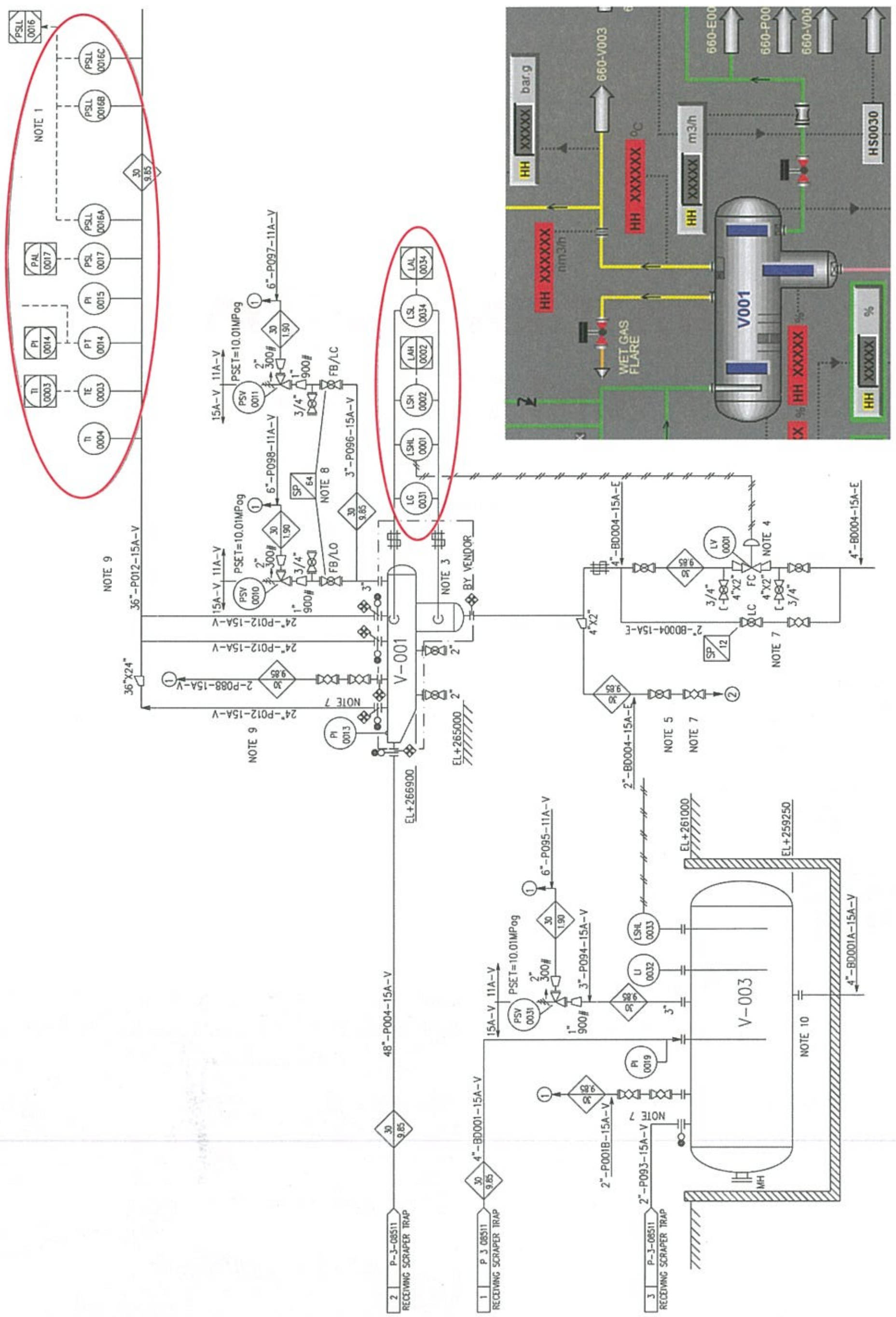
Instrumentation and Control



Instrumentation design starts from the P&IDs, on which all required instruments, controls and automations have been shown by the Process discipline covering:

- process monitoring,
- process control,
- process safety (alarm, shutdown).

Process not only defines and shows on the P&IDs the required function: process value to be measured (Pressure, temperature, flow) but also the required function (indication, recording, control) and whether the information shall be available locally (like pressure is, for instance, on the gauge shown here), in a local instruments panel located in the field next to the equipment, or remotely in the control room.



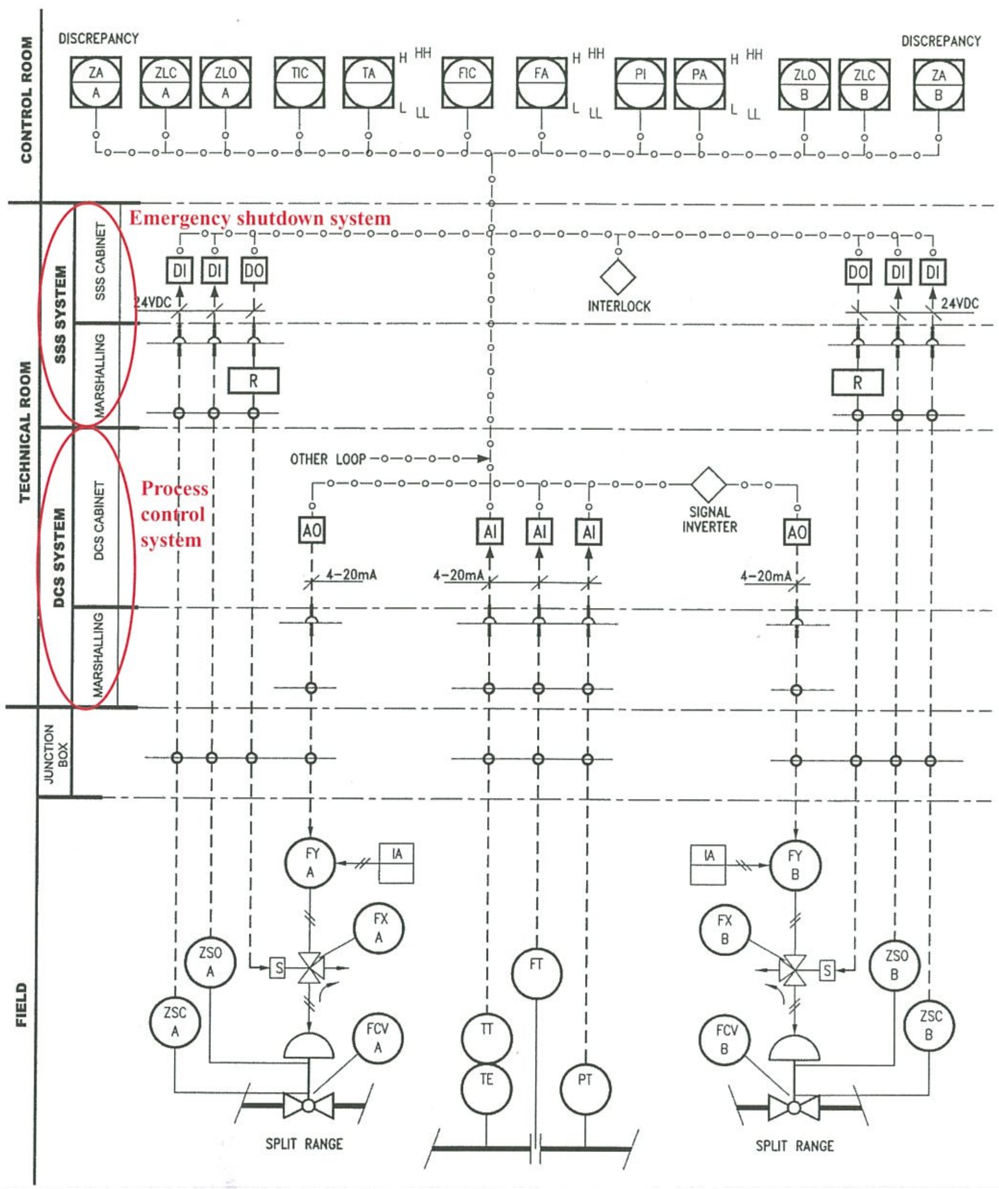
Instrumentation discipline implements the requirements specified by Process:

- specifying and ordering the systems, and developing their detailed functional specifications,
- specifying and ordering field instruments, and all accessories necessary for their installation, i.e., accessories for instrument process and electrical connections,
- producing all the drawings required for equipment and instruments installation and wiring.

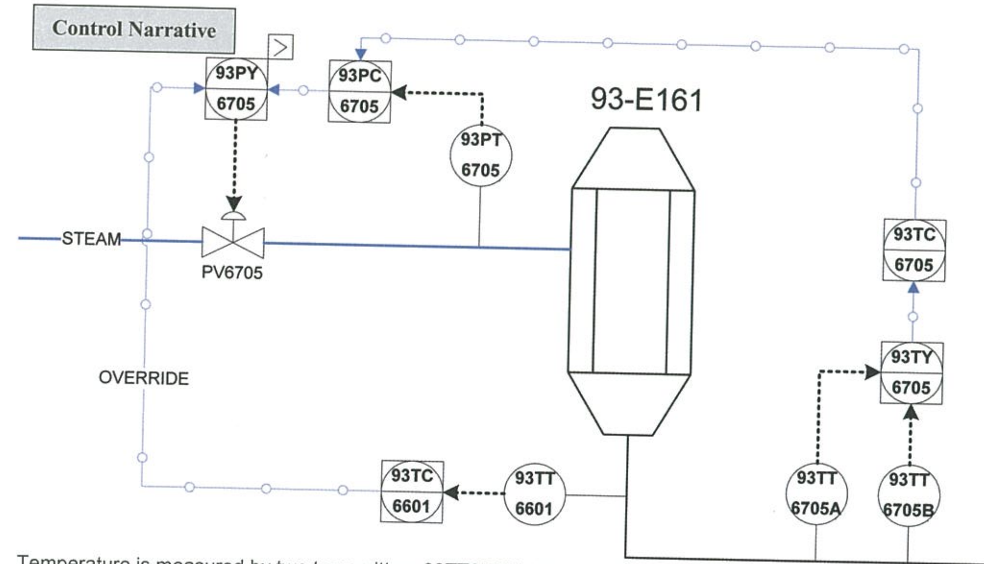
Monitoring and control of the process is performed by the Process Control System (PCS). Process controls consist of both logic (ON/OFF) and analog (continuous) controls.

Control requirements, e.g., temperature in such vessel shall be controlled by varying flow of cooling medium using such control valve, are defined by Process, shown on the P&IDs and described in the Operating & Control philosophy.

Functional requirements are specified by means of **Functional diagrams**. One such diagram is issued for each type of control: these are typical diagrams. The one shown here is for a split-range control, by the process control system, coupled with an emergency shutdown function, by the emergency shutdown system.



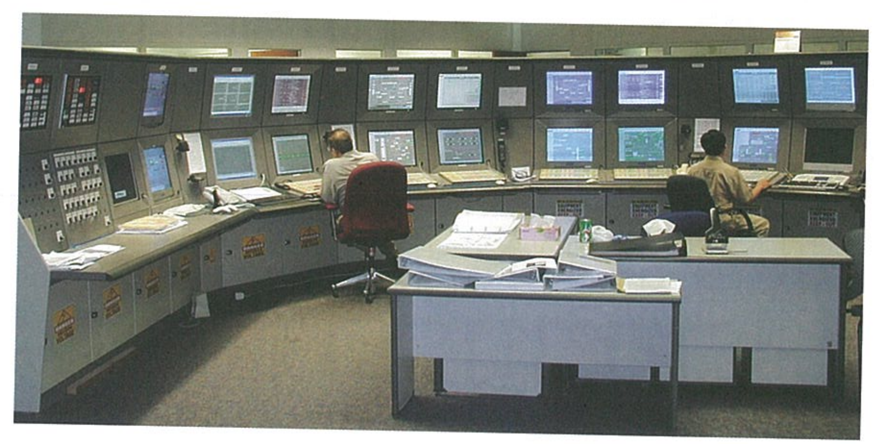
Specific and complex controls are described to the control system supplier in **Control Narratives**.



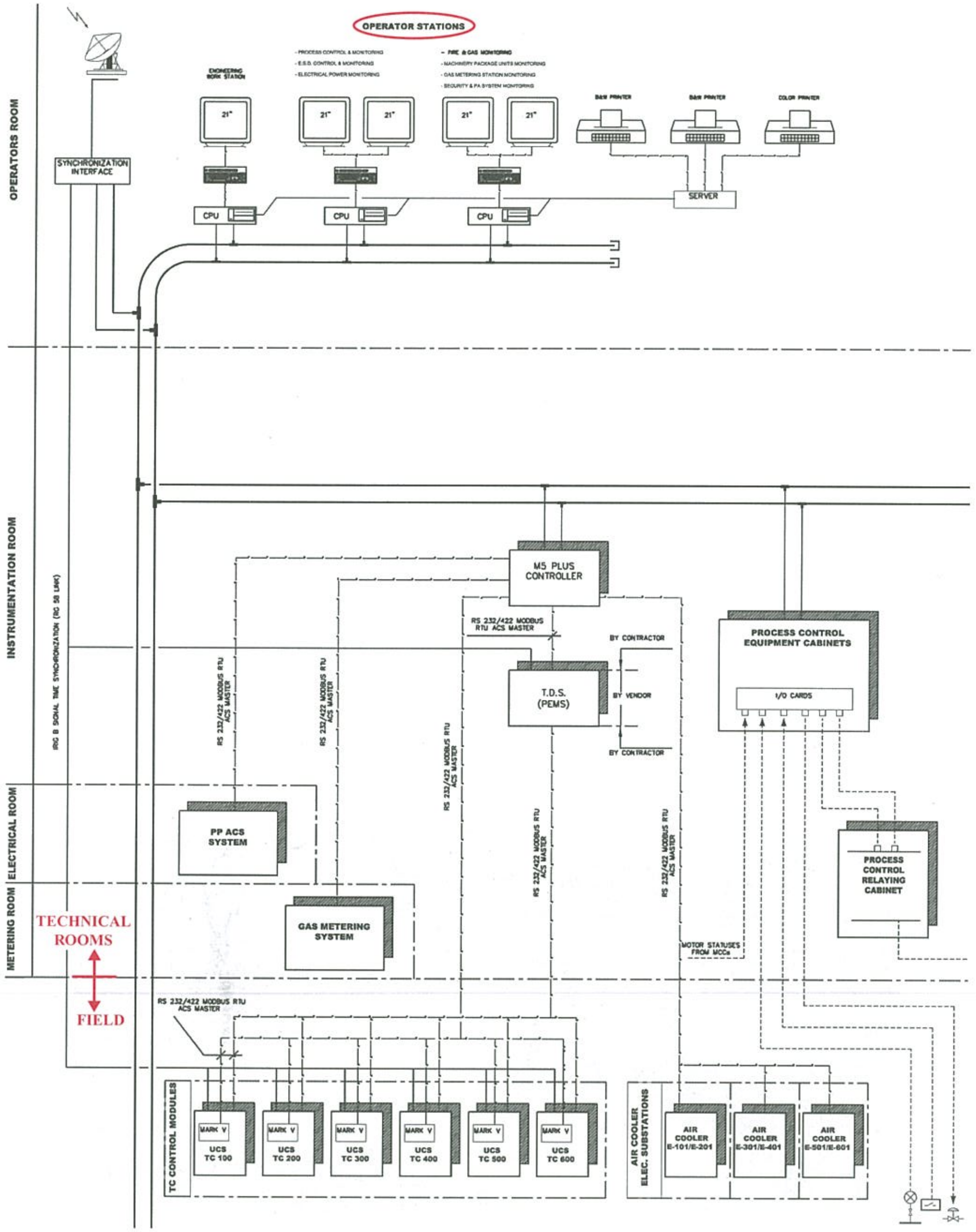
Temperature is measured by two transmitters 93TT6705A/B.Operator selects the transmitter by 93HS6705 and a ramp is performed during switchover. When one transmitter is in bad value, controller used the value from the healthy one.

Controller 93PC6705 acts on valve 93PV6705. If temperature measured by 93TT6601 (93-E161 outlet) is very low (output of 93TC6601 will increase), 93PC6705 will be overridden by 93TC6601. This in order to prevent low temperature at 93-E161 outlet (93TT6705A/B are close to GF distribution utility area). Set point of controller 93TC6601 will be lower than set point of controller 93TC6705.

The specification of the system will entail gathering all the requirements in the **System specification**, and producing a number of other documents describing the system capacity, geographical spread and functionnalities.



The **System Architecture drawing** shows the various pieces of hardware of the system, their location, and the interfaces with other systems, including the electrical control system and the equipment control systems supplied by vendors.



Marshalling cabinets and programmable controllers are located in instrumentation buildings/rooms spread throughout the plant. Indeed, they must be located close to the field instruments, to reduce cable lengths. Operator interface units (consoles) are centrally located in the control room.

The **I/O count** determines the required capacity of the system.

1) DISCRETE INPUT /OUTPUT LIST

POS.	DESCRIPTION	DI	DO	AI	AO	RTD
1	FIELD INSTRUM.	300	20	150	20	40
2	VALVES	280	60	-	-	-

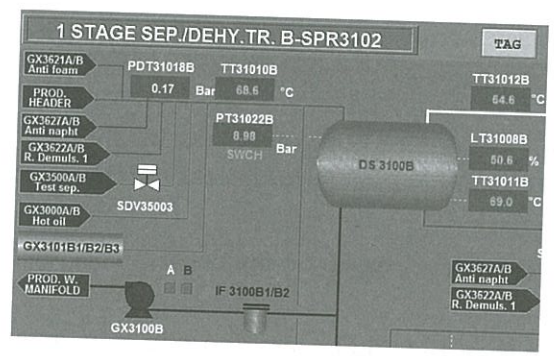
In addition a +10 % spare Input /output shall be considered and additionally +20% space for future requirements.

I/O COUNT

2) SERIAL INPUT /OUTPUT LIST

POS.	DESCRIPTION	DI	DO	AI	AO
1	TC-100	200	-	50	-
2	TC-200	200	-	50	-
3	TC-300	200	-	50	-
4	TC-400	200	-	50	-
5	TC-500	200	-	50	-
6	TC-600	200	-	50	-
7	FIRE & GAS	1200	-	-	-
8	GAS METERING	60	20	60	10
9	POWER SUPPLY	100	-	30	-

The system engineer specifies the **Mimic displays** to the control system vendor, i.e., the content of the views that will be displayed on the operator consoles.

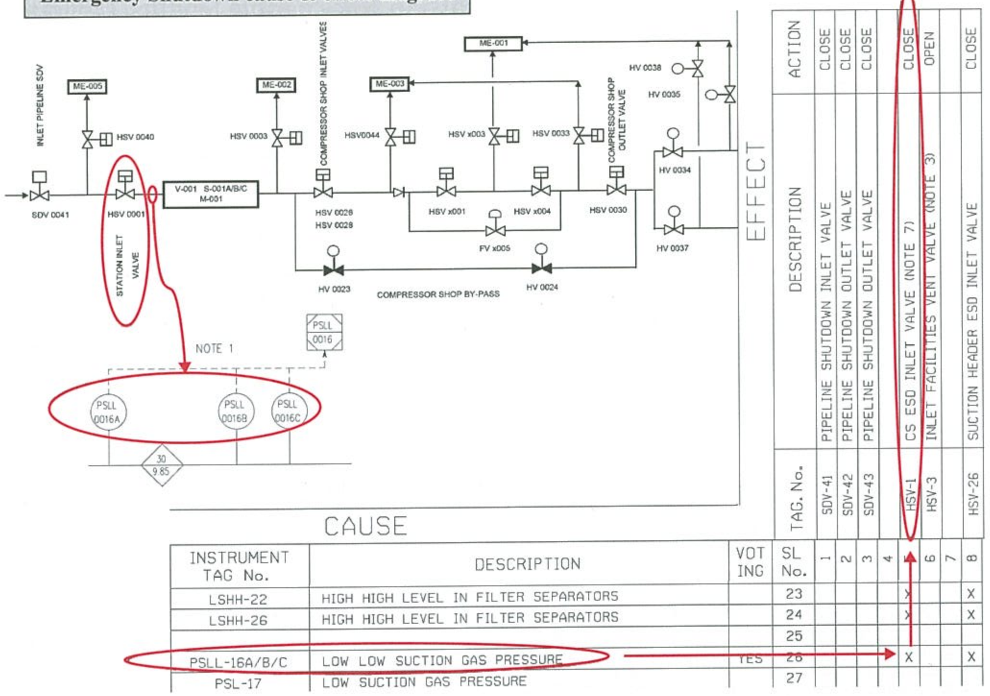


Such displays are the Plant Operator's interface with the control system. Their adequacy is critical. They are reviewed with the Client's operations staff.

Process emergency shutdown is performed by the Emergency ShutDown (ESD) system. The ESD system is a separate system from the Process Control system. This ensures redundancy and independence. The ESD system has its functions internally duplicated or triplicated to ensure high reliability.

The ESD system initiates process equipment shutdown and closure of isolation valves in an emergency. The shutdown logic is implemented in the ESD system as defined by Process on the ESD Cause & Effects diagrams.

Emergency Shutdown cause & effect diagram



A **SIL (Safety Integrity Level) review** is carried out to check the reliability of critical safety automations. Such a critical automation is, for instance, the closure of an isolation valve in case of a major leak.

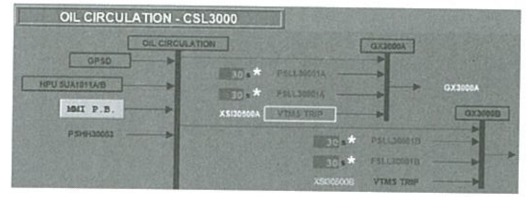
Each automation is allocated a severity level based on the consequence that would result from its failure.

The severity is ranked, for instance level 1 would be loss of production, level 2 damage to equipment, level 3 release of flammable substance to atmosphere, level 4 would be loss of containment, etc.

The frequency of occurrence times the severity, the risk level, determines the required level of reliability, for instance failure on demand between 10^{-3} to 10^{-4}.

The reliability of the automation foreseen to be installed is then estimated using information from the instrumentation hardware (transmitter, I/O card, system). Should it prove below the required reliability, additional/redundant components are added to increase its reliability.

In the example shown above, three low pressure sensors had to be provided to secure the closure of the isolation valve upon detection of a major leak/line rupture.



The ESD system vendor programs the automation logic in the system. The system displays the status of activation of emergency levels and implementation of actions to the operator.

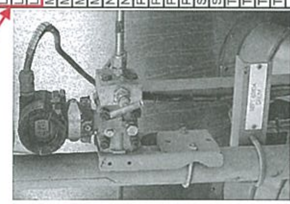
All plant instruments are logged in a master register: the **instrument index**. This data base is progressively filled with all information: service conditions (P,T), instrument type, signal output, material of construction, range, set point, etc.

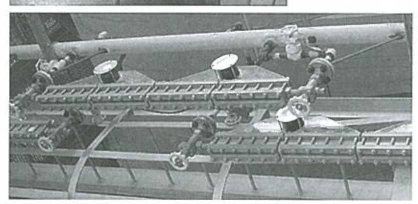
The instrument data base centralizes all information pertaining to each instrument. Many documents (wiring diagrams, loop diagrams, etc.) and list of materials (hook-up) are produced directly from this unique data base, ensuring their consistency.

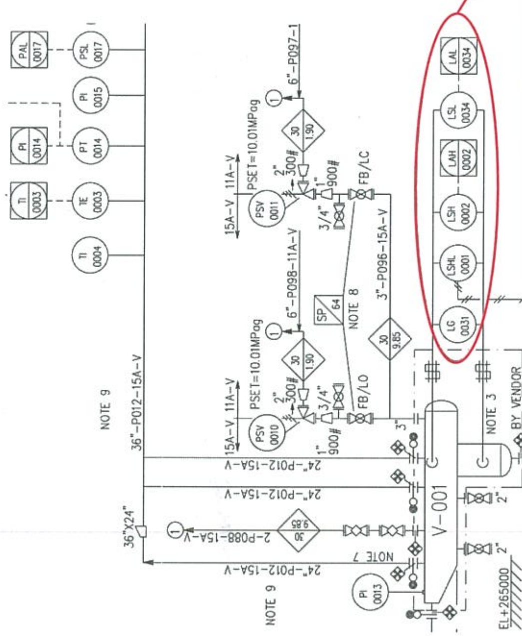
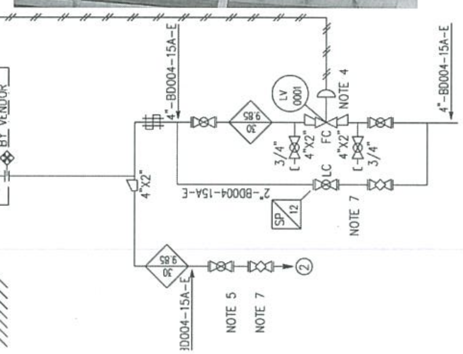
Tag Number	Instrument Type	Location	Service	Equipment/ Line	PID N°	I/O Type	Signal	System
AE -0701-1	Analyse measure	MAH	Gas metering station		P-3-08540	AI	4-20 mA	-
AT -0701-1	Analyser transmitter	SBMR	Gas metering station		P-3-08540	AI	SL	GMS
AI -0701-1	Analysis indicator	SBMR	Gas metering station		P-3-08540	-	Soft	GMS
AXA -0703-6	Apparatus failure alarm	SBMR	Gas metering station		P-3-08540	DO	24 Vdc	GMS
ASHH -0703-2	Very High dew point switch	SBMR	Gas metering station		P-3-08540	DO	24 Vdc	ESD
AT -1061	Moisture analyser	Field	Pilot gas system TC-100	S-105	P-3-08555	-		
BE -1201-1	Flame detector	Field	Power turbine TC-100		NUO/10.07/00171	AI	UV	UCS (TC-100)
BL -1201-1	Flame indicator	CMTC-100	Power turbine TC-101		NUO/10.07/00171	-	Soft	UCS (TC-100)
BXA -1201-1	Flame detector fault alarm	CMTC-100	Power turbine TC-102		NUO/10.07/00171	-	Soft	UCS (TC-100)
FT -0013	Flow transmitter	Field	Fuel gas for turbocompressors	8"-FG001-15A-V	P-3-08541	AI	4-20 mA	PCS
FO -1003	Restriction orifice	Field	TC-100 Emergency vent	4"-P107-28A-V	P-3-08514	-	-	-
FE -1005	Orifice plate	Field	TC-100 Suction	20"-P101-18A-B	P-3-08516	-	-	-
FT -1005	Flow transmitter	Field	TC-100 Suction	20"-P101-18A-B	P-3-08516	AI	4-20 mA	PCS

Instrument index

Tag Number	Instrument Type	I/O Type	Signal	System
AE -0701-1	Analyse measure	AI	4-20 mA	-
AT -0701-1	Analyser transmitter	AI	SL	GMS
AI -0701-1	Analysis indicator	-	Soft	GMS
AXA -0703-6	Apparatus failure alarm	DO	24 Vdc	GMS
ASHH -0703-2	Very High dew point switch	DO	24 Vdc	ESD
AT -1061	Moisture analyser	-		
BE -1201-1	Flame detector	AI	UV	UCS (TC-100)
BL -1201-1	Flame indicator	-	Soft	UCS (TC-100)
BXA -1201-1	Flame detector fault alarm	-	Soft	UCS (TC-100)
FT -0013	Flow transmitter	AI	4-20 mA	PCS
FO -1003	Restriction orifice	-	-	-
FE -1005	Orifice plate	-	-	-
FT -1005	Flow transmitter	AI	4-20 mA	PCS
FY -1005-1	Computing device	-	Soft	PCS
GD -0108	Gas detector (IRGD)	AI	4-20 mA	CF-001
GAH -0108	Gas alarm (10%LEL)	-	-	CF-001
HZLH -2002-1	Status valve opened	Hold	Soft	UCS (TC-200)
JQ -0737	Energy flowrate totalizer	-	Soft	GMS
JI -0738	Energy flowrate indicator	-	Soft,	GMS
LSHL -0001	Pneum.level switch	-	3-15 psi	-
LV -0001	Control valve	-	3-15 psi	-
LSH -0002	High level switch	DI	24 Vdc	PCS
LAH -0002	High level alarm	-	Soft	PCS
MXS -0730-3	Remote position switch	DI	24 Vdc	CF-004
MXL -0730-3	Local/remote status	-	24 Vdc	CF-004
MXS -0730-4	Start order	DO	220Vdc	CF-004
MXS -0731-1	Electrical fault switch	DI	24 Vdc	CF-004
ND -0034	Fire detector(UV/IR)	DI	24 Vdc	CF-001
NAH -0034	Fire detection alarm	-	-	CF-001
PSLL -0049-C	Very low pressure switch	DI	24 Vdc	ESD
PALL -0049	Very Low pressure alarm	-	Soft	ESD
PSH -0050	High pressure switch	DI	24 Vdc	PCS
PAH -0050	High pressure alarm	-	Soft	PCS
ST -4602	Speed transmitter	AI	Analog	BNR
SI -4602	Speed indicator	AO	Analog	TDS
TT -0707	Temperature transmitter	AI	Hard	GMS
TI -0707	Temperature indicator	-	Soft	GMS
TAL -0707	Low temperature alarm	-	Soft	GMS
TAH -0707	High temperature alarm	-	Soft	GMS
VT -1201-2	Vibration transmitter	AI	Analog	BNR
VI -1201	Vibration indicator	-	Hold	UCS (TC-100)
WI -1102-1	Torque indicator	-	Soft	UCS (TC-100)
WI -1102-2	Torque indicator	-	Soft	UCS (TC-100)
ZAHH -2602	Very high displacement alarm	-	Soft	UCS (TC-200)
ZE -2604-1	Displacement detector	Hold	Hold	-





A **data sheet** is produced for each instrument, specifying the range, material of construction, etc. in order to purchase it, as well as for reference for its maintenance at site.

Control valve data sheet

TAG
Tag No. : 84 FV -6703A
PID No. : RG6-D-84-1225-340
Service : SM TO 84FL061

Instrument Type : Air Actuated CV (Globe) E/P positioner
Valve Type : Control Globe
Valve Service :
Quantity Tags : 1

VALVE GEN
Manufacturer Name : FISHER
Model No : ET Ser No. : 17982719
Air Failure Action : FC
Max. Shut Off Pressure : 19 bar
Leakage Class : IV (standard)
Material Corrosion Requirement :

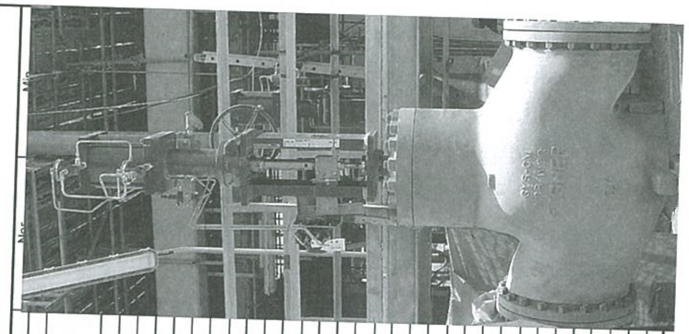
Line
Line No.: 84SM-60020-8"-3S1-1
Line Size 8 in Schedule: 30

ACTUATOR

53	Manufacturer : FISHER Model : 667-4
54	Type of Actuator : spring & diaphra Size : 70
55	Material
56	Case : Yoke : Stem :
57	Mechanical Design Pressure : 4.1 barg
58	Actuator Force Design Pressure :
59	Required Air Supply Pressure : 4.5 barg
60	Stroke Speed : within 10 seconds
61	Travel Indicator : Yes
62	Orientation : vertical up

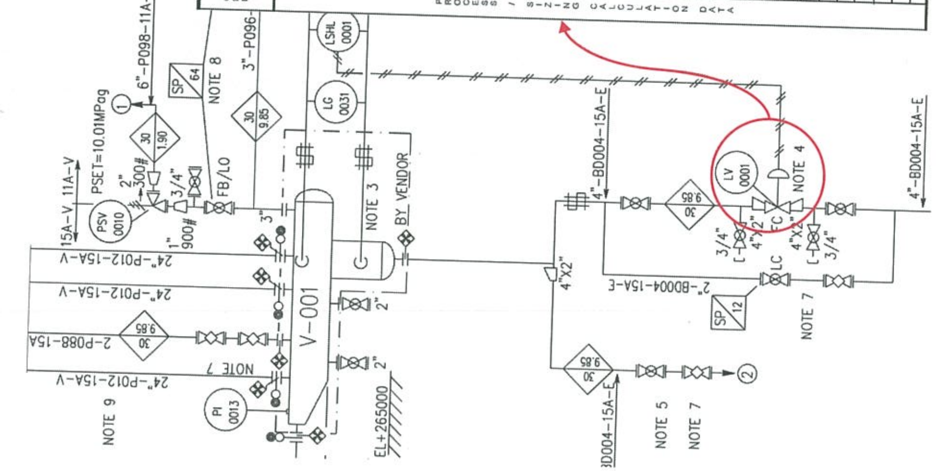
GEN
Tag No.: 84 FV -6703A
PID No.: RG6-D-84-1225-340
Service : SM TO 84FL061
Line No. :84SM-60020-8"-3S1-1

Instrument Type : Air Actuated CV (Globe) E/P positioner
Valve Type : Control Globe
Valve Service :



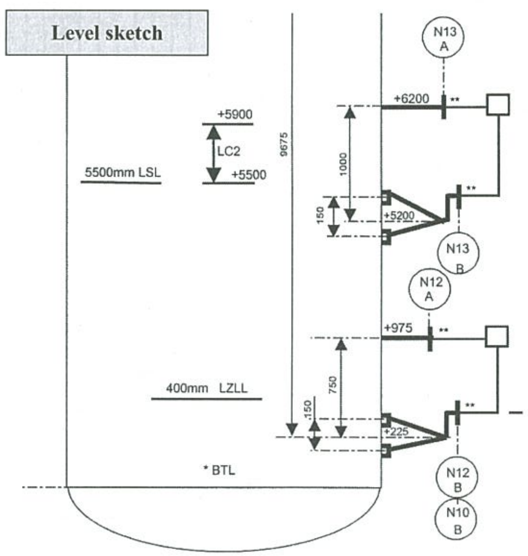
PROCESS / SIZING CALCULATION DATA

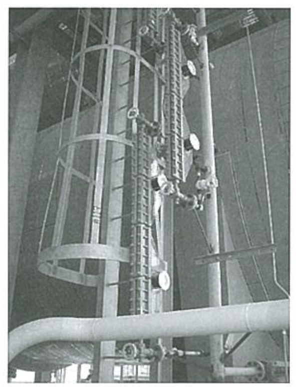
Process Condition	Unit	Max	Nor	Min
Process Case		120		
Case Description		Maximum flow		
Phase				
Fluid Name				
Flow Rate	t/h	15		
Upstream Pressure	bar-g	11.6		
Downstream Pressure	bar-g	6.3		
Temperature	°C	217		
Density @ Condition	kg/m³	6.463		
Molecular Weight		18.02		
Viscosity	cP	0.0165		
Specific Heat Ratio		1.402		
Compressibility Factor				
Superheat Temperature	BtuIT/lb°F			
Critical Pressure	bar-a			
Vapour Pressure	bar-a			
Flash Ratio	%			
FL(Liquid Pressure recovery factor)				
Xt(Pressure drop ratio factor)				
Calculated CV		125		
Required CV		129		
Travel of Valve	%	95		
Predict SPL	dBA	84.8		
Allowable SPL	dBA	85		
Max. Shut Off Pressure		19		
Design Pressure		18 /		
Design Temperature		270 /		



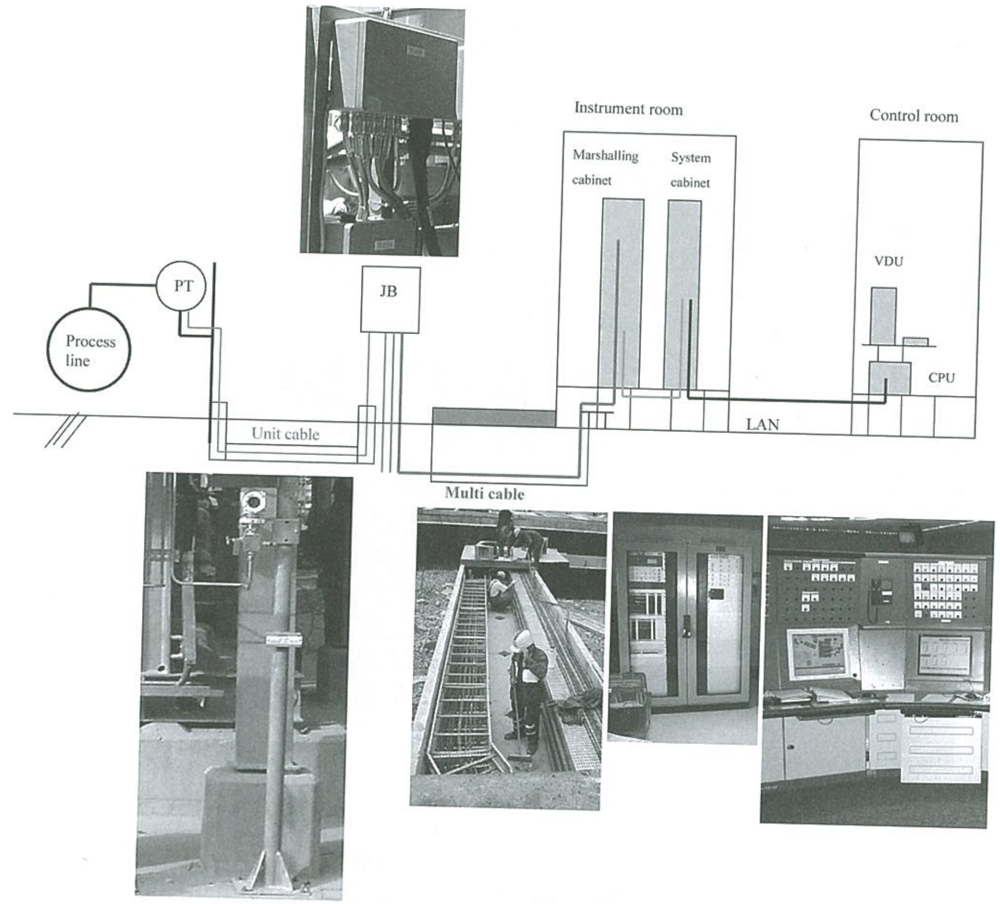
The specification of level instruments requires the Instrument engineer to perform a level study based on the liquid levels specified by process. Level instruments deduct the liquid level by measuring the weight of the liquid column. Such weight is obtained from the difference of pressure at the bottom and on top of the column. A level instrument therefore includes a pair of pressure sensors: one located above the level to be measured and one located below.

Defining the elevation of the two pressure connections so that they adequately sense the weight of the liquid column is the purpose of the level study. It results in the **level sketches**, which serve to specify the level instruments and to define the elevations of the nozzles on the vessel. These elevations are specified to the vessel vendor. Level sketches are also issued to the Piping/Installation discipline, which addresses the requirements for access to instruments, e.g., definition of adequate access platforms/ladders, etc.



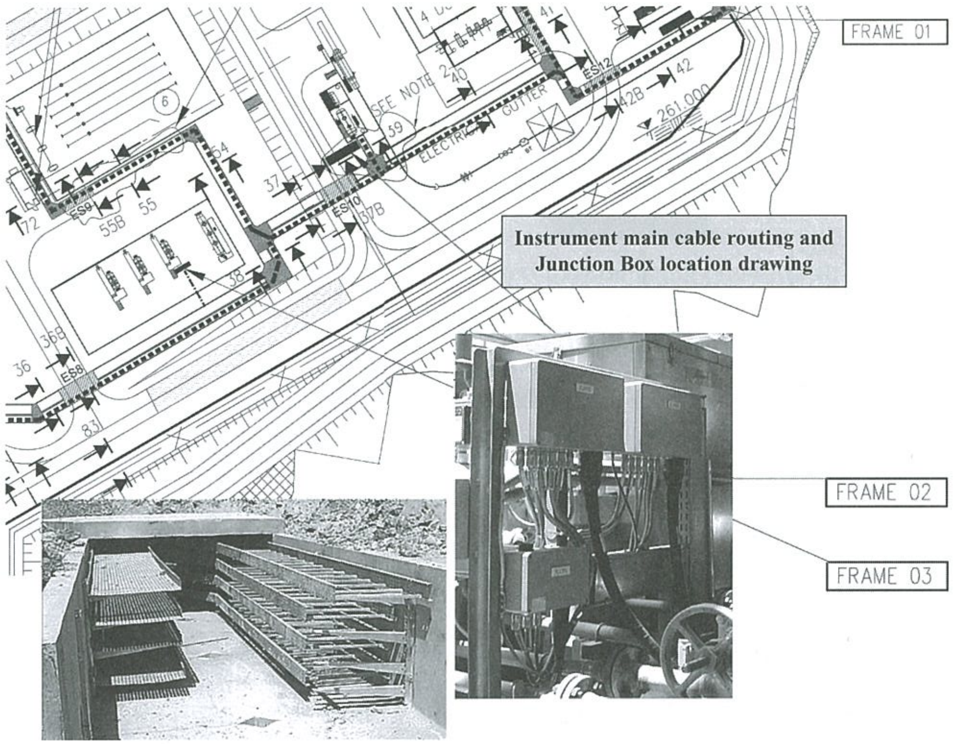


Instrumentation equipment and materiels, from the field sensor to the control room, are shown on the synoptic below.



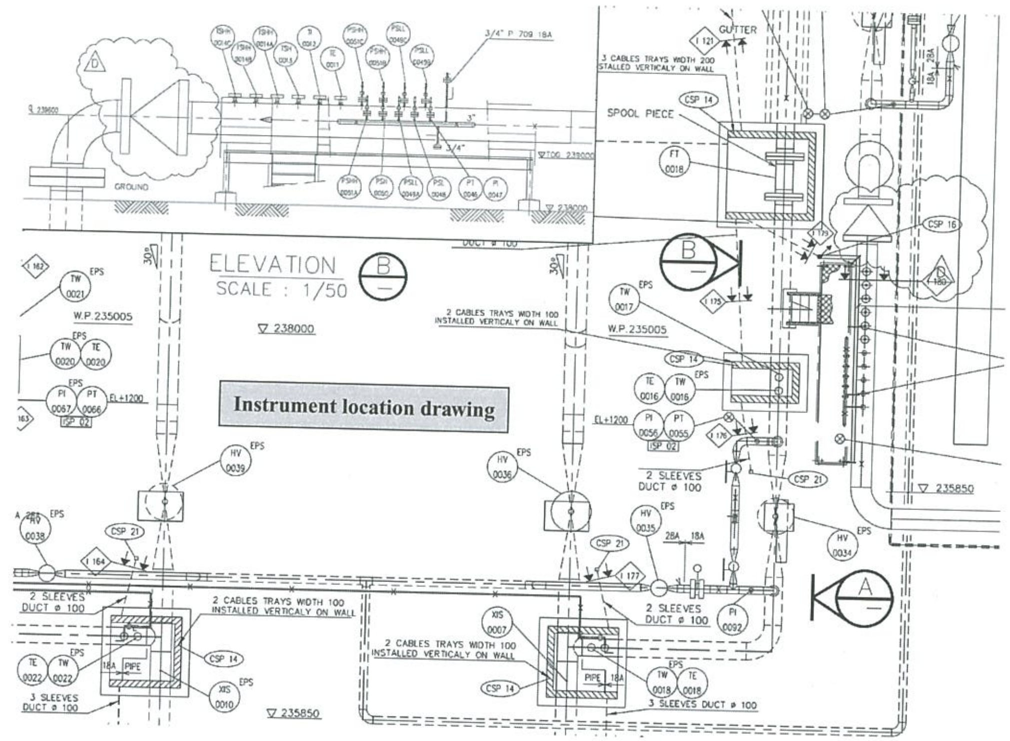
Instrumentation produces all drawings required for installation of these equipment and materials at Site, which include:

- The **Junction Box Location drawings**, which show the location of the junction boxes[1].

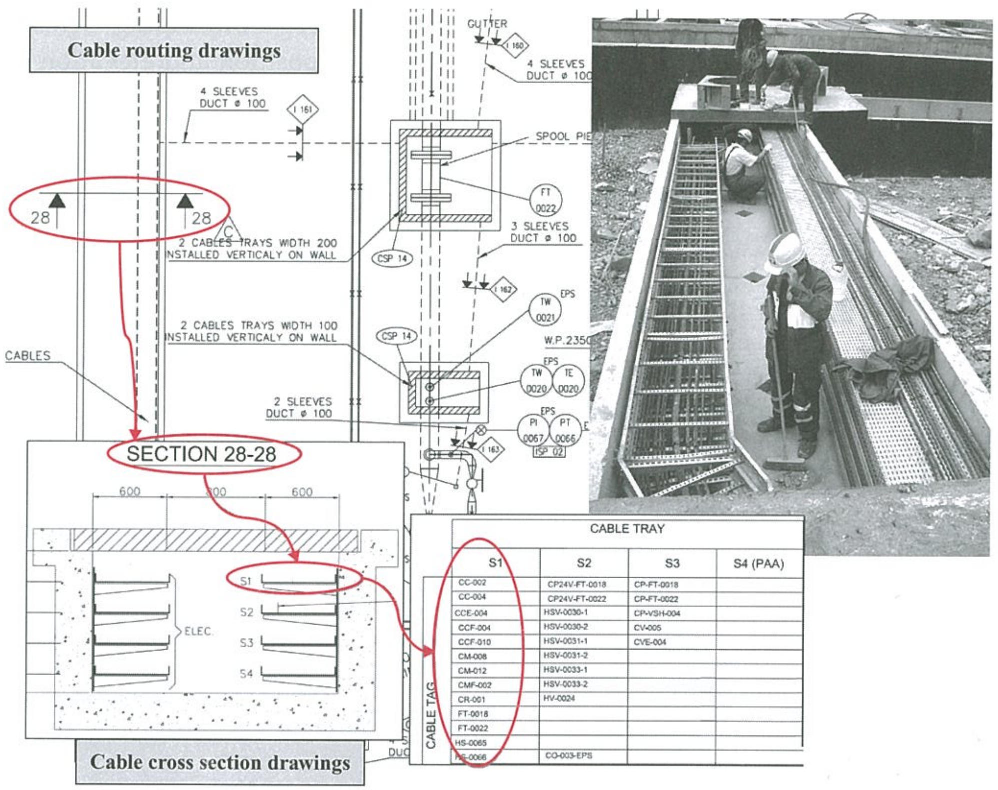


1. In order to reduce the number of cables connecting field instruments to cabinets in technical rooms, multi-core cables are used. They connect several instruments (typically 7/12/19), located nearby in the field, to the cabinet located in the instrumentation room. Instruments are connected to multi cables by means of junction boxes. Grouping of instruments in multi-core cables is done according to the nature of their signal (analog, digital, voltage level) and service/system (process monitoring, emergency shutdown).

- **Instrument location drawings**, which are derived from Piping General Arrangement drawings and show the location, position and elevation of fields instruments.



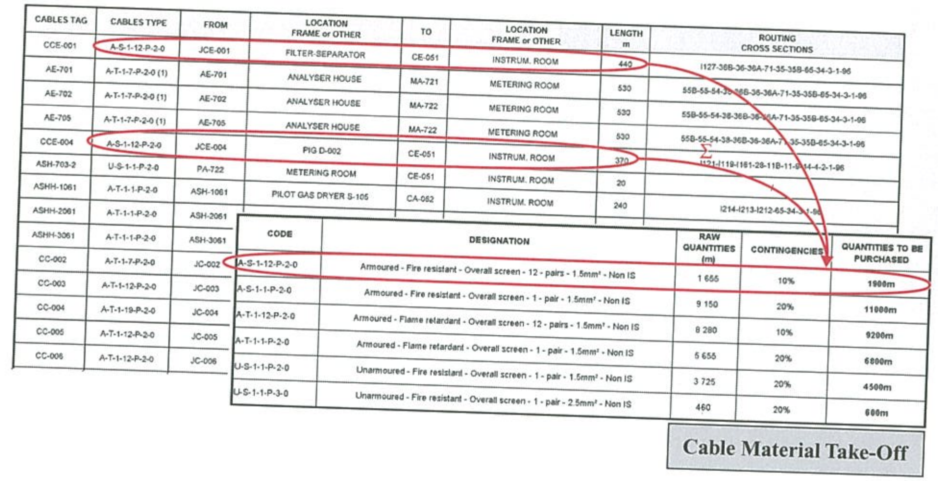
- **Cable routing drawings** showing in which cable trench/duct the cables shall be installed and **Cross section drawings** showing on which cable tray each cable shall be installed, in compliance with segregation rules, e.g., control cables and power supply cables on different trays,



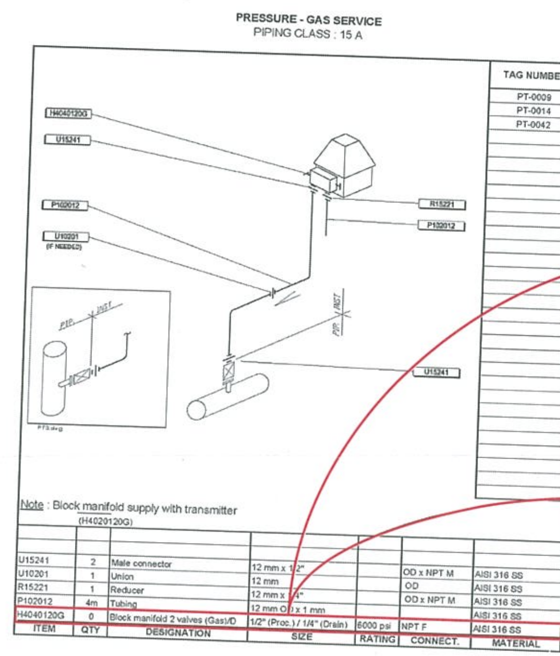
- **Instrument cable schedule**, showing the list of cables to install, cable type, length, origin, destination and route,

CABLES TAG	CABLES TYPE	SUPPLY BY (1)	FROM	LOCATION FRAME or OTHER	TO	LOCATION FRAME or OTHER	LENGTH m	ROUTING CROSS SECTIONS
CC-004	A-T-1-19-P-2-0	CONTRACTOR	JC-004	PIG D-002	CA-052	INSTRUM. ROOM	370	I121-I119-I161-28-11B-11-9-44-4-2-1-96
CC-005	A-T-1-12-P-2-0	CONTRACTOR	JC-005	FILTER-SEPARATOR	CA-052	INSTRUM. ROOM	440	I127-36B-36-36A-71-35-35B-65-34-3-1-96
CC-006	A-T-1-12-P-2-0	CONTRACTOR	JC-006	FILTER-SEPARATOR	CA-052	INSTRUM. ROOM	440	I127-36B-36-36A-71-35-35B-65-34-3-1-96
CC-007	A-T-1-7-P-2-0	CONTRACTOR	JC-007	STATION INLET VALVES	CA-052	INSTRUM. ROOM	370	I193-I190-36A-71-35-35B-65-34-3-1-96
CC-008	A-T-1-7-P-2-0	CONTRACTOR	JC-008	DIESEL GENERATOR	CA-052	INSTRUM. ROOM	120	I350-30-70B-70
CC-009	A-T-1-7-P-2-0	CONTRACTOR	JC-009	FIRE WATER	CF-004	FIRE BUILDING	100	I185-I183-I182-I181
CC-101-1	A-T-1-19-P-2-0	CONTRACTOR	JC-101	AERO E-101	UA-101	S/S ELECTRICAL 27-1	160	I207-I205-I204-I202-I200-24-62-27
CC-101-2	A-T-1-7-P-2-0	CONTRACTOR	JC-101	AERO E-101	UA-101	S/S ELECTRICAL 27-2	160	I207-I205-I204-I202-I200-24-62-27

The **Cable Material Take-Off** sums up the length of all cables, by type, showing the overall quantities to purchase.



- Instrument **Hook-up drawings**, which show mounting and connection of instrument to process lines and corresponding list of required material (tubing, manifold, connectors, etc.),



Instrument Hook-up drawings

& material take-off

ITEM	QUANTITY	DESIGNATION
1	195	Gauge adapter – ½" x ½"
2	37	Block manifold 2 valves (Gas) – ½"
3	23	Block manifold 5 valves (Gas) –½"
4	0	Ball valve ½" – 12mm
5	300m	Tubing – 12mm OD x 1mm
6	200	Reducer – 12mm x ¼"
7	50	Union tee – 12 x 12 x 12mm
8	50	Female connector – 12mm x ½"
9	350	Male connector – 12mm x ½"

The **Bulk Material Take-Off** indicates the quantity of junction boxes, cable trays, small installation accessories (cable glands, cable markers, etc.), hook-up material, etc. to be purchased.

DESIGNATION	MATERIAL	RAW QUANTITIES	CONTIN GENCIES	QUANTITIES TO BE PURCHASED
CABLE TRAYS . (Return flange). (d: 50mm / w: 100mm) - Note 1	HOT-DIP GALVANIZED	956m	10%	1100m
CABLE TRAYS . (Return flange). (d: 50mm / w: 200mm) - Note 1	HOT-DIP GALVANIZED	419m	10%	500m
CABLE TRAYS . (Return flange). (d: 50mm / w: 400mm) - Note 3	HOT-DIP GALVANIZED	690m	10%	800m
CABLE TRAYS . (Return flange). (d: 75mm / w: 600mm) - Note 1	HOT-DIP GALVANIZED	8000m	10%	8800m
COVERS FOR CABLE TRAYS. (w: 100mm)	HOT-DIP GALVANIZED	700m	10%	770m
COVERS FOR CABLE TRAYS. (w: 200mm)	HOT-DIP GALVANIZED	419m	10%	470m
COVERS FOR CABLE TRAYS. (w: 400mm) - Without junction boxes frames	HOT-DIP GALVANIZED	660m	10%	750m
COVERS FOR CABLE TRAYS. (w: 600mm)	HOT-DIP GALVANIZED	2100m	10%	2400m
HORIZONTAL TEES . (Return flange). (d: 75mm / w: 3x600mm)	HOT-DIP GALVANIZED	65	10%	75
90° HORIZONTAL BEND. (Return flange). (d: 75mm / w: 600mm)	HOT-DIP GALVANIZED	67	10%	75
COVERS FOR TEES. (w: 3x600mm)	HOT-DIP GALVANIZED	17	10%	20
COVER FOR 90° HORIZONTAL BEND. (w: 600mm)	HOT-DIP GALVANIZED	17	10%	20

For junction boxes, the MTO specifies the number of terminals, the number and diameter of cables (for cable entries in the JB), the size of the cores (for sizing of terminals, etc.). An **arrangement drawing**, such as the one shown here, may be attached to the junction boxes requisition to provide more detailed or specific requirements.

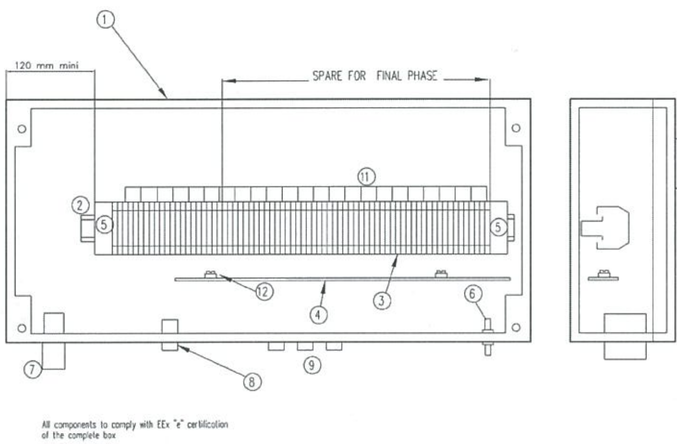
Junction box arrangement drawing

TYPICAL 1

EEx e FIELD JUNCTION BOX
FOR ANALOGIC SIGNALS - TYPICAL1

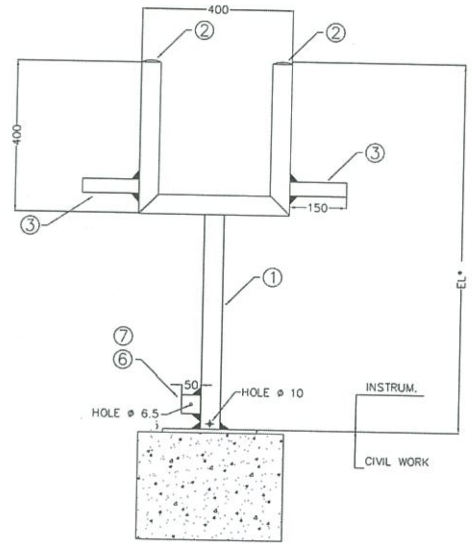
MATERIAL TO BE SUPPLIED BY VENDOR

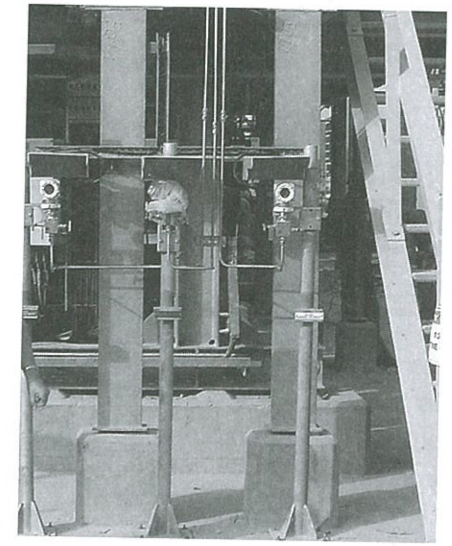
ITEM	QTY	DESCRIPTION
1	1	JUNCTION BOX EExe II A T3 (min) FLAME RETARDANT GRP (GLASS FIBER REINFORCED POLYESTHER) IP 55 INCLUDING GASKET , BOLTS
2	1	DIN STEEL GALVANISED AND CHROMATED RAIL
3	*	TERMINAL BLOCKS EExe 2 SIDES TO SCREW WIDTH = 6 mm SECTION WIRING = 1 to 1.5 mm ² PROVIDED WITH TAGGING SYSTEM COLOR OF TERMINALS = GREY COLOR OF TERMINALS = BLUE FOR "IS"
4	1	CONNECTING BAR FOR CABLE ARMOUR EARTHING
5	2	END BLOCKS
6	1	EXTERNAL MAIN EARTH CONNECTION BOLT
7	*	CABLE GLAND PVC FOR MULTICORE CABLE
8	*	CABLE GLAND PVC FOR SINGLE CABLES
9	*	PVC PLUGS
10	1	NAME PLATE OF JUNCTION BOX
11	1	CROSS CONNECTING FOR SCREENS
12	*	CLAMPING SCREW + PRESSURE CLAMP



- **Standard installation drawings**, such as instrument, junction box and cable tray support drawings, earthing drawings, etc., which show typical arrangements,

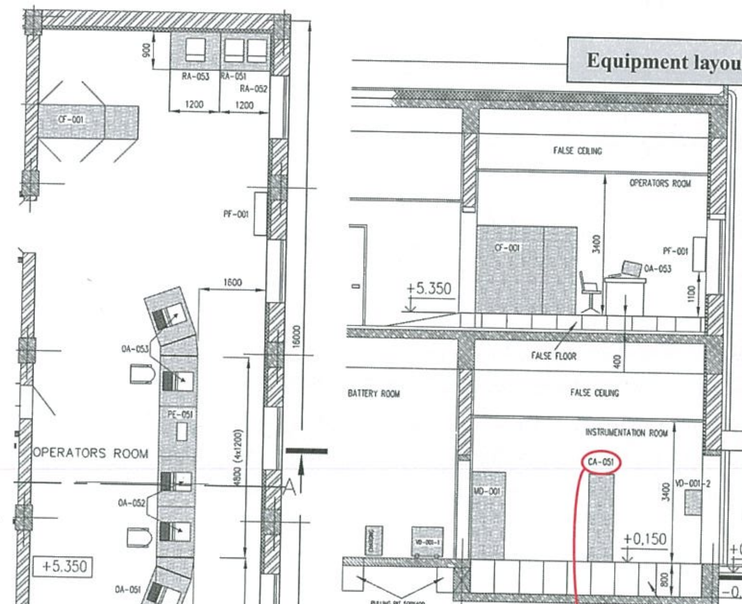
Standard installation drawings

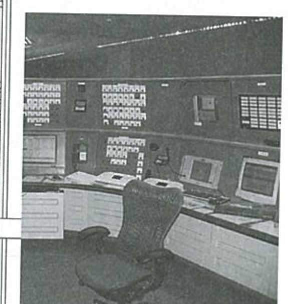




- **Equipment Layout drawings**, showing arrangement of cabinets inside instrumentation technical/control rooms,

Equipment layout drawing

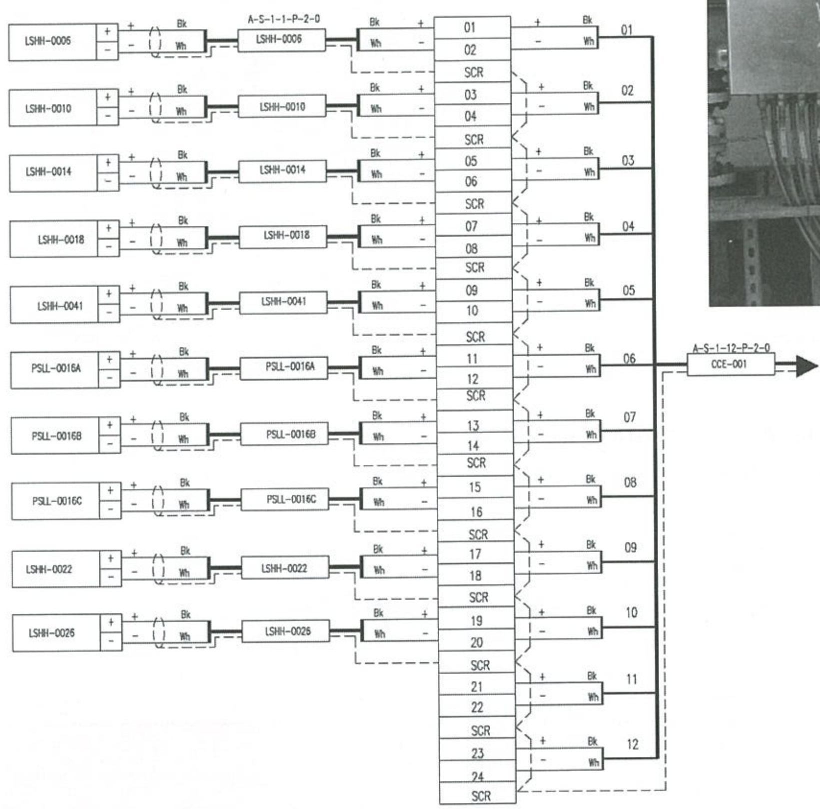


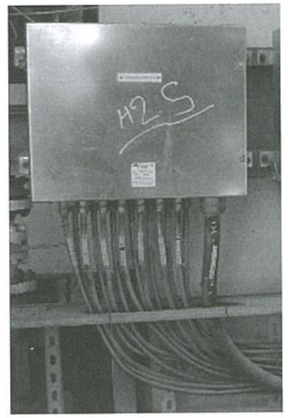


TAG EQUIPMENT	DESIGNATION	OVERALL DIMENSION mm (HxWxD)
CA-051	SYSTEM CABINET DUAL ACCESS	2100x1200x800
CA-052	SYSTEM CABINET DUAL ACCESS	2100x1200x800
CA-053	SYSTEM CABINET DUAL ACCESS	2100x1200x800

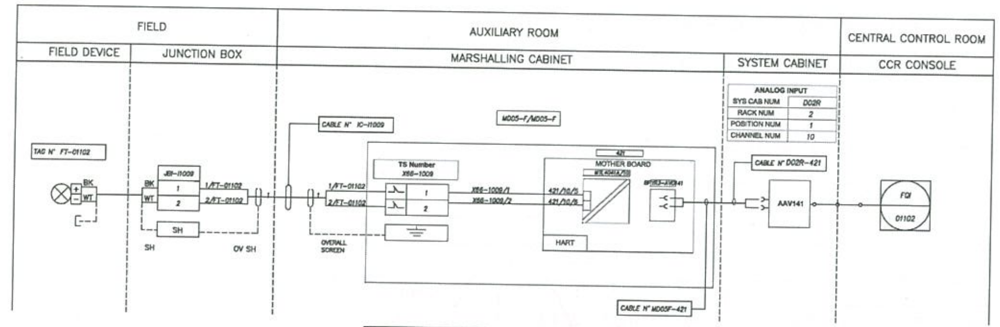
- **Wiring diagrams** show cable connections at terminals of junction boxes and marshalling cabinets,

Junction box wiring diagram





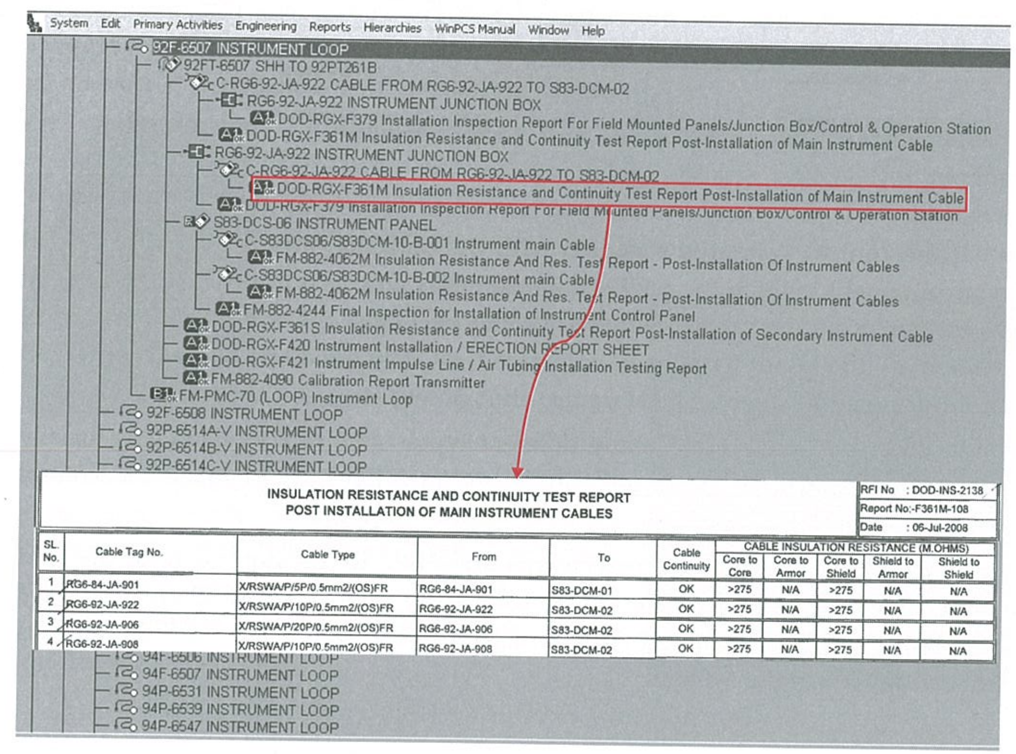
- **Loop Diagrams**, also called troubleshooting diagrams, show the complete wiring of each instrument. They are used during the testing of the instrument (from the field to the display on screen) during commissioning and for maintenance,



Instrument loop diagram

The lists of tagged items, such as the instrument index, cable schedule, etc. are used for the inspections and tests, prior the hand-over to the client, as part of Mechanical Completion activities. The type of inspection required depends on the type of item: calibration for instruments, insulation test for cables, etc. Each inspection is recorded against the item inspected.

A computer software "the mechanical completion system" is used to record the requirements and status of the inspection and testing of the thousands of individual tagged items.



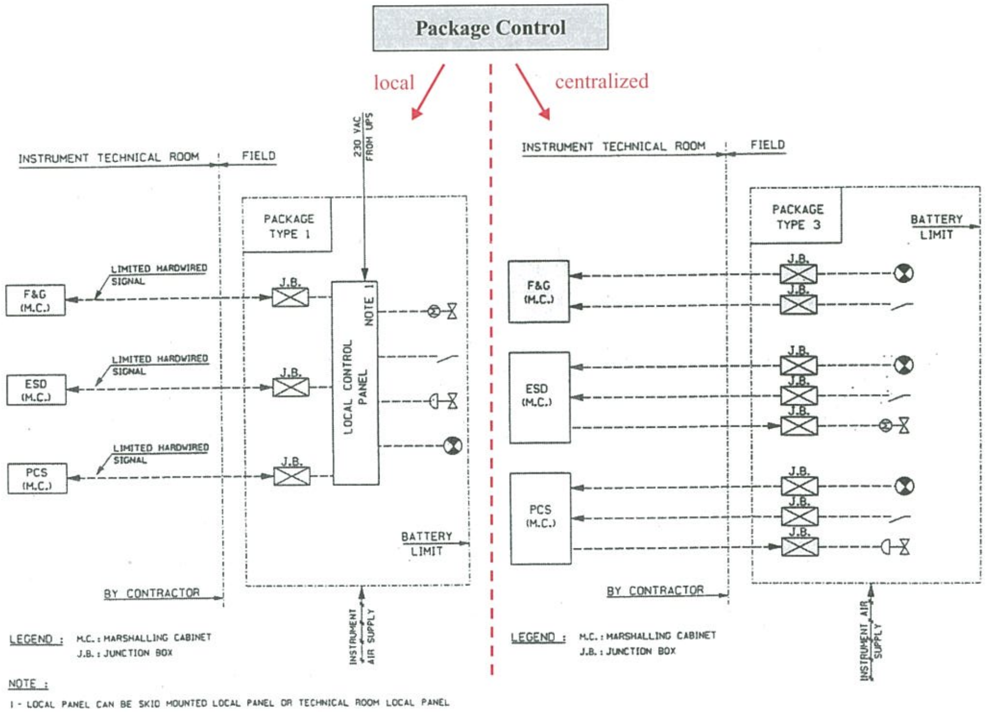
INSULATION RESISTANCE AND CONTINUITY TEST REPORT
POST INSTALLATION OF MAIN INSTRUMENT CABLES

RFI No : DOD-INS-2138
Report No:-F361M-108
Date : 06-Jul-2008

SL. No.	Cable Tag No.	Cable Type	From	To	Cable Continuity	CABLE INSULATION RESISTANCE (M.OHMS) Core to Core	Core to Armor	Core to Shield	Shield to Armor	Shield to Shield
1	RG6-84-JA-901	X/RSWA/P/5P/0.5mm2/(OS)FR	RG6-84-JA-901	S83-DCM-01	OK	>275	N/A	>275	N/A	N/A
2	RG6-92-JA-922	X/RSWA/P/10P/0.5mm2/(OS)FR	RG6-92-JA-922	S83-DCM-02	OK	>275	N/A	>275	N/A	N/A
3	RG6-92-JA-906	X/RSWA/P/20P/0.5mm2/(OS)FR	RG6-92-JA-906	S83-DCM-02	OK	>275	N/A	>275	N/A	N/A
4	RG6-92-JA-908	X/RSWA/P/10P/0.5mm2/(OS)FR	RG6-92-JA-908	S83-DCM-02	OK	>275	N/A	>275	N/A	N/A

As stated in the Equipment section, sub-functional units of the plant are often purchased as "packages", already assembled and wired.

In such case, the instruments of the packages come with the package. The control of the unit may be performed in a dedicated local system, supplied by the package vendor, or integrated within the plant central process control system.



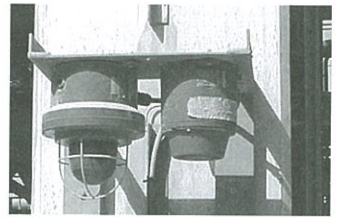
If the control system is supplied with the package, it will consist of a local control panel to which the package instruments will be wired. The local control panel performs the control actions for the package. The main process control system of the plant is simply interfaced to this panel to allow centralized monitoring and control, e.g., start-up/shut down, etc.

In order not to have too many different types of control systems it is usually preferable to have the package controls performed by the plant central control system.

In this case, the package instruments are wired to junction boxes at the skid edge. The junction boxes are connected to the plant Process Control System marshalling cabinets as all other field instruments and the controls/automations are configured in the system.

It is in such case critical that the control functions and automations are properly described by the package vendor: the lube oil pump must be started before the turbine is ignited!

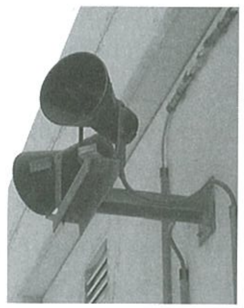
To this end the package vendor provides the **Control Philosophy, Cause & Effect charts, Logic analysis and Schematics** to describe in details all sequence (start-up, shut down, etc.).



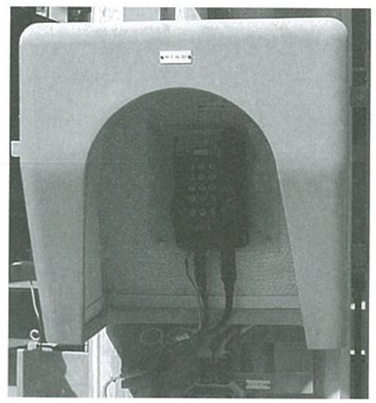
Similarly to the Process control system, Instrumentation discipline implements a **Fire and Gas detection and alarm system**. This is generally a similar system to the ESD system. The functional requirements are given by Safety (see corresponding section). Instrument discipline specifies and procures the materials (detectors, sounders, etc.), the system, and produces all drawings for Site installation.

The system is purchased based on the required capacity (I/O count). It is also specified to interface with the stand-alone Fire & Gas detection and Fire fighting systems of the main equipment packages, and with the plant ESD system. The system vendor programs the logic shown on the F&G matrix (see Safety section) in the system.

The same deliverables are produced for the Fire and Gas system as for the Process Control System: instrument list, location drawings, cable schedule, bill of materials, wiring and troubleshooting diagrams, etc.



Other systems fall in the scope of the Instrumentation engineer, such as the Public address system (for paging personnel or sounding general alarm using loudspeakers, etc.), the plant internal telephone system (PABX), the computer network (LAN), the access control system, CCTV, etc.



An Off-Shore facility requires telecommunication with land, supply boats, tankers, etc. This will involve a variety of systems, which will be designed by the Telecommunication engineer, such as radio frequency (UHF, VHF), microwave, satellite, entertainment system (TV) in living quarters, etc.

Chapter 12

Electrical

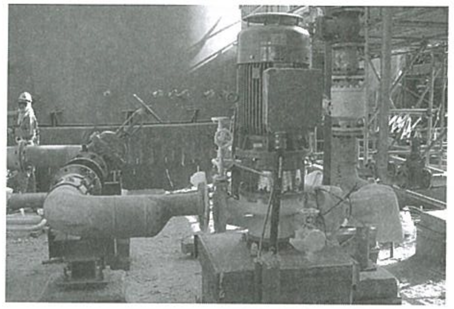
Electrical engineering is in charge of the design of the plant electrical power generation and distribution.

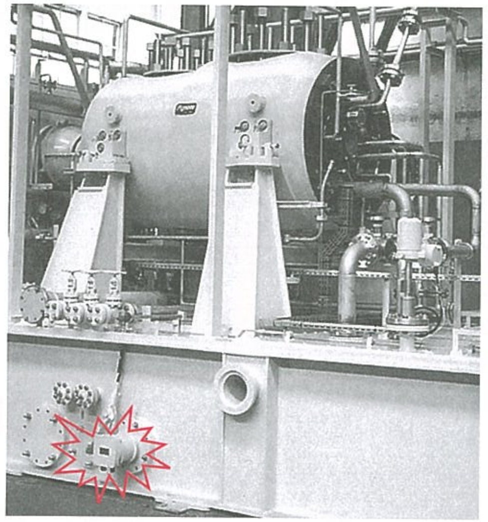
Similarly to Instrumentation, the activities of the Electrical discipline can be categorized as follows: architecture (of the electrical power generation and distribution system), specification of all equipment and materials, and production of installation drawings.

Electrical engineering activities start with the identification of all consumers. This is done from the Equipment list and shall also include all electrical consumers "hidden" inside packages, such as a machinery lube oil heater, HVAC of buildings – sometimes a major load -, outdoor lighting, building lighting and small power, etc. All electrical consumers are registered in the **Electrical Load List**.

Equipment actual power consumption is not available initially, as the equipment make and model is not known yet. Electrical discipline estimates the power consumption first. The estimate is then replaced by the actual power consumption once the equipment (make and model) has been selected.

Once the consumers are identified, the total electrical power requirement of the plant can be evaluated. This is not the sum of the power requirements of all consumers. Indeed, they do not all operate simultaneously. A more refined approach is required to work out the realistic overall power demand.





LV Motor Control Center TG-MCC-002 (V=400/230V)							
Equipment No.	Description	Vital	Essential	Normal	Restatring	Duty Type	ABSORBED LOAD (A) kVA - kW
TG-002	Turbo Gen.						
88CR	Turb. Gen. Start. Motor					C	160
23QT-1	Lube Oil tank heater					C	7,50
23QT-2	Lube Oil tank heater					C	7,50
23FG-1	Fuel Gas Electric Heater						60
88BA-1	Turbine enclosure Ventilation duty fan					C	13,50
88BA-2	Turbine enclosure Ventilation duty fan						13,50
88FC-1	Oil Cooler Fan Motor						3,10
88FC-2	Oil Cooler Fan Motor						3,10
88FC-3	Oil Cooler Fan Motor						3,10
23WK-1	Heater OFF-LINE washing skid						4,00
88TW-1	Water wash pump motor OFF-LINE skid						2,20
88QA	Aux, Lube Oil Pump Motor					D	10,00
88QV	Lube Oil vapour separator motor					C	1,50
DCP-A	Direct current supply panel side A					C	25,00
DCP-B	Direct current supply panel side B					C	6,50

Electrical Load List

Consumers are classified according their frequency of operation, as continuous, intermittent or spare.

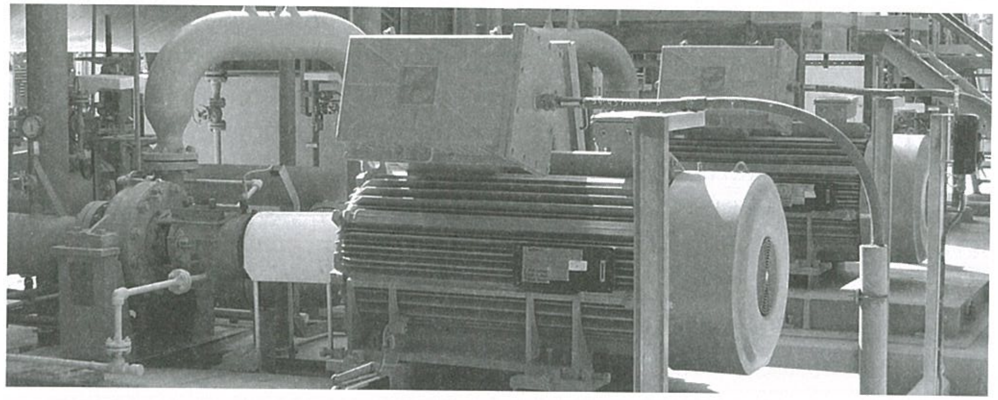
E - "Continuous"; loads of machines or consumers which operate continuously when the plant is in operation, except for breakdowns.

F - "Intermittent "; machines or consumers with a start-stop cycle: pumping, storage, loading...

G - "Spare"; machines or consumers which act as a spare for other machines and which do not therefore normally operate when the plant is in operation.

Each type is assigned a coincidence factor, which is applied to its absorbed load to work out the total power requirement.

Intermittent consumers, such as offloading pumps working under start/stop cycle for instance, are counted 60%.



Spare consumers, such as pump B that operates only in case pump A does not, are counted 10% only, etc.

The factored loads are summed up in the **Electrical Load Summary**, which gives the total plant power demand and also the load on each electrical equipment (switchboard, transformer) allowing its sizing.

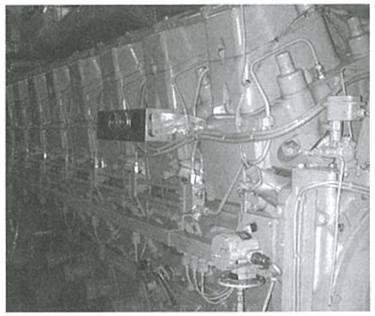
Item	LV MCC MCC-002 (V=400/230V)		CONSUMED LOAD		
	Equipment No.	Description	Continuous (E) kW	Intermittent (F) kW	Spare (G) kW
1	LP003-1	Fire Fighting pump Bldg Light&Small Pwr	10,0		
2	LP003-2				
3	HSV-0011	Valve for gas metering station		1,3	
4	HSV-0012	Valve for gas metering station		1,3	
5	PM-032A	Fire Fighting Jockey Pump	5,2		
6	PM-032B	Fire Fighting Jockey Pump			5,2
Maximum of normal running plant load : (Est. 1 . E + 0.6 . F)		kW = 16,7	15,2	2,6	5,2
Peak Load (Est. 1 . E + 0.6 . F + 0.1 . G)		kW = 17,2			

Electrical Load Summary

The most demanding operating modes, such as start-up of large motors, are considered to define the maximum load condition. This will size the power generation.

Maximum and minimum power requirements, and required availability, allow to define the number (redundancy) and capacity of power generators. A typical arrangement would include 4 generators, each having a capacity of 50% of the plant total power requirement. 3 generators will be running at 2/3 of their capacity while the 4th one could be under maintenance in normal circumstances. Should one generator trip, the remaining 2 will ramp up to full capacity, allowing no disruption in power supply, until the 3rd generator comes back on line.

Power supply to some consumers cannot be interrupted without impact on the production of the plant. Additionally, some consumers shall remain powered at all times to ensure equipment or plant safety: rotating machinery lube oil pumps, fire fighting water pumps, etc. These consumers are classified as "**essential consumers**", for which redundant power supply is required, on top of the power supply from the main power generators.



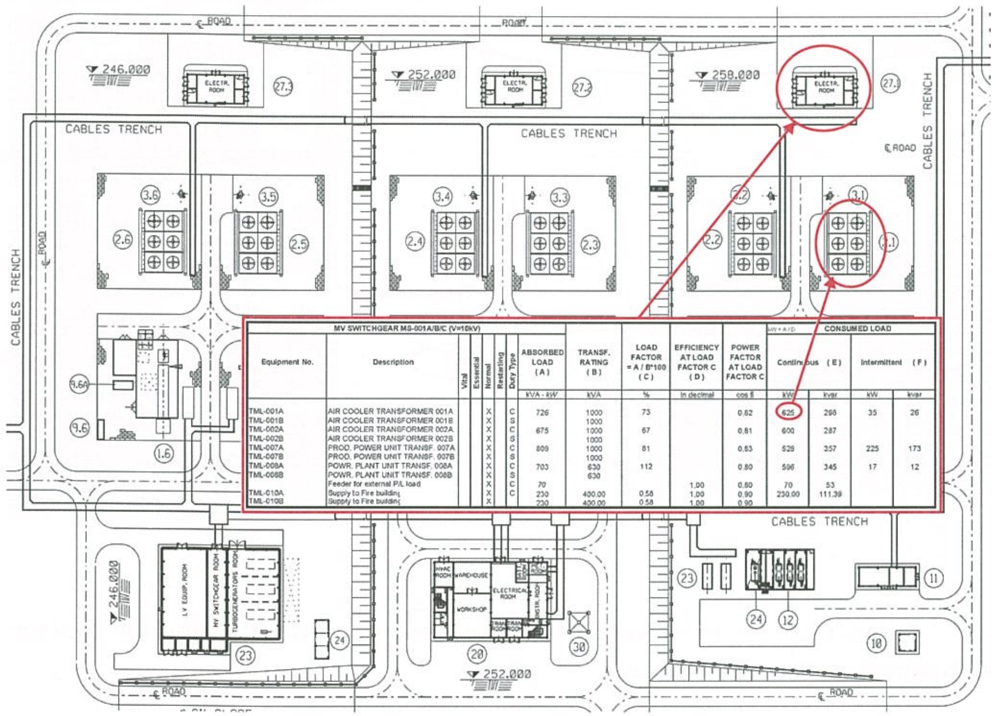
Back-up power supply is provided by diesel generators. Unlike the main power generators, which run on fuel (gas) fed from the Process, diesel generators have their own stand alone (diesel) fuel supply. In such a way, fuel supply is not dependent on plant operation. Sizing of the diesel generators takes into account the power requirement to re-start the main power generators, e.g., starters of gas turbines, etc.

The requisition for the main power generators and the diesel generators is prepared by the Mechanical Engineer. It includes the data sheet for the electrical part (alternator) prepared by the Electrical Engineer besides the data sheet for the driver.

All plant systems, i.e., Process Control System, Emergency Shutdown system, Electrical Control System, etc. shall remain operational in the event of loss of the power generation. Equipment of these systems are called "**vital**" and must remain powered at all times. An Un-interruptible Power System (UPS), with batteries, is provided for this purpose. Capacity of the UPS is the sum of the power consumption of the equipment of the above systems. This information is obtained from equipment vendor and can take time to finalize.

The architecture of the electrical distribution system is determined by a number of factors including:

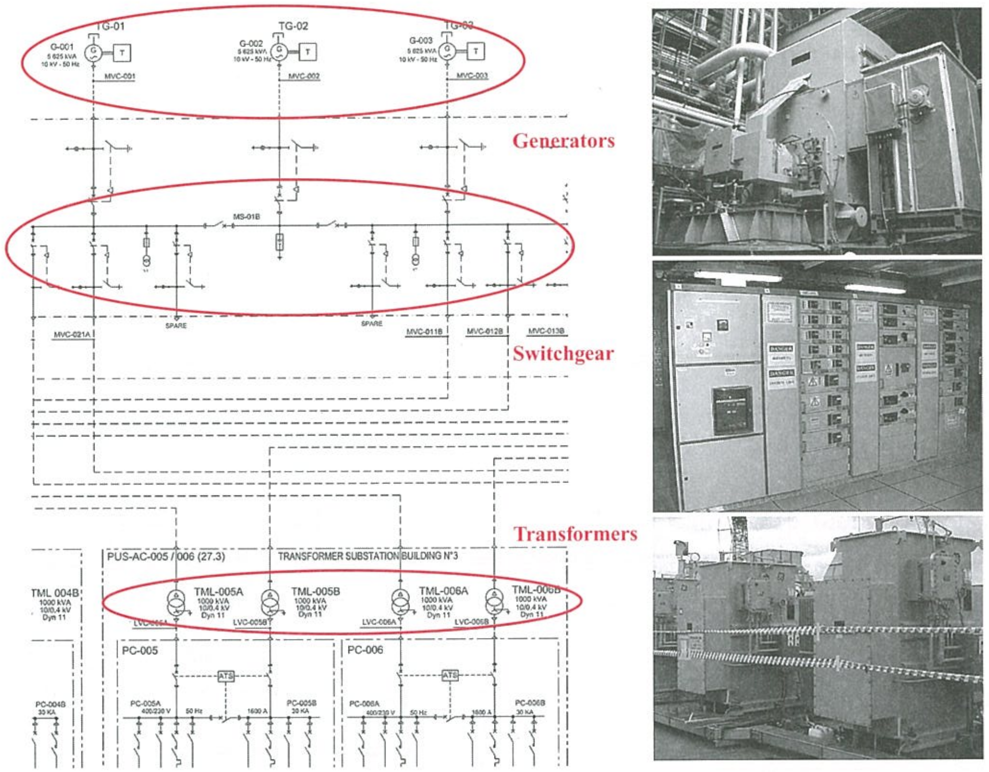
- connection to external grid (On-Shore),
- voltage levels, which depends on consumers, e.g., large motor require MV instead of LV for ordinary motors, e.g., 11kV, 6.6kV, 400V, 230V, 110V DC, etc.,
- segregation between normal and essential consumers,
- number and location of transformers and Electrical sub-stations, which depend on the geographical distribution of consumers[1].



MV SWITCHGEAR MS-001A/B/C (V=10kV)												CONSUMED LOAD			
Equipment No.	Description	Vital	Essential	Normal	Restarting	Duty Type	ABSORBED LOAD (A)	TRANSF. RATING (B)	LOAD FACTOR = A / B*100 (C)	EFFICIENCY AT LOAD FACTOR C (D)	POWER FACTOR AT LOAD FACTOR C	Continuous (E)		Intermittent (F)	
							kVA - kW	kVA	%	in decimal	cos fi	kW	kvar	kW	kvar
TML-001A	AIR COOLER TRANSFORMER 001A			X		C	726	1000	73		0.82	625	298	35	26
TML-001B	AIR COOLER TRANSFORMER 001B			X		S		1000							
TML-002A	AIR COOLER TRANSFORMER 002A			X		C	675	1000	67		0.81	600	287		
TML-002B	AIR COOLER TRANSFORMER 002B			X		S		1000							
TML-007A	PROD. POWER UNIT TRANSF. 007A			X		C	809	1000	81		0.83	528	357	225	173
TML-007B	PROD. POWER UNIT TRANSF. 007B			X		S		1000							
TML-008A	POWR. PLANT UNIT TRANSF. 008A			X		C	703	630	112		0.80	596	345	17	12
TML-008B	POWR. PLANT UNIT TRANSF. 008B			X		S		630							
	Feeder for external P/L load			X		C	70			1.00	0.80	70	53		
TML-010A	Supply to Fire building			X		C	230	400.00	0.58	1.00	0.90	230.00	111.39		
TML-010B	Supply to Fire building			X			230	400.00	0.58	1.00	0.90				

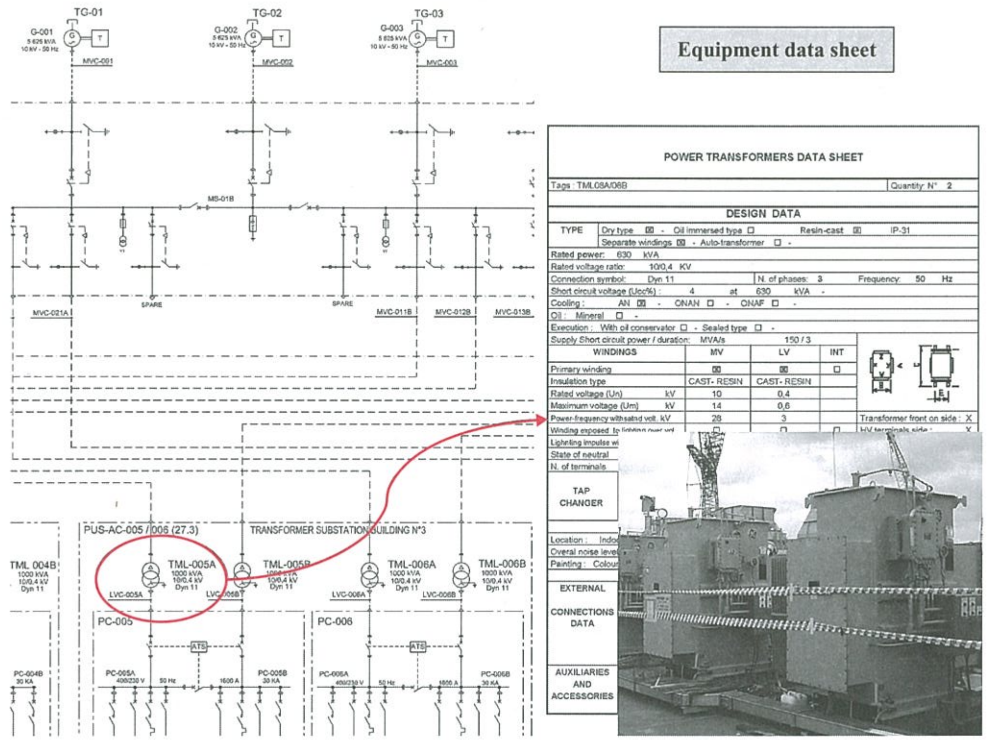
1. Sub-stations shall be as close as possible to main consumers to reduce cable length and section: on the plot plant shown here the power plant is item 23. Power supply to the gas-coolers (items 2.1-6), which are large low voltage consumers, is not done directly from the power plant but through sub-stations 27.1 to 3 equipped with high/low voltage power transformers. In such a way, high voltage cables are provided between the power plant and the sub-stations, which reduces the cable section, whereas low voltage cables, with large section, are required only on the short distance between the sub-stations and the consumers.

The overall power generation and distribution system is depicted on the **General One Line Diagram**, which shows generators, switchboards of various voltage levels, transformers and main consumers.

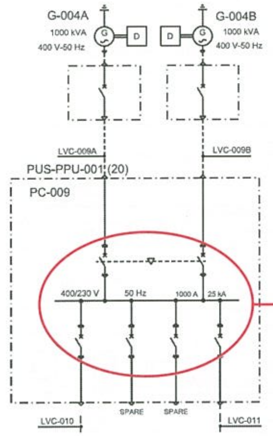


The Electrical Engineer specifies all equipment of the distribution system: switchboards, transformers, etc.

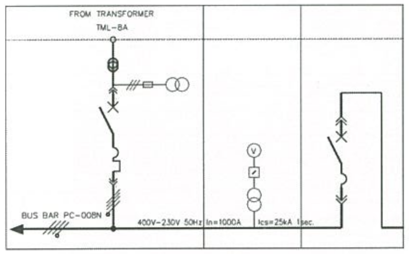
It produces a **data sheet** which, together with a **specification**, usually a general specification per type of equipment, will form the requisition for purchase.



Single Line Diagrams are produced for electrical switchboards, specifying to the vendor the content of the switchboard (incomers/outgoers), capacity, protections, control and monitoring devices.



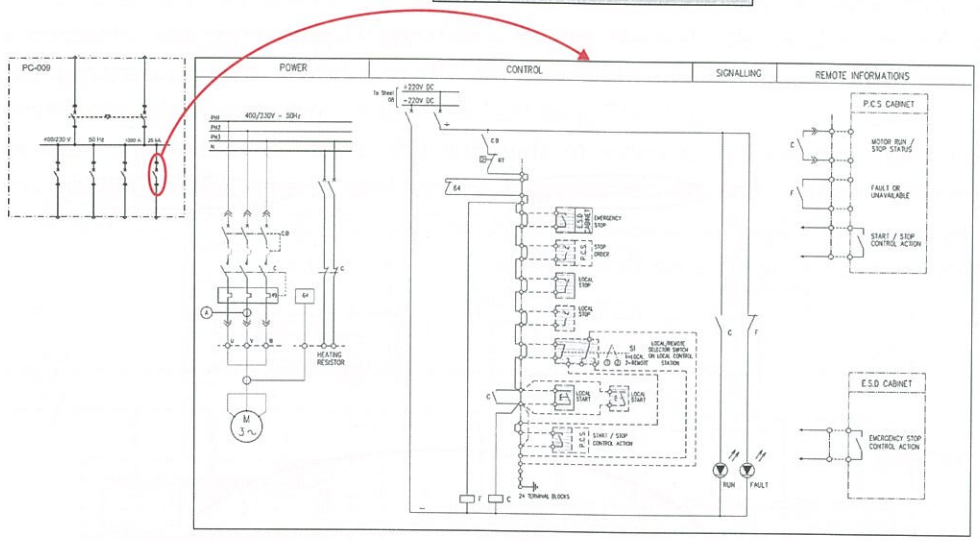
Switchboard Single Line Diagram



	CUBICLE DESIGNATION	INCOMER Q008N	BUS BAR VOLTAGE TRANSFORMER	BUS TIE
CHARACTERISTICS / INCOMERS	CUBICLE TAG NUMBER	Q008N	VT 008N	BT008
	CIRCUIT BREAKER RATED CURRENT			
	FUSE RATING			
	VOLTAGE AND / OR CURRENT TRANSFORMER RATIO	3CT 1000A/1A 20VA Cl. 0.5 Fs5 /1A 20VA Cl. 0.5 Fs5 3VT $\frac{400V}{\sqrt{3}} / \frac{110V}{\sqrt{3}}$ 30VA Cl. 0.5	3VT $\frac{400V}{\sqrt{3}} / \frac{110V}{\sqrt{3}}$ 30VA Cl. 0.5	
	PROTECTIVE RELAYS	86 LOCKOUT RELAY 27 UNDER VOLTAGE RELAY 25 SYNCHRO CHECK DEVICE 51 AC TIME OVERCURRENT RELAY 49 THERMAL RELAY	27 UNDER VOLTAGE RELAY	86 LOCKOUT RELAY 25 SYNCHRO CHECK DEVICE 51 AC TIME OVERCURRENT RELAY
	METERING	-1 AMMETER WITH SELECTOR SWITCH -1 VOLTMETER WITH SELECTOR SWITCH -1 WATTMETER -1 POWER FACTOR METER	-1 VOLTMETER WITH SELECTOR SWITCH	
	TERMINAL TAG NUMBER			
	SUPPLY RATED POWER / RATED CURRENT	630 kVA		
	SUPPLY SHORT CIRCUIT POWER			
	CABLES: POWER: CROSS SECTION AND TYPE	4X2x(1x240 mm2) Cu		
	CABLES: CONTROL: CROSS SECTION AND TYPE			
REF. DWGS.	TYPICAL DIAGRAM NUMBER	E-3-42005	E-3-42005	E-3-42005
	SHEET	10-11-07-08	06	13-14

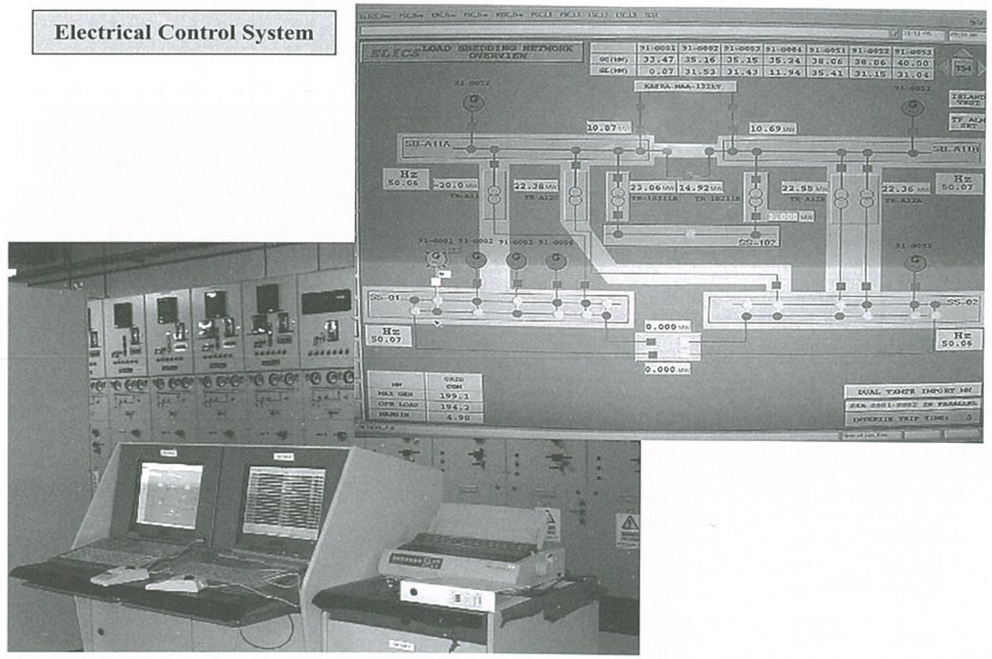
The power connection, the control, indication and remote monitoring features of switchgear cubicles are specified, for each type, e.g., motor outgoer, on the **Switchgear Typical Diagrams**.

Switchgear Typical Diagram



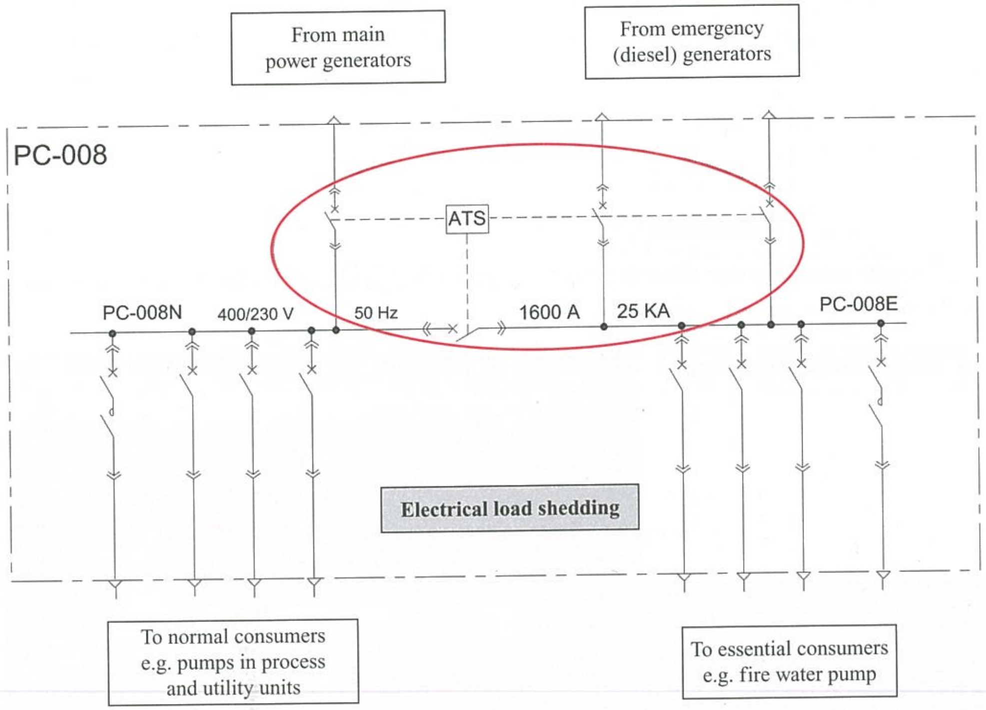
The electrical power distribution is monitored and controlled by an automated system: the Electrical Control System.

Electrical Control System



The Electrical Control System allows monitoring (status of protections, voltage/amperage/power values) at various points of the electrical system and control (start/stop of motor, etc.).

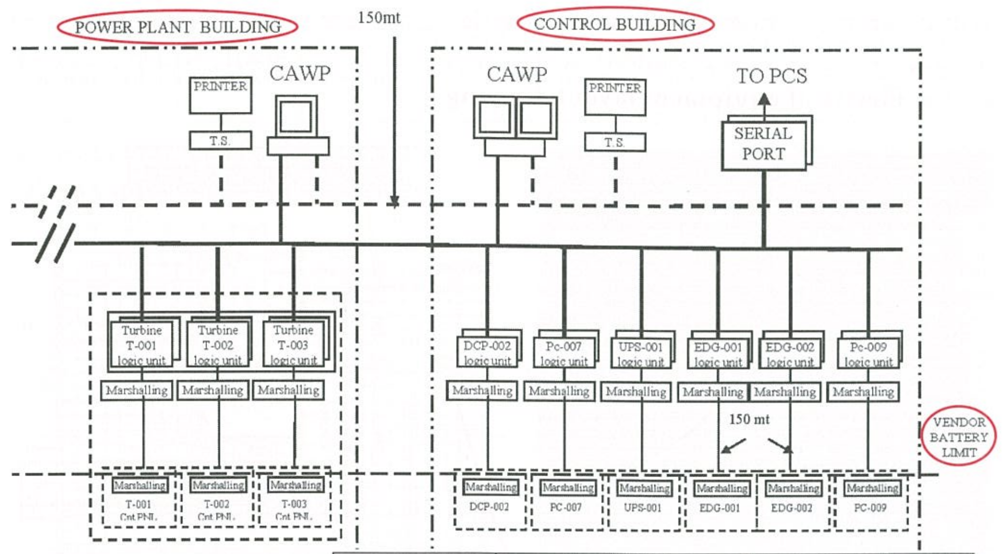
It also performs the key function of load shedding, interrupting power supply to non-essential consumers upon loss of power from the main generators, in order to reserve the limited power available, supplied by the emergency generators, to essential consumers. In the scheme shown here, for instance, the Automatic Transfer Switch will open the bus tie upon loss of normal power (from the main generators) in order to shed the non essential consumers, such as process pumps. The power supplied by the emergency generators is thus segregated and directed to essential consumers, connected to the right side of the bus bar, such as the fire water pumps.



Electrical load shedding

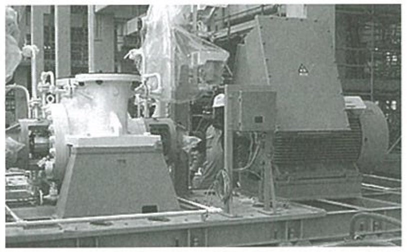
The Electrical Control System is interfaced to the Process Control System, e.g., pump start/stop command is received from the PCS. It is also interfaced with the vendor supplied control system of the power generators.

A specification is produced to define the functionalities and capacity of the Electrical Control system: architecture and geographical distribution of equipment (allowing the vendor to identify the number and location of equipment its system will connect to, such as electrical switchboards, generator control equipment, etc.).



I/O	Power Plant Building									Control Building						
	MS-001	T-001	T-002	T-003	TG-001	TG-002	TG-003	PC-008	DCP-001	EDG-001	EDG-002	PC-007	PC-009	UPS-001	DCP-002	Serial Link to PCS
DI hardwired	348	33	33	33	5	5	5	23	5	10	10	23	23	5	5	
DO hardwired										4	4	6	6	10	10	
AI hardwired	64	9	9	9	10	10	10	6	5	15	15	6	6	5	5	
DI via serial link	348	33	33	33	5	5	5	23		10	10	23	23	5	5	600

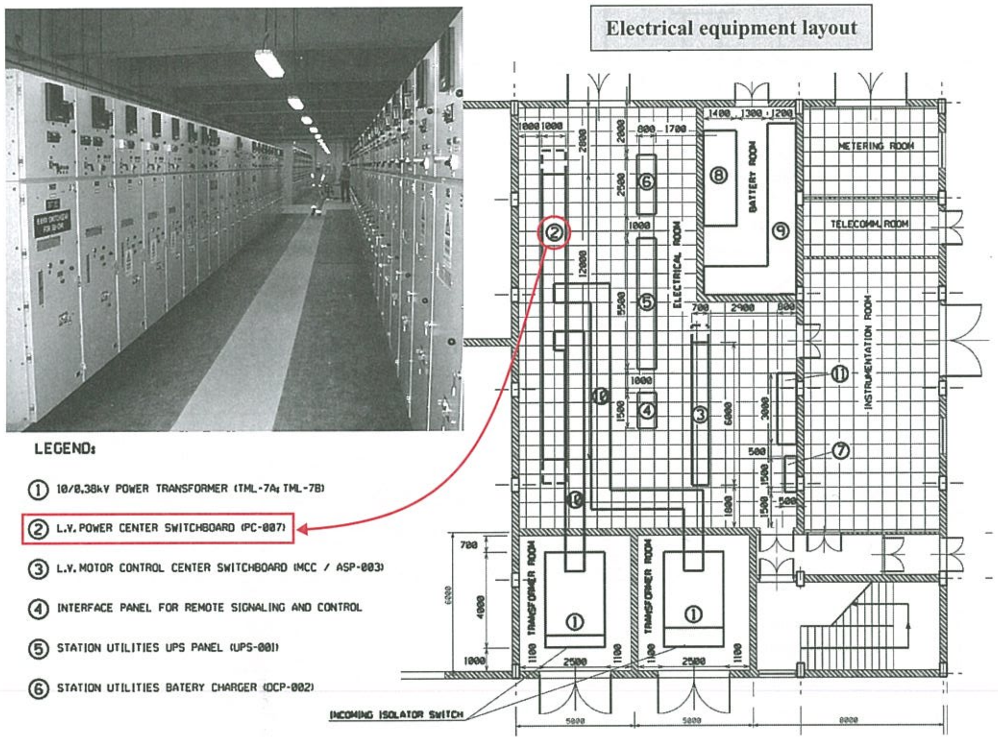
Electrical Control System Architecture drawing



As discussed above, data from equipment vendors is not available initially, including power consumption which is estimated at first. When actual power consumption is known from vendor, the capacity of all electrical generation and distribution equipment is checked (main power generators, emergency generator, switchboards, transformers, cables, etc.).

Once the electrical equipment (switchboards, etc.) is purchased, its actual size will be known. This will allow the electrical engineer to define the equipment arrangement inside sub-stations, including provision for spare, which is shown on the **Electrical equipment layout drawing**.

Electrical equipment layout



Electrical discipline also contributes to the specification of the mechanical equipment by preparing the **electrical data sheets** for the motors that are the drivers of these equipment, e.g., pumps, gas-coolers, etc. Such data sheet specifies in particular the type of explosion protection required for the equipment.

Indeed, an electrical field equipment located in an area where an explosive atmosphere can form shall have a special design so that it cannot be a source of ignition.

Such special design, called Hazardous area (Ex) classification of the equipment, is specified by the Safety engineer, according to the type of explosive atmosphere, its probability, ignition energy and temperature, etc. Refer to the Safety section for more details.

The Electrical engineer implements the Ex requirement for the various types of electrical equipment (electric motor, electrical socket, local control stations, etc.).

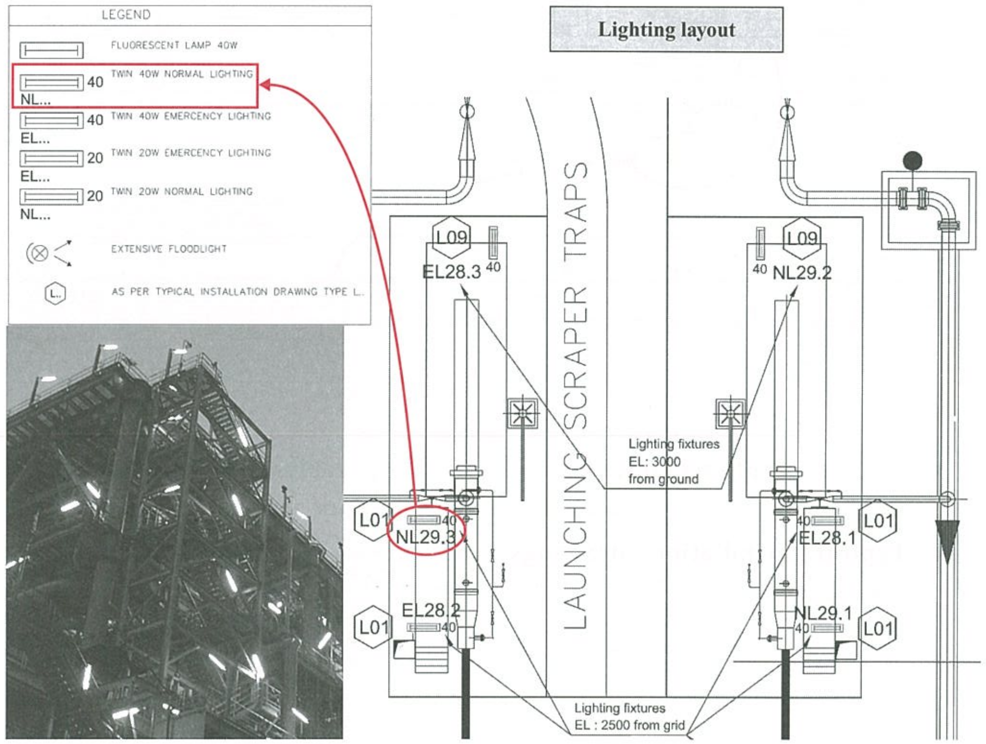
Electric cables are sized in order not to exceed a certain temperature under normal duty and also to sustain the short circuit current (the cable shall be able to handle short circuit of field equipment until the circuit breaker located at switchboard feeder opens). The Cable specification is governed by service, e.g., fire resistance for cables supplying critical equipment, armour for outdoor service, etc.

The specification of each cable is shown in the **Cable Schedule**.

Besides the electrical power distribution network, Electrical discipline also designs:

- the lighting system (as per illumination level requirements in each area),

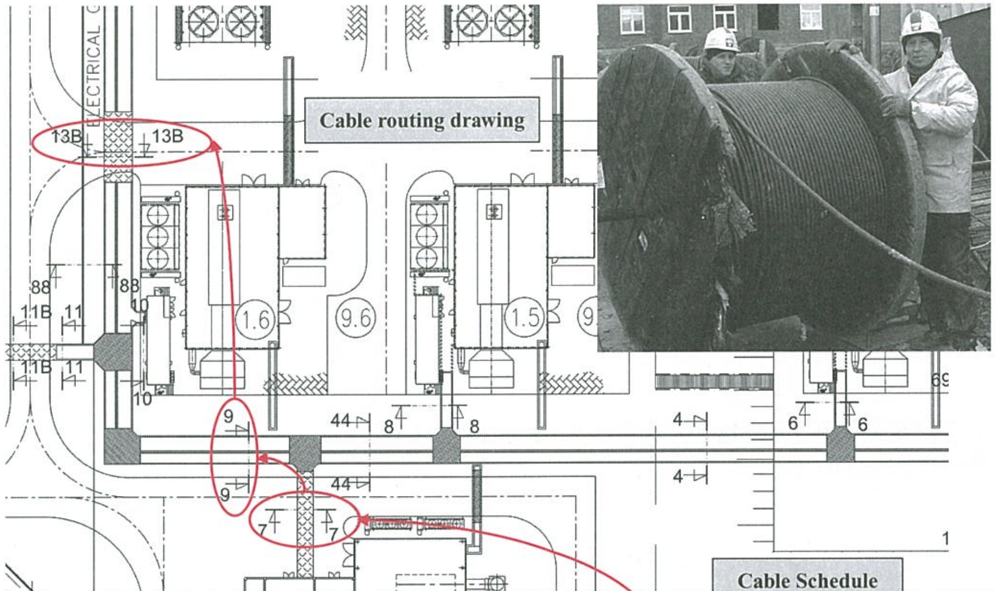
Lighting layout



- the earthing system,
- the lightning protection system,
- the underground piping cathodic protection (see Material & Corrosion section),
- the heat tracing system of some process lines (to avoid freezing).

Electrical installation studies result in the production of all drawings required to install and connect the electrical equipment at Site:

- Electrical **cable routing drawings**,

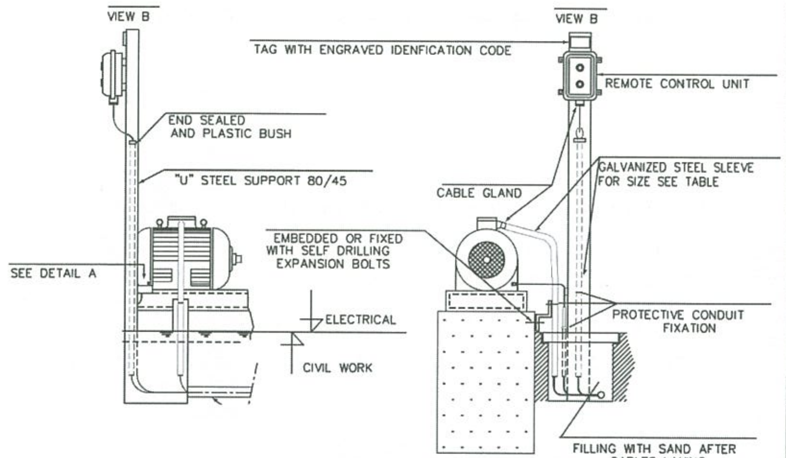


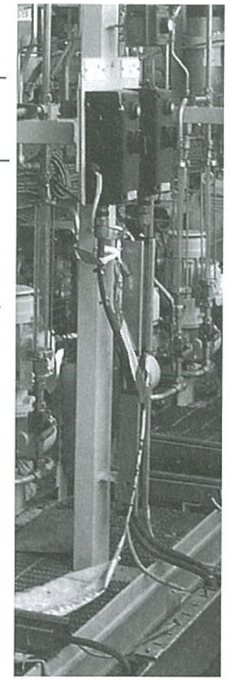
Cable routing drawing

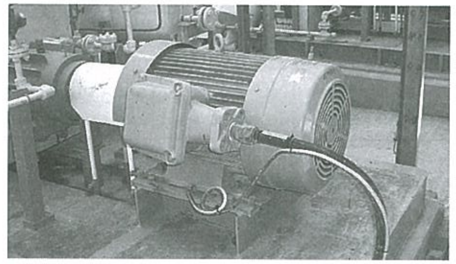
Cable Schedule

Cable N°	Coming from	Going to	Voltage (V)	Type (sheet 3)	N° of Cores	Cross section (sqmm)	Length (m)	cable routing
MVC-010A	MS-001A	TML-010A	10 000	2	3	50	720	-7-9-13B-13-60-18-61-23-62-74-36A-36-36B-37-37B-40-41-E32.2-E32.3-E32.1-
MVC-010C	MS-001C	TML-010C	10 000	2	3	50	720	-7-9-13B-13-60-18-61-23-62-74-36A-36-36B-37-37B-40-41-E32.2-E32.3-E32.1-
MVC-011A	MS-001A	TML-001A	10 000	2	3	50	520	-7-9-13B-13B-13-60-18-61-23-62-27-
MVC-011B	MS-001C	TML-001B	10 000	2	3	50	520	-7-9-13B-13B-13-60-18-61-23-62-27-
MVC-012A	MS-001A	TML-002A	10 000	2	3	50	520	-7-9-13B-13-60-18-61-23-62-27-
MVC-012B	MS-001C	TML-002B	10 000	2	3	50	520	-7-9-13B-13-60-18-61-23-62-27-
MVC-013A	MS-001A	TML-003A	10 000	2	3	50	430	-7-9-13B-13-60-18-61-22-

- Electrical **cable schedule** (showing the list of cables, the type, such as fire resistant, section size, number of cores, length of each cable),
- **Typical installation drawings**, for power, lighting, earthing, heat tracing, etc.,

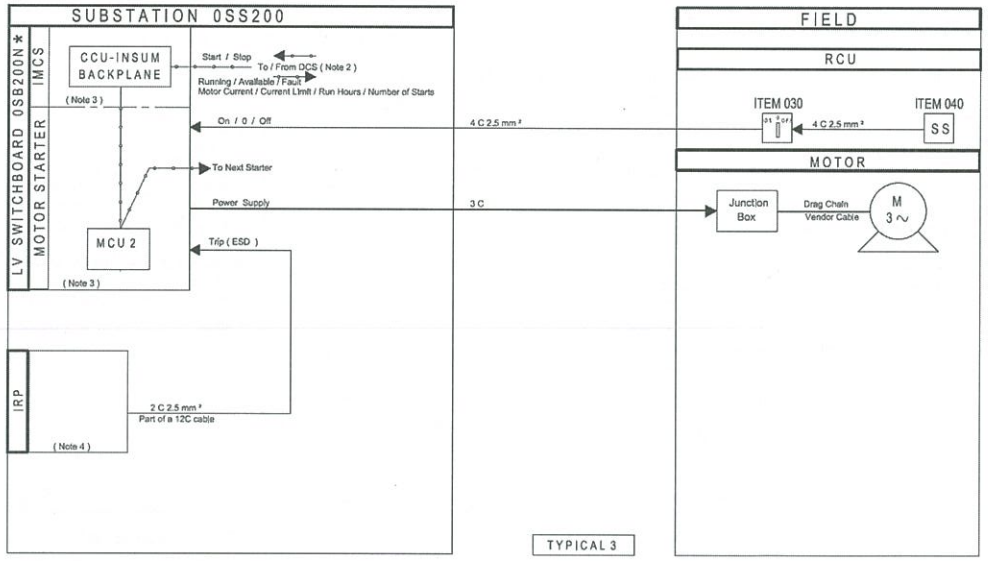


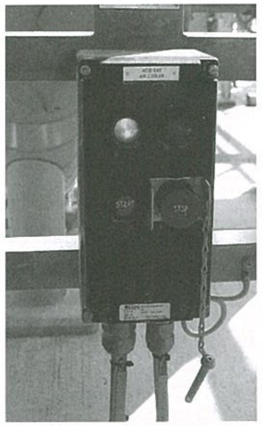




Typical installation drawings

- **Block diagrams** show typical (repetitive) connections,



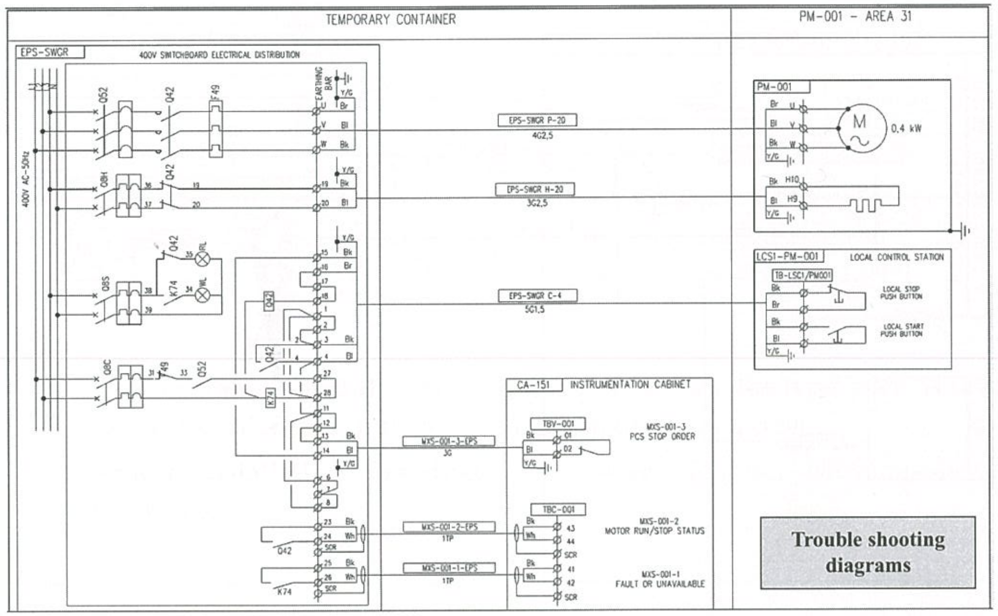


- **Electrical equipment location drawings**, showing location of all electrical consumers: motor local control stations, field sockets, lighting fixtures and junction boxes, etc.,

Alongside installation drawings the **Electrical bulk material take-off** is prepared in order to purchase cables, cable ladders, motor local control stations, junction boxes, cable glands and all other small installation materials.

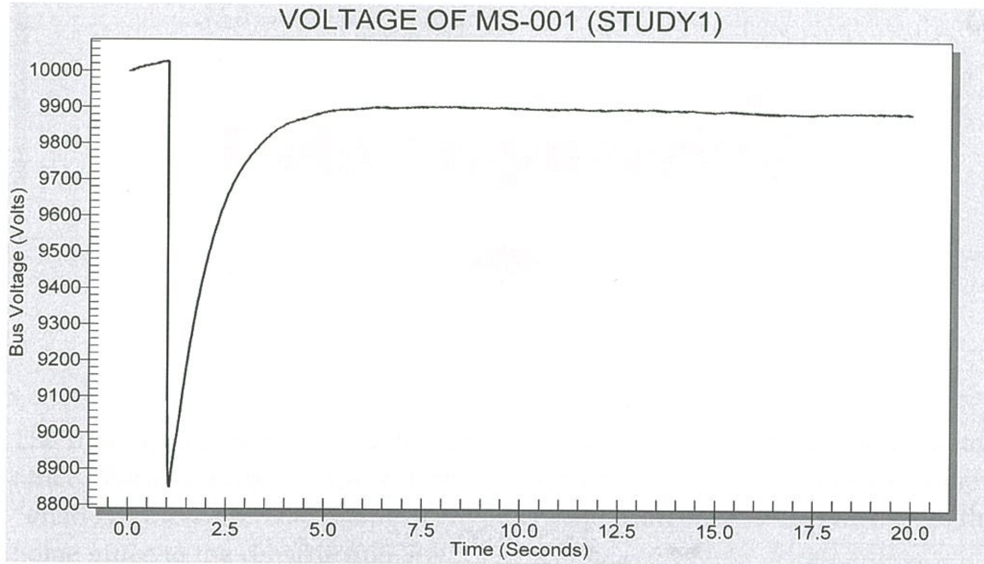
ITEM	DESCRIPTION	QTY
1	local control station enclosure with: – 1 "START" push button with 1NO + 1 NC contact block – 1 "STOP" push button with 1NO + 1 NC contact block – 1 cable entry and metallic cable gland (non armoured cable 5 G1,5)	27
2	Welding socket 63 A – 400V – 3Ph + E – IP44 with: – connection to 35mm2 terminal – 1 cable gland for non armoured cable (4G35)	18

Lastly, Electrical discipline produces the **Trouble Shooting Diagrams**, which show the wiring of each consumer and will also be used for the Plant maintenance.



The electrical generation and distribution system is modelled using a computer software allowing to perform calculations and run simulations.

Simulations will include, for instance, the loss of one of the main power generators. The resulting transient conditions, before the stand-by generator has taken over, are checked to ensure that, for instance, process pumps will not have stopped.



Final **Electrical calculations** are performed once all consumers and electrical equipment characteristics are known, all cables are sized, etc. The calculations will define the right setting of electrical protections. This right setting ensures selectivity. Selectivity means that, in case there is a short circuit on a motor, the protection of that motor only will open, no higher level protection will open, leaving the other consumers unaffected. The results are collected in the **Electrical Relay Schedule**, which is used at Site during commissioning to set the protections.

Chapter 13

Field Engineering

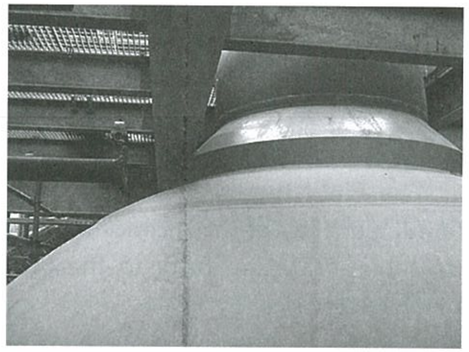
The description above related to Engineering activities performed in the home office. When a Project goes in Construction phase, a small multi-disciplinary "Field Engineering" team made of engineers and draftsmen is seconded from the home office to the construction Site.

These Engineers and draftsmen are fully familiar with the engineering documents and drawings that have been produced.

They know on which document to find information.

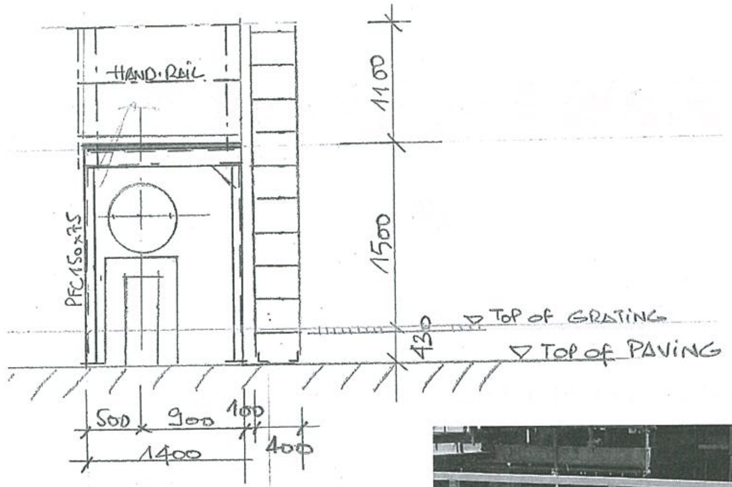
Their first task is to familiarize the Construction contractor(s) working at site with the Engineering deliverables.

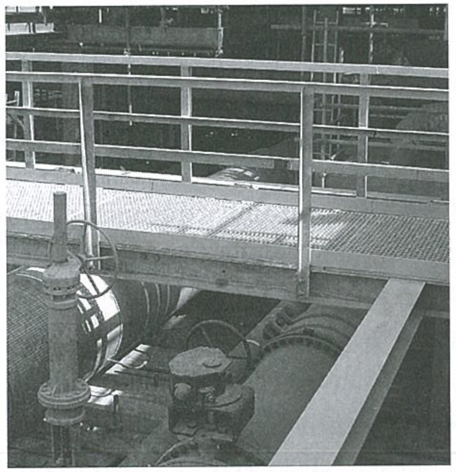
They are also there to solve issues discovered during construction, such as:



- engineering errors, such as interferences between a pipe and a steel structure,
- construction errors, e.g., a foundation has been cast slightly off its designed position and a design change is required to avoid re-cast,

- Site, equipment or material conditions differ from what was anticipated,
- overlooked engineering: the construction contractor needs some information that have not been prepared, e.g., cable routing was not defined in full, etc.,
- additions to the design. During the final inspection of the facility with the client before the hand-over a number of shortcomings are identified in the design, such as lack of access to valves as shown here…





The Field Engineer performs the corresponding design. It would typically entail a survey of the location, dimensional measurements, sketching a solution on the spot, going back to the office to draft the drawings, issue the bill of material, etc.

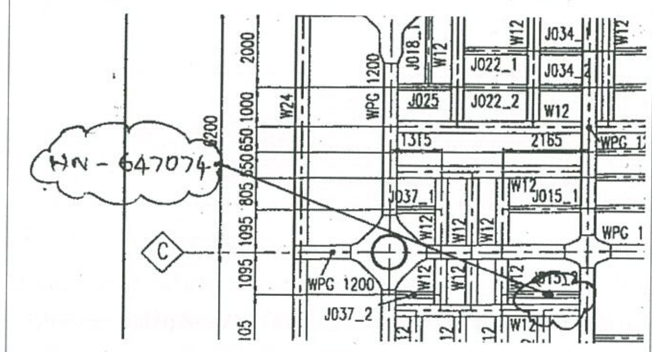
Changes to the design made at the Site must be approved by Engineering. To this end, the **Site Query** system is put in place:

Upon identification of a required change, the construction contractor issues a Site Query to the Engineer.

FROM: Construction Sub-Contractor	**SITE QUERY NO.:**	**Rev.:**
TO: Contractor	**DISCIPLINE:** Piping	**SYSTEM:** -
SUBJECT: Penetration clash with beams		
REF.: drawing #...		

DESCRIPTION:
Pipe penetration found to clash with the beams on the above drawing
Module-P, line HN-647074.
Contractor to advise on the alternative.

Module	Pipe number	Pipe size(Inch)	Sleeve Size (mm) [F… OD + 100 + Insulation from PDMS]	Sleeve Location East	North	Elevation
P	LA1PD-HN-647074	12"	424	115617	285494	106000



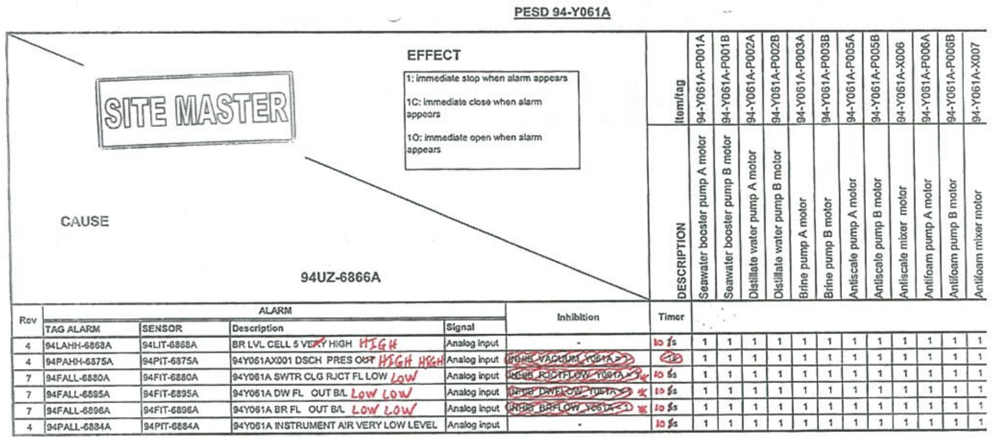
ORIGINATOR:		**POSITION:**	Engineer	**DATE:**	
CHECKED BY:		**POSITION:**	Snr. Engineer	**DATE:**	
AGREED BY:		**POSITION:**	Proj. Manager	**DATE:**	
ANSWER:		**ANSWER REQUIRED BY:**			

ANSWER BY:	**SIGNATURE:**	**POSITION:**	**DATE:**
ANSWER APPROVED BY:	**SIGNATURE:**	**POSITION:**	**DATE:**

The Site query describes the issue encountered and, preferably, proposes a solution. The Engineer checks that the proposed change is acceptable or proposes an alternative.

In order to always work with up-to-date documents, Engineering updates a unique, called MASTER, set of engineering documents, with all changes. Changes are usually marked by hand and in red on the drawings, which are for this reason called "red-line mark-ups". The reference of the change is indicated next to the mark to trace it.

The Master set of **red-line mark-ups** is the reference on Site to which every party (Construction, Commissioning, etc.) refers.



PESD 94-Y061A

SITE MASTER

EFFECT

1: immediate stop when alarm appears

1C: immediate close when alarm appears

1O: immediate open when alarm appears

CAUSE

94UZ-6866A

Rev	ALARM				Inhibition	Timer	Seawater booster pump A motor	Seawater booster pump B motor	Distillate water pump A motor	Distillate water pump B motor	Brine pump A motor	Brine pump B motor	Antiscale pump A motor	Antiscale pump B motor	Antiscale mixer motor	Antifoam pump A motor	Antifoam pump B motor	Antifoam mixer motor
	TAG ALARM	SENSOR	Description	Signal			94-Y061A-P001A	94-Y061A-P001B	94-Y061A-P002A	94-Y061A-P002B	94-Y061A-P003A	94-Y061A-P003B	94-Y061A-P005A	94-Y061A-P005B	94-Y061A-X006	94-Y061A-P006A	94-Y061A-P006B	94-Y061A-X007
4	94LAHH-6868A	94LIT-6868A	BR LVL CELL 5 ~~VERY~~ HIGH HIGH	Analog input	-	10 ~~5s~~	1	1	1	1	1	1	1	1	1	1	1	1
4	94PAHH-6875A	94PIT-6875A	94Y061AX001 DSCH PRES ~~OUT~~ HIGH HIGH	Analog input	~~INHIB_VACUUM_Y061A > 1~~	10	1	1	1	1	1	1	1	1	1	1	1	1
7	94FALL-6880A	94FIT-6880A	94Y061A SWTR CLG RJCT FL LOW LOW	Analog input	~~INHIB_RJCTFLOW_Y061A > 1~~ *	10 ~~5s~~	1	1	1	1	1	1	1	1	1	1	1	1
7	94FALL-6895A	94FIT-6895A	94Y061A DW FL OUT B/L LOW LOW	Analog input	~~INHIB_DWFLOW_Y061A < 1~~ *	10 ~~5s~~	1	1	1	1	1	1	1	1	1	1	1	1
7	94FALL-6896A	94FIT-6896A	94Y061A BR FL OUT B/L LOW LOW	Analog input	~~INHIB_BRFLOW_Y061A < 1~~ *	10 ~~5s~~	1	1	1	1	1	1	1	1	1	1	1	1
4	94PALL-6884A	94PIT-6884A	94Y061A INSTRUMENT AIR VERY LOW LEVEL	Analog input	-	10 ~~5s~~	1	1	1	1	1	1	1	1	1	1	1	1

At the end of the Project, red-line mark-ups allow to revise the engineering documents with all changes and issue a final "**As-Built**" revision. As-built's are part of the final documentation handed over to the client, and are used for the Plant Operation, maintenance, future expansion, etc.

Chapter 14

The challenges: matching the construction schedule

As explained above, Engineering delivery is twofold: the list and specifications of all equipment and materials, issued to Procurement for purchasing, and the construction drawings, issued to Site.

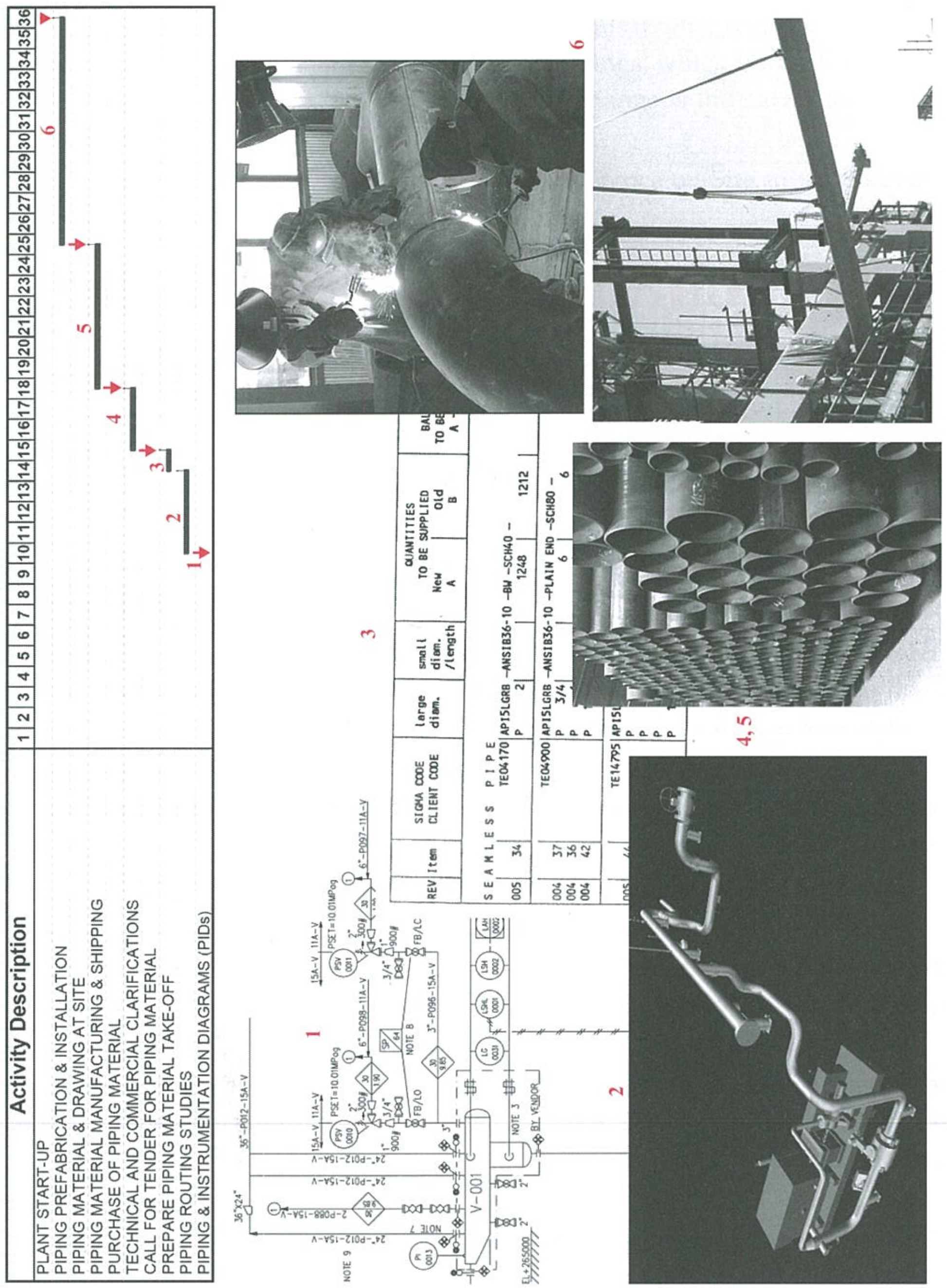
Ever decreasing EPC Project durations have stretched the engineering schedule: equipment must be purchased and construction drawings must be issued at a very early stage.

This has created a real challenge for Engineering.

Engineering deliverables (requisitions for ordering equipment and materials, drawings for construction) are indeed required to be issued in strict compliance with the Project schedule.

The logic of the Project schedule is the following: One starts by the end, i.e., required plant completion date, then works backwards, adding the duration of the various activities and their sequence, to work out the required start/completion date of each one.

In piping discipline, for instance, the Engineering, Procurement and Construction schedule will look as follows:

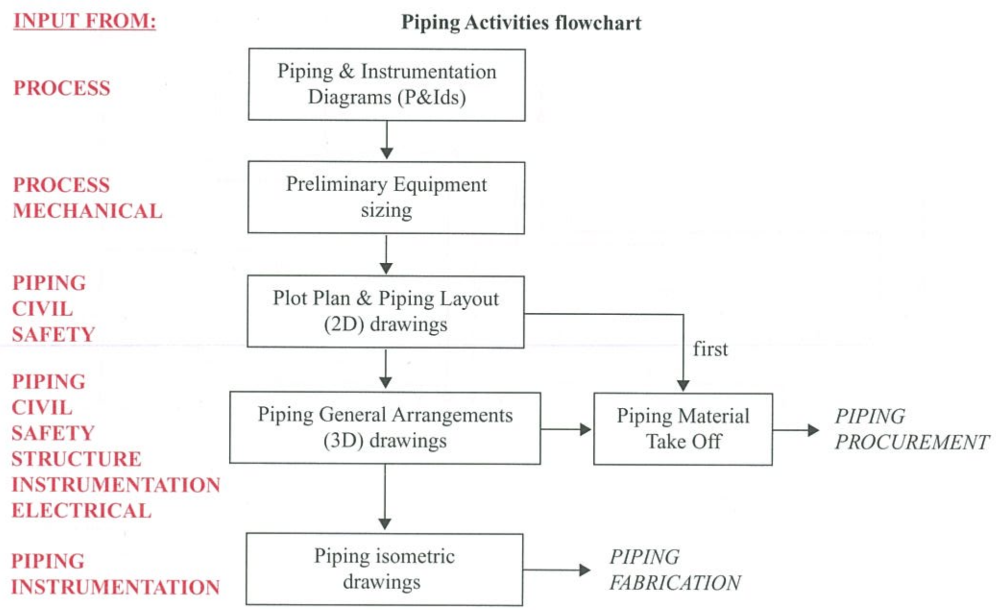


Which reads: Plant completion is due in month 36. If piping construction (pre-fabrication and erection) takes 10 months, then it should start at month 25. Piping material and drawings should be available at Site by this ROS (Required on Site) date. If piping takes 7 months to procure and ship, then it should be purchased by month 18 latest. Before Piping can be procured, inquiries must be issued to piping suppliers, then analyzed and clarified (technically, commercially). Allowing 3 months for the latter shows that inquiries shall be issued by month 15. Before inquiries can be issued, list of required material (Material Take Off) needs to be done, which takes 1 month: month 14. In order to do the piping material take-off, the piping routing studies must be completed, which takes 4 months, and must therefore be started on month 10. Piping routing studies are done on the basis of the P&IDs and Plot Plan, which are therefore required to be completed in month 10…

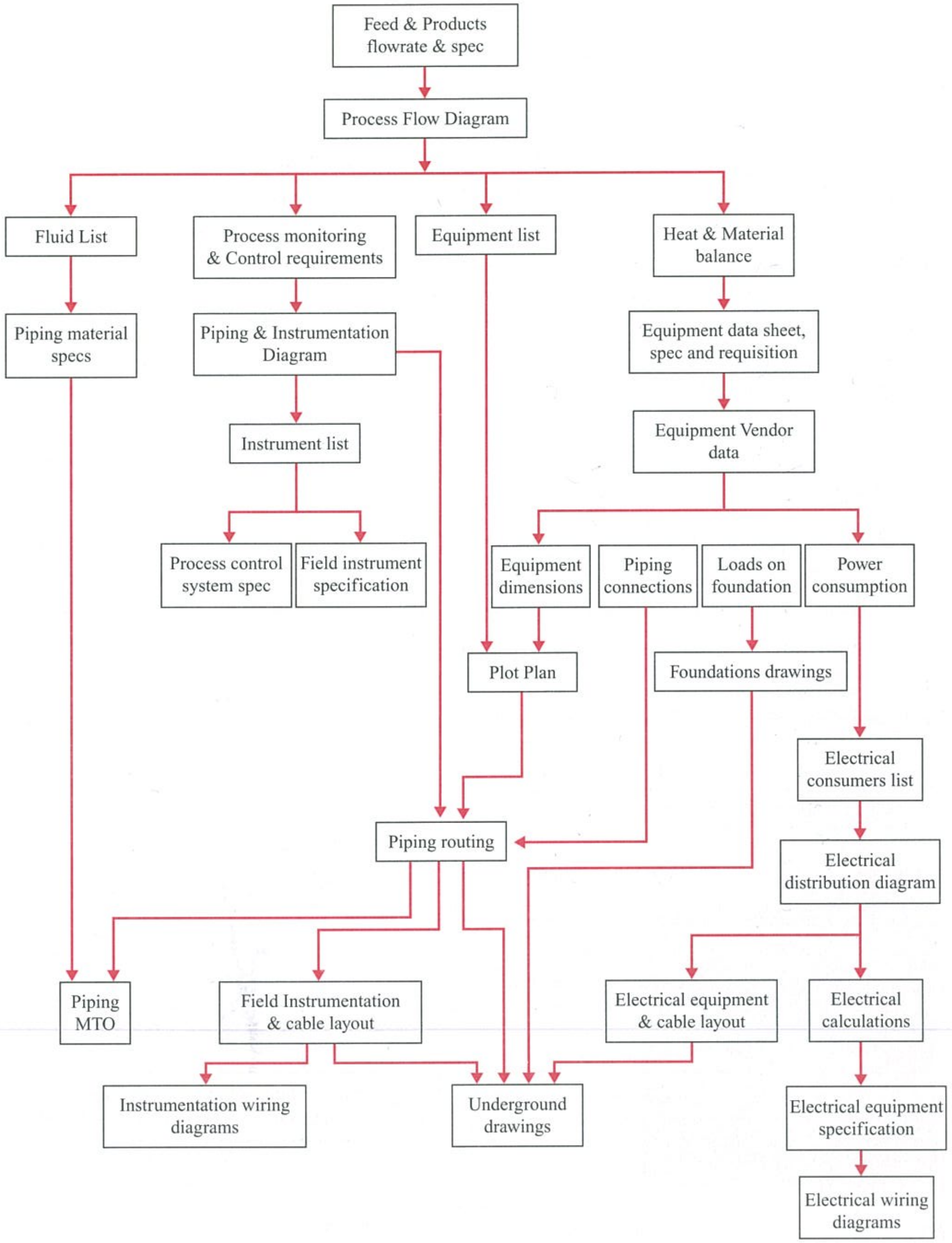
This retro-planning logic is how schedule requirements are defined for all activities of the project.

One sees that the schedule above, although dedicated to Piping, has set schedule requirements for P&IDs and Plot Plan, which are issued by other disciplines (Process resp. Plant Layout).

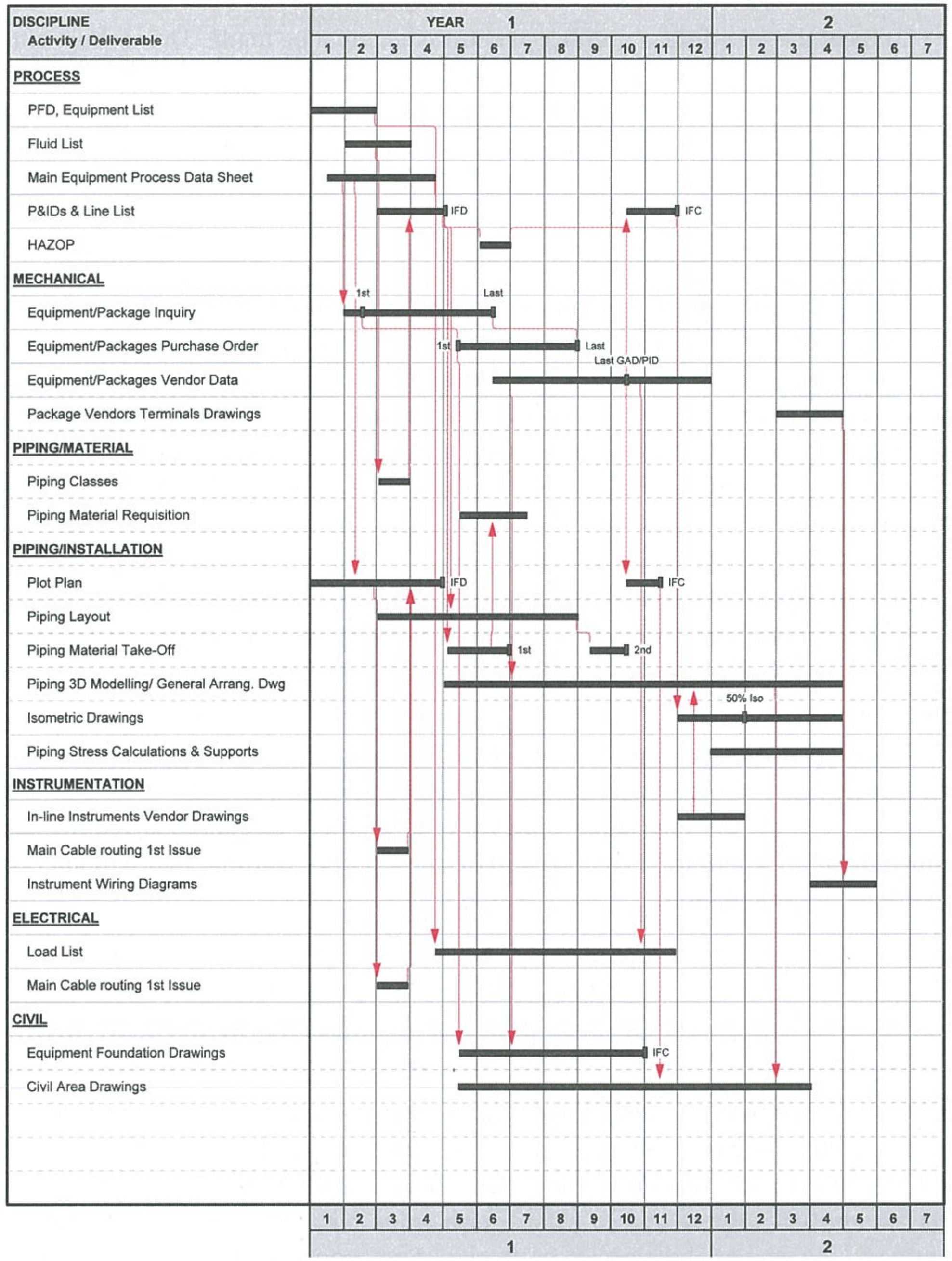
In fact, as depicted on the flowchart below, as piping studies go into higher levels of details (2D to 3D, etc.), they involve inputs from an increasing number of disciplines. The space occupied by the equipment/materials of all disciplines indeed needs to be considered to define the detailed pipe routes.



Engineering activities in the various disciplines are strongly dependent on one another, and on vendor information, as shown on the following Engineering activities and document flowchart.



This translates into the main schedule inter-discipline relations shown here.



Integrating all schedule requirements and constraints results in an integrated schedule. The typical schedule of Engineering activities is shown in Appendix.

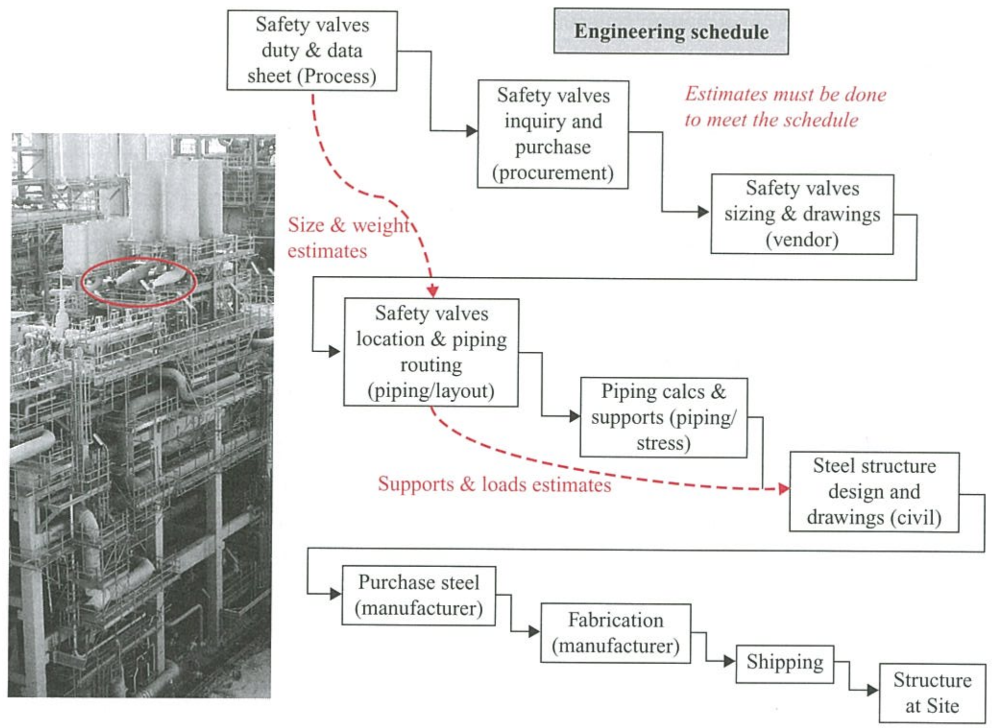
To meet the schedule, a number of short cuts, must be made. These short-cuts consist of making **estimates** before actual data is available. Such estimates must be as accurate as possible in order not to require rework later on. They must be conservative, i.e., contain some level of contingencies, but not too much in order to avoid a costly over-design.

In a lot of cases, engineering experience is required to anticipate a correct design before all information is available.

The design of a steel structure supporting pressure safety valves is one of them. The loads to be borne by the structure will depend on the position of these valves, as pressure safety valves will subject the structure to large reaction loads when operating. Such large horizontal loads at the top of the structure have a very significant impact on the required strength of the structure. The elevation of the safety valves must therefore be correctly defined as it is a key input to the design of the structure.

This elevation will depend on the routing of their inlet and outlet pipes. The routing must provide enough flexibility to allow for thermal expansion of these normally non flowing lines. This requires a routing with a number of direction changes, or even a purpose made expansion loop, which could determine a higher elevation for the valves.

Location and loads of pipe supports, which also serve as design input to the structure, must also be guessed. It is not be feasible to run calculations at this stage to confirm the envisaged pipe routing, as these calculations require too much details. Experience is required to define a proper routing, that will later be validated by calculations.



Engineering activities are highly dependent on availability of **vendor information**. Engineering indeed integrates individual vendor supplied equipment into an overall facility.

Layout activities for instance, depend on size information from equipment vendors. Such size will only be known once the vendor has completed its design. For complex packages, such as a turbo-compressor, the vendor will usually purchase sub units, such as the fuel gas unit, from sub-vendors.

This will further delay the availability of equipment dimensions and finalization of the layout and position of equipment.

This delay might put casting of the equipment foundation at Site on a very tight schedule.

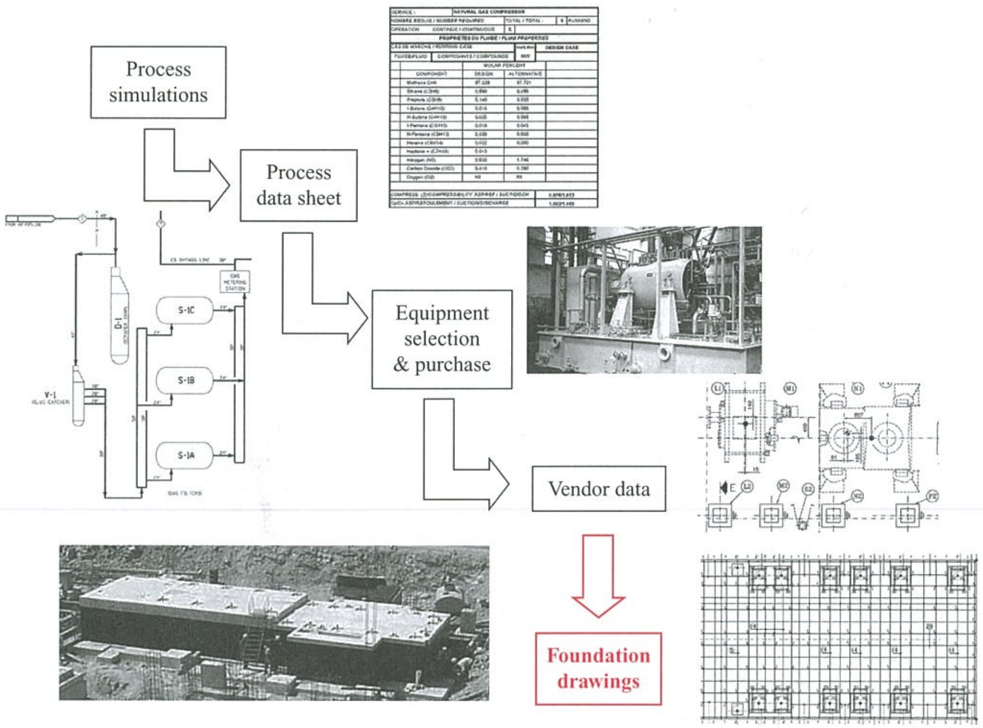
Similarly, the electrical engineer might not be able to complete its design before the actual electrical consumption of the fuel gas heater is known.Timely availability of vendor information is critical not to impede the progress of the design. To this end, required submission dates of key vendor documents are specified in the requisition and penalties associated to delays in their submission.

SUPPLIER'S DOCUMENTS – REQUIREMENT SCHEDULE		DOCUMENT STATUS	
ITEM	DESIGNATION	FOR APPROVAL	APPROVED FINAL, COMMENTS INCORPORATED
1	DIMENSIONAL OUTLINE DRAWINGS OF TURBOCOMPRESSOR SET*	D + 45 DAYS	D + 60 DAYS
2	GENERAL ARRANGEMENT DWG OF TURBOCOMPRESSOR BUILDING WITH INSIDE AND OUTSIDE INSTALLATIONS*	D + 45 DAYS	D + 60 DAYS
3	AIR INLET AND EXHAUST SYSTEMS ARRANGEMENT DRAWINGS*	D + 45 DAYS	D + 60 DAYS
4	LUBE OIL AIR COOLER ARRANGEMENT DRAWINGS*	D + 45 DAYS	D + 60 DAYS
5	TURBOCOMPRESSOR SET FOUNDATION PLAN WITH STATIC AND DYNAMIC LOADS*	D + 45 DAYS	D + 60 DAYS
6	FOUNDATION PLAN WITH STATIC AND DYNAMIC LOADS FOR TURBOCOMPRESSOR BUILDING AND OTHER AUX.EQUIPMENT	D + 45 DAYS	D + 60 DAYS
7	CUSTOMER MECHANICAL CONNECTIONS LIST AND PLAN WITH MAX. ALLOWABLE LOADS*	D + 45 DAYS	D + 60 DAYS

D : EFFECTIVE DATE OF PURCHASE ORDER

*NON-SUBMITTAL OF THESE DOCUMENTS WITHIN SPECIFIED TIME DELAY WILL ENTAIL PENALTIES

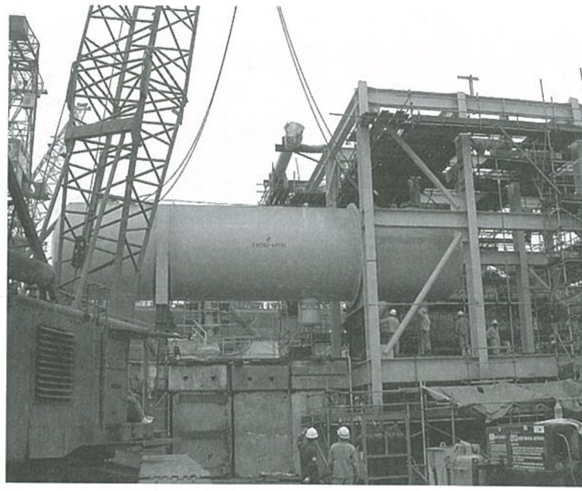
Ironically, the first drawings required at Site are produced last in the engineering work sequence. For example, foundations are one of the first activities done at Site, just after general earthworks. However, foundations data are the last data available for an equipment: first comes the equipment process duty, then its mechanical specification, then its design by the vendor, then only its size, loads, etc.



Schedule requirements for engineering deliveries related to specific equipment/networks will come from the **construction sequence**. Underground networks, for instance, must be installed very early. Indeed, their installation requires excavations which occupy a large footprint and prevent any overhead work (for safety reason). Hence, before above ground erection can proceed, undergrounds need to be installed and backfilled. This will require piping discipline to freeze the routing of underground piping and issue the material requisition early, and for electrical and instrumentation disciplines, whose cable networks are shallower hence installed later, to freeze the routing of cable trenches not so long afterwards, etc.

Another classical example is paving. Construction will aim to complete early the paving works in areas that will be crowded during erection activities, e.g., areas around equipment with a lot of connecting pipe work. It will indeed ensure a safer and more productive erection, avoiding underground/erection activities interferences. This will set an early schedule requirement to the Civil engineer to issue the paving drawings.

Another example is that of heavy equipment whose lifting requires close access of the crane to the equipment installation location. In such case, the crane may have to stand on an area to be built at a later stage during the installation of the equipment. Construction activities in such area cannot start before the equipment is installed. The installation of the equipment must therefore be done early, which will translate into a requirement for the civil engineer to issue the equipment foundations and supporting structures drawings at an early stage.



This is similar to what happens on an Off-Shore project, where the installation of large equipment requires clearance, which delays construction activities in the equipment installation way until after the equipment is installed.

Engineering deliveries to Construction do not only include the construction drawings. Ahead of production of such drawings, Engineering issues to Site the bill of quantities that allow the Construction contractor to plan its work. Combined with material delivery schedule, e.g., for pipes, it allows the construction contractor to identify the required manpower and the appropriate time to mobilize it to avoid both idle time and shortage of manpower. This is particularly critical for an On-Shore project in a remote location where mobilization of resources takes time.

Chapter 15

The challenges: controlling information

Engineering, unlike manufacturing, is not about processing matter but information, which is far more elusive. Managing information quality and flows is critical.

The nature of information varies, from technical requirements of the Client, design criteria, site data, output information from one discipline serving as input to another one, information from equipment suppliers, etc.

Parties exchanging information, either as a receiver or as a provider or both, are the Client, the various engineering disciplines, procurement, vendors, construction contractor(s), third parties, etc.

Procedures are produced as part of the **Engineering Quality Plan** and implemented to ensure quality of information and control over its exchange. These procedures describe in details how to implement the good practices, which this section will describe.

First of all, information is recorded and communicated in formal documents. Information is not communicated through email and other informal ways but through controlled documents, bearing a number, a revision, transmitted in a traced manner and listed in a register.

The first set of information is the one serving as input to the design: functional and performance requirements, design criteria, codes to be used, specifications to be followed, etc. It is defined and recorded in the **Design Basis** document.

Any information missing from the Client is requested in a recorded way through a **Query**. Any deviation from the contractual requirements will be submitted to the Client's approval in a formal and recorded manner by means of issuance of a **Deviation Request**. Technical information exchanged with third parties is recorded in **Interface Agreements** , which are described in more details at the end of this section.

Many engineering documents are not produced at once. Instead, they are developed progressively as the design progresses, with increasing levels of details, up-dated with information received from other disciplines, vendors, etc. The proper way to ensure that all modifications are properly collected in order to be incorporated in a document's next revision is to keep a document **Master** copy. All comments are collected on this one copy of the document that is clearly marked "MASTER".

Documents are issued in controlled manner by means of **revisions**. Document issues will be made for various purposes: internal review (a document from one discipline is distributed to the others for review), Client approval, issue for design (a document from one discipline is issued to serve as a basis for other disciplines), issue for construction, etc.

The purpose of the revision is usually indicated in the revision codification and label, e.g., IFA (Issue for Approval), IFC (Issue for Construction), etc.

A	23/11/2000	IFC- FIRST ISSUE
2	30/08/2000	UPDATED FURTHER NEW GENERAL ONE LINE DIAGRAM
1	16/06/00	UP DATED
0	29-06-99	ISSUE FOR CUSTOMER APPROVAL
Rev.	DATE	DESCRIPTION

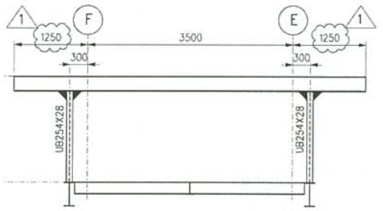
Document revision is essential to the engineering process, where disciplines work from documents originating from other disciplines. When some information contained in a document needs to be communicated, issuing a revision of the document is the way to freeze the contained information in a certain stage. This freeze is essential to the receiving party, which cannot work with moving input data. Equally important is the definition, by the issuing party, of the validity of the data, and what its purpose is.

For instance, the cable list will be continuously up-dated throughout the design phase, with addition of cables, calculation of cable sections, definition of cable routings, cable lengths, etc.

The purchase of cables cannot, however, be delayed until the end of the design phase. The cable list will need to be issued to the purchasing department much earlier, consistently with the cable lead time (several months).

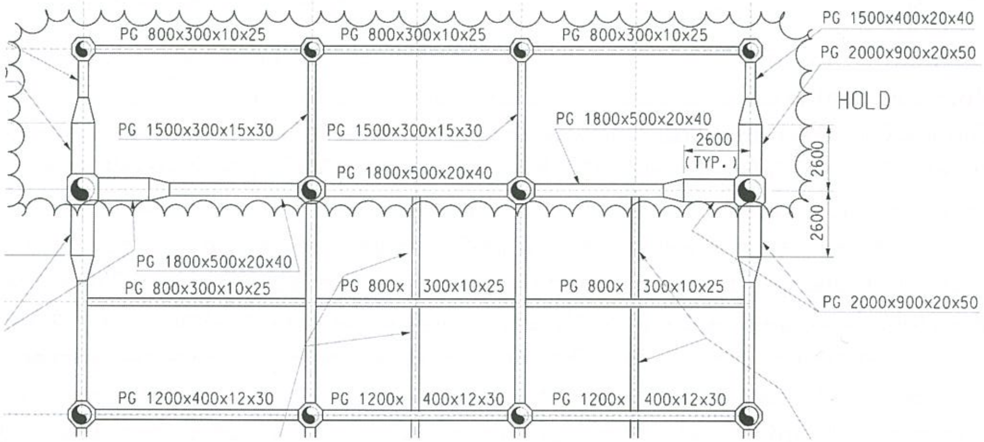
The revision of the cable list issued by Engineering to Procurement needs to clearly identify its purpose. The revision will, for instance, be labelled "issue for inquiry" or "issue for order 70%" (ordering 70% of quantities only will allow to prime the supply while avoiding surplus should cable length decrease as design progresses), etc.

Another example showing the importance of properly identifying the **document status** is the civil area, also called composite, drawings. These drawings show all underground constructions in a given area. Whereas main equipment foundations are defined early, other underground objects, such as cable trenches, pipe support foundations, etc. are defined much later. The area drawings being used to locate the main equipment foundation are needed early at Site. They must be issued at a time where pipe support have not been defined. They will therefore be issued initially with only part of the information – the main equipment foundation - valid. The revisions shall clearly specify the validity, e.g., rev 0 "for main equipment foundations", rev 1 "for foundations and underground piping", rev 2 "for foundations, underground piping, pipe support foundations", rev 3 "for foundations, underground piping, pipe support foundations, cables", etc.



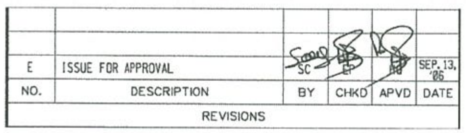
Revised parts of documents must be highlighted, which is usually done by means of "clouds". These revision marks allow the recipient of the revision of a document to visualize immediately what has changed compared to the previous revision, without having to read it all again.

It may happen that part of a drawing is not finalized at the time the drawing needs to be issued. In such a case, this part is highlighted (usually by means of an "inverted" cloud) and marked "**HOLD**".



The design output must be checked before issue. Documents issued by a discipline are first checked within this discipline, by a person different from the one who prepared the document. The **verification** shall cover compliance to design basis, absence of errors, orders of magnitude checked, incorporation of latest changes, etc. Documents which concern several disciplines are submitted to an Inter-Discipline check. The discipline lead engineer determines which parties are to be involved in the review. The review can take the form of circulating the document to collect comments or by joint review during a meeting.

Each document is validated before it is issued. Such **validation** consist of checking that the document is fit for its purpose and complete, that the latest changes/instructions have been taken into account, etc.



Evidence of the **verification** and **validation** (approval) is materialized by signatures on the document.

Information must be communicated to all concerned parties. A **Document Control Procedure** which includes a distribution matrix is prepared to ensure systematic distribution of each document according to type.

Document			Distributed to															
Issuing engineering discipline	Type of document	Document code	Safety and Environment	Process	Piping/layout	Piping/material	Piping/stress	Drafting office	Civil	HVAC	Structure	Electrical	Instrumentation & telecom	Vessels & Heat exchangers	Pipelines	Mechanical	Materials, coating, painting & welding	Cathodic protection
PIPING	LAYOUT DRAWING, PLOT PLAN	M1	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
	GENERAL ARRANGEMENTS DRAWING	M2	x	x	x		x	x	x		x	x	x	x	x	x		x
	LIST, MATERIAL TAKE-OFF	M4		x	x	x	x	x										
	ISOMETRIC DRAWING	M5			x			x										
	CALCULATION	M6			x		x	x										
	SPECIFICATION	M7			x	x	x	x					x				x	x
	DATA SHEET	M8			x	x	x	x					x				x	
	REQUISITION	M9			x	x		x										
INSTRUM	INSTALLATION DRAWINGS	A1	x		x			x	x	x		x	x					
	DETAILS DRAWINGS	A2			x			x		x			x					
	DIAGRAMS	A3			x			x					x					
	LIST, MATERIAL TAKE-OFF	A4	x	x	x			x				x	x					

This requirement translates in making sure that everybody uses the up-dated information hence has access to the latest versions of documents. The latest revision of documents is indicated in the **Engineering Document Register**.

Document number			Document title	Document revision
A	1	48104	Service building instrument. rooms cables routing	B
A	2	48102	Trouble shooting diagrams	D
A	3	48134	F&G system architecture drawing	E
A	4	50100	Instrument index	B
A	7	50003	Spec for instrument installation works and service	C
A	8	50960	Instrument Data sheets for temperature switches	B
A	9	50110	Requisition for pressure relief valves	B
M	1	62059	General plot plan	B
M	2	62020	Piping details standard	C
M	2	62070	Piping general arrangement Area 1	D
E	1	42020	Cable routing general layout	D

In the case where the document library is an on-line library rather than a paper one, this up-to-date requirement will be automatically met.

Quality of the design itself is challenged during **design reviews**. The design review is best done by people outside the project team who have "cold eyes" allowing them to stand back from the context and to question.

Consistency of the design at interfaces is checked during **Interface reviews**. Interface reviews are attended by the various engineering disciplines and focus on making sure that they all work on the same page.

In the longer run, experience gained on one job is fed back in the engineering company's method. Engineering guidance documents, templates and check list are produced/up-dated as a result of this **feed-back** process.

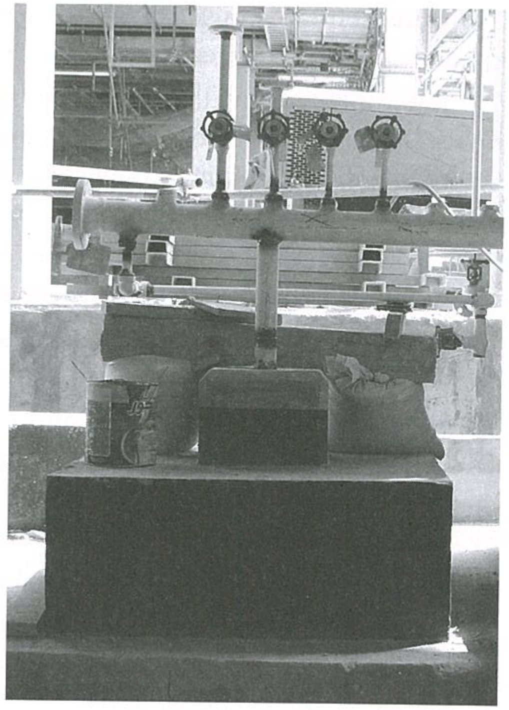
Mere copy/paste of documents from one project to the next puts at risk of over specifying by carrying over, without noticing, some constraints specific to one job to the other. Production of universal templates is preferable.

Information management is of paramount importance at Interfaces between parties.

Exchange of technical information takes place between numerous parties: between engineering disciplines, between engineering and vendors, between engineering and third party, e.g., contractors building other parts of the plant, etc.

The most numerous interfaces are **internal interfaces**: between engineering disciplines.

In many instances, the input information of one discipline is the output of another. Civil, for instance, designs structures supporting equipment and pipes. The civil design is directly dependent on the equipment and pipes to be supported: Piping defines to Civil the required geometry, and advises the location and values of the loads to be supported.



Such information must be precise and properly communicated. This avoids inefficient design such as the one shown here where the foundation of the pipe support is grossly over-sized. This was due to the bad quality of the information provided by Piping to Civil.

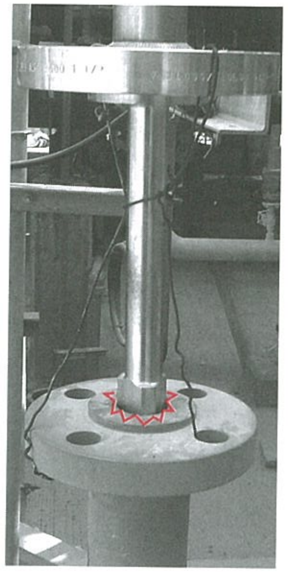
The difficulty is that Piping will not have finalized its design when the information has, in order to comply with the schedule, to be given to Civil. Piping must therefore make some assumptions and include some allowances to avoid later changes.

Should a change occur, Piping should advise Civil, without delay in order to minimize the impact. In such a way Civil will be able to advise Site on time not to cast the foundation but to wait for a revised design.

Dedicated internal documents are issued from one discipline to the other for the exchange of information.

Timely exchange of these documents and precision of the information contained is key to ensure that the receiving disciplines works on the good information.

External interfaces include that with equipment vendors and third parties.



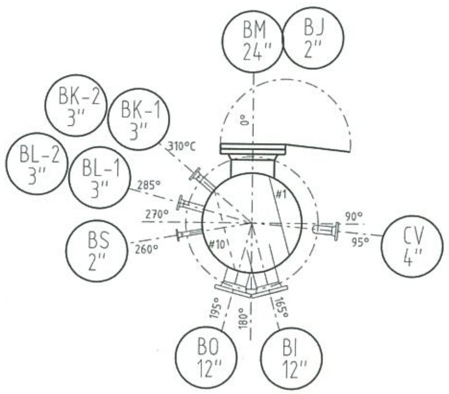
Proper interface with equipment vendors is key to the match, at Site, between equipment and their environment, e.g., piping connections, electrical and instrument connections, etc.

Review by Engineering of vendor documents and incorporation in the design is key to achieve this match.

Vendor documents are not finalized at once but will undergo revisions. Engineering drawings must be up-dated with revisions of vendor drawings.

On the picture shown here, the drawings of the thermo-well vendor has obviously not been reviewed by Piping which resulted in a mismatch at Site.

The flow of information between Engineering and vendors is not one way. The orientation of the nozzles of a pressure vessel, for instance, will be specified by Engineering, upon completion of piping studies, to the vendor. Gussets to be provided on the vessel for support of piping, platforms and ladders will also be defined by Engineering.



A number of interfaces with third parties are found on a Project, such as the ones found at the plant boundary: with the Contractor installing the inlet pipeline/outlet rundown lines, with Contractors in charge of other parts of the plant, such as the product tank farm, etc.

Information to be exchanged relates to the precise limit of supply of each party, and technical data at connecting point to ensure matching.

In the case of an interface on a pipeline, for instance, the technical data exchanged will not only include the coordinates of the connecting point, the type of connection (flanged/welded), but also more subtle data, such as the load (longitudinal force that could amount to several hundred kN) transferred from one side of the pipeline to the other.

The vehicle for the information exchange is the **Interface Agreement**, such as the one shown here.

Interface Agreement

Section/Step 1

INTERFACE AGREEMENT

Interface No:	Rev:	Page: of	Revision Date:

Title:	
Short Description:	Need Date:

Supplier: Interface contact: Technical contact:	Receiver: Interface contact: Technical contact:

Interface Details (Deliverable Description)

Discussion / Comments:

Reference documents and attachments:

Interface Agreement Approval			
Supplier: Printed Name:	Date:	Receiver: Printed Name:	Date:

Section/Step 2

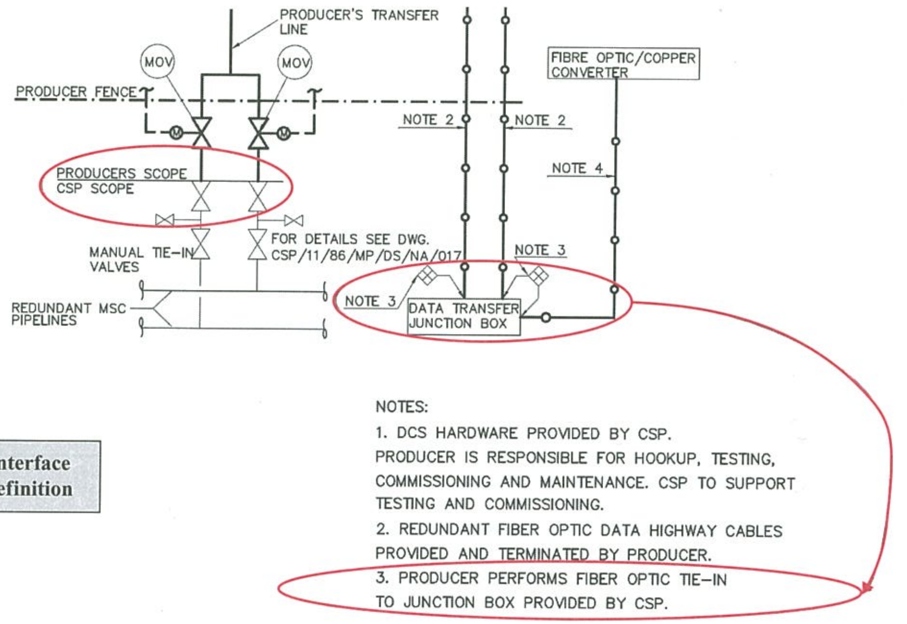
Provided Interface Deliverable (description and document coding)

Interface Agreement Close-Out			
Supplier: Printed Name:	Transmittal Date:	Receiver: Printed Name:	Closed-out Date:

A proper Interface management must be put in place, such as one operating as follows:

- first, what interface information will be exchanged, who will be the giver and who will be the receiver and when the information will be provided is defined and formally agreed (step 1). Section 1 of the Interface Agreement is filled at this stage. This will allow the receiving party to plan its work. A proper definition and schedule of the information data is critical for the receiving party. Receipt of imprecise information or delay will indeed prevent the receiving party to proceed,

- second, the actual interface information, such as the one related to precise definition of battery limit shown here, is provided, usually by means of attaching an engineering drawing to the Interface Agreement. Section 2 of the Interface Agreement is filled at this stage.



Interface definition

- the receiver finally confirms adequacy of the received data by the close out of the Interface Agreement.

Index: Common Engineering Documents

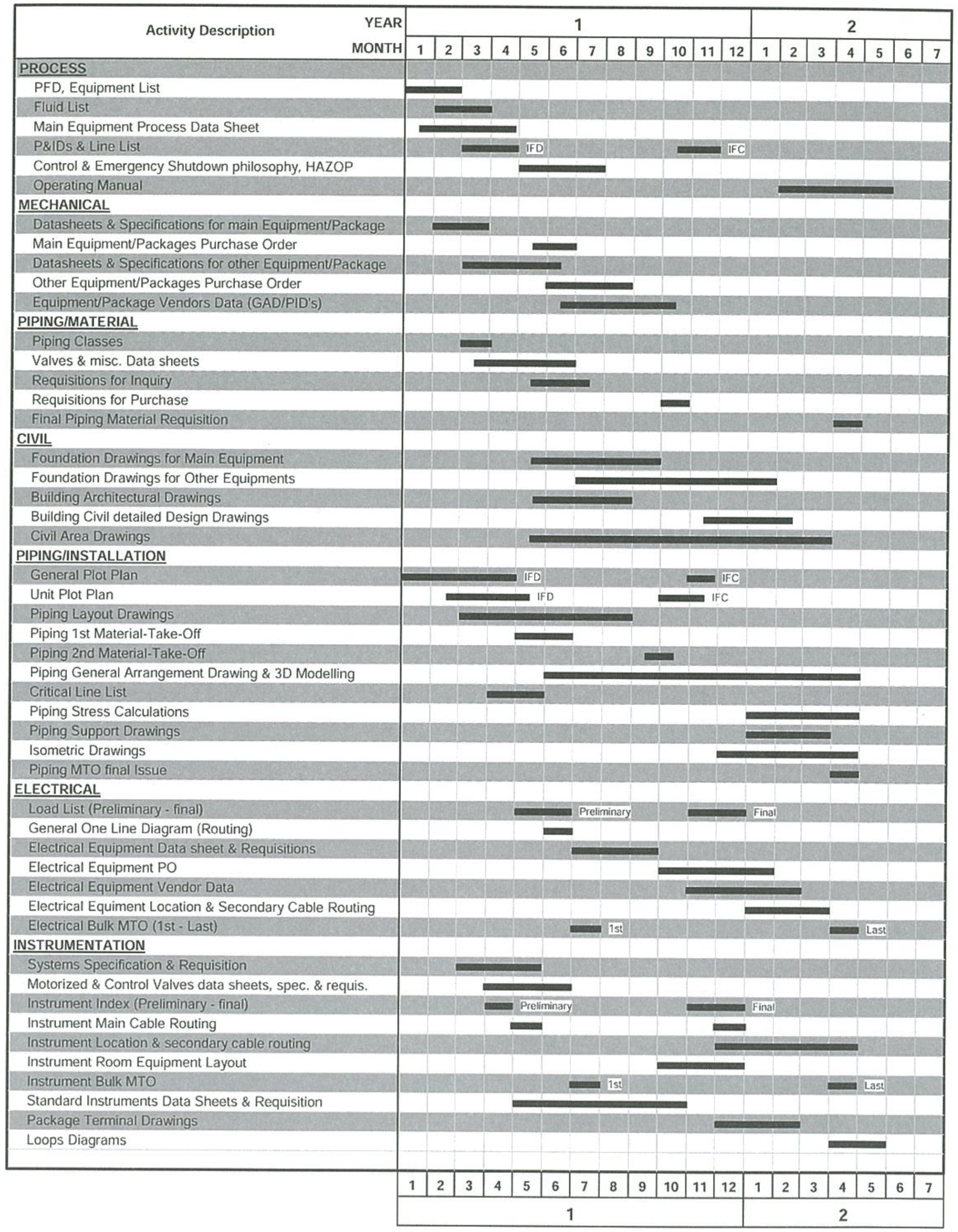
The list shown here is the standard list of engineering documents issued on a Project. An illustration of each one of them can be found at the indicated page.

General

Process

Equipment/Mechanical

Appendix: Typical engineering schedule



THE OIL & GAS ENGINEERING GUIDE

Hervé Baron

This book gives the reader an overview of how Oil & Gas Facilities are engineered. It covers their entire design cycle, from the high level functional duty to the detailed design.

Each engineering task is described and illustrated with a sample document taken from a real project.

Unlike engineering manuals which generally cover a specific discipline, such as process or civil engineering only, this work covers them all. Baron has done the hard work of distilling the essence of these disciplines and presenting them in a concise and precise fashion.

Containing more than 250 illustrations, the book gives the reader a comprehensive information to easily refer to at any point in a project's life cycle.

Contemporary engineering work for large projects is usually carried out at multiple locations. This does not make it easy for the new comer to gain an end-to-end knowledge. This work will fast track this acquisition. It will also meet the needs of anyone wishing to understand the technical factors driving the execution of a project.

The author began his professional career with an international oil company. Starting out with an interest in the Operation of Oil & Gas Facilities, his technical curiosity about their design saw him move to engineering contractors to become expert in this area. As engineering manager of large turn-key projects, he gained the insight on engineering and amassed the knowledge presented in this work.

Hervé Baron is a graduate engineer from IFP school and France's Ecole Polytechnique.

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