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IMPLEMENTING FLUE GAS DESULPHURIZATION IN AN EXISTING POWER PLANT

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I. INTRODUCTION

1. This paper describes the "turn-key" project undertaken for Sokolovska uhelna a.s. to implement Flue Gas Desulphurization (FGD) technology in Vresova Heat and Power Station, Czech Republic.

2. The project was executed solely by Fortum Engineering Ltd, Finland, now registered under the name of Enprima Engineering Ltd. All further references in the paper to this company are made as Enprima.

II. PROJECT LOCATION

3. The project was undertaken at Vresova Heat & Power Station, which is owned by Sokolovska uhelna, a.s., Sokolov. The power station is located in Sokolov in the far-western part of the Czech Republic, close to the German border and approximately 130 km from Prague.

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4. Vresova Power Station was built in two stages; the first stage (incorporating boilers 1 to 3) was put into operation in 1966, and the second stage (boilers 4 and 5) in 1969. The station has a total capacity of 325 tonnes of steam/ hour; it burns Czech lignite (from the local Sokolov region) in five identical boilers; and has four turbine-generator sets, each of 55 MWe.

III. PROJECT OVERVIEW

5. Wet FGD process-technology was applied to the flue gas volume from four boilers, with the possibility to partly manage the flue gas from boiler number five and the surplus to be by-passed into the old stack. The nominal flue gas flow for the desulphurization is 1 510 000 Nm^3/h (wet state).

6. The FGD project was the "turn-key" project and it included the phase of process design, basic design, detail design, manufacturing design, procurement, controlling, manufacturing, supplies, erection and installations, quality auditing and inspection, individual testing, commissioning, trial run, warranty testing, and a hand-over procedure to the client.

7. The project value was €31.8 million.

8. The project commenced on 3 May 2000 and was completed – and handed over to the client – on 24 October 2002. Taking into account the project's scope (which included completely changing the existing flue gas systems and replacing the existing ten ID fans with new ones) and also taking into account that replacement of the ducts had to be undertaken within a short and firmly agreed time period – the project was executed in a short time period. The important project parameter - SO_2-removal efficiency of 95% - was achieved and the actual performance values have been between 97 to 98%.

IV. SCOPE AND DIVISION OF THE PROJECT

9. Enprima was responsible for the whole scope of the project; comprising:

(a) all the engineering encompassing basic and detailed design for the process, mechanical parts, electro-parts and instrumentation; as well as other required documentation, including building permit and "as built" documentation; and

(b) procurement of all the project components:

- all civil parts; including excavations, pilling, concrete structures, building walls/ roofs, building equipment, HVAC, building sanitary systems, final terrain work, etc;
- absorber (1 pc) with spray header system; steel flue gas duct system; supporting steel structures; ID fans; process tanks; steel and FRP process piping; process and re-circulation pumps; valves; insulation of ducts and tanks; limestone unloading unit; silo for limestone storage (including de-dusting and fluidisation); two hydro-cyclone batteries; two de-watering belt filters; discharge, distribution and storing of gypsum in the gypsum store; isolation and by-pass dampers; expansion joints; agitators, etc;
- wet stack, situated on the top of the absorber;
- electro-parts supplied as HV/LV motors, trafos, switchboards, MCCs, cables, etc;

- instrumentation and control parts, including Fanuc control system, field instrumentation, cabling, analysers, etc;
- mechanical erection of the mechanical equipment;
- erection of electro and I&C, parts, including the cable work, energising, inspection;
- project management, for the full Project scope;
- commissioning and test run of the civil, mechanical, electro and I&C parts; as well as warranty testing;
- training for all equipment and disciplines; and
- warranty service, provided for a period of 24 months after the acceptance certificate issuance (and 60 months for the civil parts).

V. MAIN PROJECT SCHEDULE

10. The contract for the project was signed on 3 May 2000 and the site was opened in July 2000. The mechanical erection of the main equipment, notably the absorber, started in November that year. The first flue gas-in was installed on 6 August 2002 and the trial run started on 4 September 2002. The take-over/hand-over protocol was signed between the Parties on 24 October 2002.

VI. DESIGN PARAMETERS

11. The contract for the project specified the main design parameters, as follows:

• Flue gas flow/nominal, wet conditions; total from all the boilers:	1 510 000 Nm^3/h
• Inlet temperature of flue gases/nominal:	150 - 170° C
• SO_2 mass load, in original sample:	4 008 kg/h
• SO_2 inlet concentration; nominal, wet (CN):	2 655 mg/Nm^3
• SO_2 inlet concentration; nominal, dry (CSN):	2 998,3 mg/Nm^3
• Dust content; inlet:	120 mg/Nm^3
• Outlet temperature after in the wet stack:	55° C
• SO_2 content; outlet, dry 6%O_2:	max. 500 mg/Nm^3
• (and 1 700 mg/Nm^3 - in case of SO_2 inlet concentration (CN) is	5 000 mg/ Nm^3)
• Dust content; outlet:	max. 50 mg/Nm^3
• SO_2 removal efficiency	min. 95%

VII. PROCESS FEATURES DETERMINED IN THE CONTRACT

12. As per the contract the next principal process features to be observed and respected by Enprima were as follows:

(a) The supply of one absorber, with three spray banks in use when the sulphur overload reaches 100 to 110%;

(b) Gypsum de-watering; including direct feeding, overflow tanks and pumps; consisting of a further two vacuum belt filters, each with a capacity of 100% nominal (design) flue gas flow of 1 510 000 Nm^3/h (wet), nominal sulphur load of 4 008 kg/h, and gypsum (product) moisture 10%; and two gypsum slurry pumps;

(c) Treated flue gases to be discharged into one wet stack, and this to be anchored in a steel structure at the top of the absorber;

(d) A limestone unloading ability of four wagons unloaded in two hours;

(e) Limestone feeding process to be designed into two separate lines, each having a feeding capacity of 100% of limestone feed to cover the desulphurization of 1 510 000 Nm^3/h of flue gas (wet), at sulphur load of 4 008 kg/h;

(f) One limestone slurry tank; and

(g) Two limestone slurry pumps to be used (one under operation, and one always ready as a stand-by).

VIII. PROCESS FEATURES (OWN SOLUTION)

13. Enprima itself selected some of the main technical solutions as follows:

(a) The design of the limestone unloading and storage system was based on Enprima's own experience combined with the experience of the local sub-supplier. All four wagons can be in unloaded in parallel, with a maximum unloading time of two hours. The unloading is based on a pneumatic principle; the limestone in the silo is stored in fluidised conditions (with air inlets in the central and bottom parts of the silo); and there is a de-dusting filter on the top of the silo.

(b) Process pumps were selected to be from alloy steel (casings, impellers and wear plates). Re-circulation pumps were used with an inside rubber liner, and alloy-steel used for the impellers and wear plates.

(c) The wet stack for the discharge of cleaned flue gases (of diameter of 7 metres) was made from FRP, wound in integral rings at site and laminated together in the elevated position. The stack wall thickness varied from 32 to 20 mm. Derakane 511 resin, glass-fibre multi-layers and reinforcing ribs were used to manufacture the rings. In addition appropriate design of the anchoring and support/sliding of the wet stack was needed.

(d) Density control of feeding and gypsum slurry was provided using the radiometric principle.

(e) The slurry pipes were made from FRP (using vinyl-ester Derakane 511 resin and glass-fibre layers). The final anti-abrasion layers were made from pure resin, with approximately 30% of Al_20_3 added.

(f) Endress-Hauser provided the pH measurement, together with water cleaning and calibration.

(g) One tank was used for the de-watering plant.

(h) New ID fans were used in place of the original old ones, notably two per boiler, including the auxiliary equipment and its feeding.

(i) Batch-wise operation of belt filters.

IX. SCOPE OF DELIVERY

14. The "turn-key" delivery included the following:

- Absorption system
- Wet stack
- Limestone unloading and storage
- Gypsum de-watering system
- Gypsum storage
- Automation and Control
- Electrification
- Civil work

15. ID fans and new duct system are situated in the area of an old stack. The remainder of the technology is situated approximately 250 metres away, crossing the railway siding area. The above layout required the erection of extra long, large and fully pre-fabricated duct segments over the railway siding area – and all in an extremely short build time in order not to block the railway siding operation (only two days were provided for the final installation over the railway siding (Figure 2: General Layout)).

16. The limestone unloading platform is located alongside the process building, close to the absorber.

17. Gypsum is stored in a gypsum storage house located across from the process building. The integration of the equipment inside - and next to - the process building was undertaken with the intention to optimise the use of the space and to minimise the pipelines. The equipment was located on the three basic floors and comprised a gypsum slurry tank, waste-water tank, re-circulation tank and vacuum pumps on the ground-floor; belt filters on the second floor; and hydro-cyclone batteries on the third floor. The silo passes through the process building with its feeding lines located on the second floor (Figure 3 - Absorber Layout). Figure 1 shows the process in simplified form.

X. PROCUREMENT SYSTEM AND ORGANISATION

18. The procurement process and procedure were organised to meet the Project Master Schedule and also the Project Implementation Schedule and Procurement Schedule.
The procurement philosophy was based on the necessity to adapt the procurement to the demanding project execution due dates (which were under penalty), and also to the time availability of the design inputs. The procurement packages were also split to enable the favourite commercial parameters of the supplies to be used. Therefore many procurement packages were defined and used. In total 306 sub-contracts or separated purchase orders were expedited and concluded during the execution of the project.

19. The main procurement packages were:

(a) Local supplies (L):

- Civil design detail (civil permit, basic and detailed design)
- Mechanical design (detail, application and manufacturing design)
- Electro-design (detail and manufacturing design)
- Instrumentation and control-design (detail and manufacturing design)
- Civil works – total scope
- Flue gas duct system/manufacturing design, supply, erection and commissioning
- Absorber/manufacturing design, supply, erection and commissioning
- FRP wet stack/erection
- ID fans/manufacturing design, supply, erection and commissioning
- Unloading and limestone storage system/detail design, manufacturing design, supply, erection and commissioning
- Belt filters/erection
- Re-circulation and process piping (including FRP piping)/manufacturing design, supply, erection and commissioning
- Re-circulation pumps/erection
- Insulation/detail design, supply and erection
- HVAC/basic and detail design, supply, erection and commissioning
- Control system/ basic design, detail design, supply, installation and commissioning (supply of Fanuc control system done by the local sub-supplier).
- Detail design, supplies and installation field instrumentation (I&C)
- Detail design, supplies and installation of field and building electrification
- Emission monitoring system/ supply, installation, commissioning

(b) Imports (I):

- Mechanical design (basic and selected special calculations)
- Electro-design (basic design)
- Instrumentation and control-design (basic design)
- FRP Wet stack/design, supply and commissioning
- Belt filters/manufacturing and process design, supply and commissioning
- Re-circulation pumps/supply and commissioning
- Process pumps/supply
- Valves/supply
- Main electrical motors and trafos/delivery (6 kV)

20. The locally procured portion covered more than 65 % of the total project value.

XI. PROJECT EVALUATION

21. The warranty measurement results were as follows:

(i) One warranty test (Warranty Test No.1) was performed before application for the Acceptance Certificate. (Another warranty test will be carried out after a minimum of 22 months of operation.)

(ii) Warranty Test No.1 was carried-out by the authorised local measurement agency and the results obtained were issued by it. The measurement of all quantitative and qualitative parameters was carried out over two days under design conditions. The qualitative parameters involved measurement over one day at 40% flue gas load and over one day at 110% of flue gas overload.

22. The next main values were measured with the results obtained as shown in Tables 1 and 2.

23. Figures 1 to 3 show the FGDP Operating Principle, the General Layout and the Absorber Layout respectively.

Table 1: Employer's Design Parameters

No.	Description	Unit	Design value	Actual value WP1	Actual value WP2
1.	**Fuel composition (informative):**				
	Caloric value/Q_i^r	kJ/kg	16 280	17 390	
	Grain size	mm	0 – 25		
		% weight	17,5	15,88	
	Average H_2O content in the original sample W_t^r	% weight			
		% weight	22,7	20,85	
	Average ash content in the original sample A_t^r				
	Sulphur content in the original sample S^d mean		0,9		
			1,3		
	max.		0,6		
	min.	% weight	1,3	0,971	
	design				
	Combustible:				
	Average values				
			6,30		
	Hydrogen in the orig. sample H^{daf}		70,42		
	Carbon in the orig. sample C^{daf}		0,80		
	Nitrogen in the orig. sample N^{daf}		21,10		
	Oxygen in the orig. sample O^{daf}		1,38	1,147	
	Sulphur in the orig. sample S_t^{daf}				
3.	**Inlet flue gas :**				
	Wet flue gas composition:	% volume			
	SO_2		0,09		
	O_2		8,5	8,2	7,6
	CO_2	mg/Nm^3	9,65		
	NO_x	mg/Nm^3	max. 650		
	Dust	mg/Nm^3	max. 120	24,2	14,7
	Cl^-	mg/Nm^3	max. 10	1,7	1,8
	F^-		max. 25	14,9	13,2
	SO_2 content – design value	kg/h	4008	2 498	3 055
	Flue gas volume – design	Nm^3/h	1 510000	1645985	693 220
	Flue gas temperature at the inlet BL	^{o}C	150 – 170	154,6	146,5
4.	**Limestone powder**				
	Informative composition:	% weight			
	$CaCO_3$		min. 90,0	98,02	
	$MgCO_3$		max. 4,0		
	SiO_2		max. 2,9		
	Al_2O_3		max. 0,6		
	Fe_2O_3		max. 0,6		
	MnO		max. 0,03		
	Others:		max. 1,87		
	out of this SO_3		max. 0,02		
	Σ		100,00		
	Limestone Fineness		80-88 % finer than 0,045 mm	80,29 %	

No.	Description	Unit	Design value	Actual value WP1	Actual value WP2
5.	**Process water (water from cooling circuits)**				
	Informative composition (average):				
	CHSK	mg/l	6,4		
	Soluble matters:				
	Cl^-	mg/l	38	30,5	
	SO_4^{2-}	mg/l	255		
	Ca^{2+}	mg/l	52		
	Mg^{2+}	mg/l	27		
	NH_4^+	mg/l	1,08		
	NO_3^-	mg/l	29,39		
	$Fe_{iont.}$	mg/l	0,84		
	Insoluble matters $NL_{105\ °C}$	mg/l	8		
	m - value	mmol/l	1,64		
	Conductivity	μS/cm	751		
	pH		7,98	7,49	
	Hardness	mmol/l	2,6		
	Non-carb. salts	mmol/l	7,3		
	K^+	mg/l	14,10		
	PO_4^{3-}	mg/l	0,41		
	SiO_3^-	mg/l	10,30		
	Mn	mg/l	0,34		
	Temperature	°C	14 - 25		
	Pressure	bar	5		
	Amount	l/s	50		

Table 2: FDG Plant Guarantee Values

No.	Description	Unit	Guarantee value	Actual value WP1	Actual value WP2
1.	**Product – treated, desulphurised flue gas**				
	Emission values do not exceed the following values:				
	SO_2 content	mg/Nm^3	max. 500	270	255
	Cl^- content	mg/Nm^3	max. 10	0,6	0,5
	F^- content	mg/Nm^3	max. 6	0,17	0,2
	Dust content	mg/Nm^3	max. 50	13	6
	(valid for 6% O_2 content in dry gas)				
	Temperature at the FGDP outlet	^{o} C	min. 55	55,3	56,7
2.	**By-product – gypsum**	% weight			
	Moisture		max. 10	6,73	
	Purity as $CaSO_4.2H_2O$ content		90,00	96,8	
	Σ $CaCO_3$ + $MgCO_3$ content		1,00	0,571	
	$CaSO_3$ content		0,30	< 0,05	
	Cl^- content		0,03	0,0055	
	F^- content		0,15	0,277	
	MgO content		0,16	0,0827	
	Alkali content as Σ Na_2O + K_2O		0,02	0,0020	
	SiO_2 content		2,50	0,171	

No.	Description	Unit	Guarantee value	Actual value WP1	Actual value WP2
3.	**Gaseous waste**				
	Solids quantity	mg/Nm^3	max. 25	1,77	
4.	**Liquid by-products**				
	Quantity	m^3/h	max. 10	2,5	
	Solids content	weight %	max. 5	1,39	
	pH	ppm	4-8	6,58	
	Cl^- content		7 000	726,5	
5.	**Absorber droplet concentration** at all operation conditions	mg/Nm^3	max. 100	51	
6.	**Consumption and production:**				
	Limestone powder (purity 90%)	t/h	6,268	5,962	
	Process water (water from cooling circuit)	m^3/h	107,271	101,801	
	Steam 0,5 MPa, 170°C	t/h	0,2	fulfill.	
	Electric power				
	- Absorber				
	- Common equipment	kWh/h	1555	1410,84	
	- Total (absorber + common equip.)	kWh/h	1305	1524,94	
	- Limestone unloading	kWh/h	2860	2935,78	
	- FGDP total energy consumption	kWh/h	270	35,10	
		kWh/h	3130	2 970,88	
7.	**Total pressure loss**				
	- Guarantee test 1	Pa	2000	1 170	
	- Guarantee test 2	Pa	2100		
	- ducts Guarantee test 1	Pa	1100	160	
	Guarantee test 2	Pa	1100		
	- absorber Guarantee test 1	Pa	900	acceptable	
	Guarantee test 2	Pa	1000		
8.	**Annual availability**	%	96	according to the Contract, evaluated during Guarantee Test Number 2	
9.	**Equivalent noise level**				
	Control room	dB(A)	50	fulfilled	
	Offices	dB(A)	65		
	Plant area	dB(A)	85		
	Outside area - during the day	dB(A)	70		
	at night	dB(A)	60		
	Equipment	dB(A)	85		
	(decisive criterion is the affirmative standpoint of competent hygienic authority)				

No.	Description	Unit	Guarantee value	Actual value WP1	Actual value WP2
10.	**<u>Manpower</u>**				
	1. Control room operator	person	0,4	fulfilled	
	2. Field operator		0,2		
	3. Maintenance – mechanical		0,07		
	4. Maintenance – automation		0,05		
	5. Maintenance – electrical part		0,05		
	6. Laboratory service		0,3		
	7. Limestone unloading operator		1,5		
	8. Gypsum storage operator		0,3		

Figure 1

FGDP OPERATING PRINCIPLE

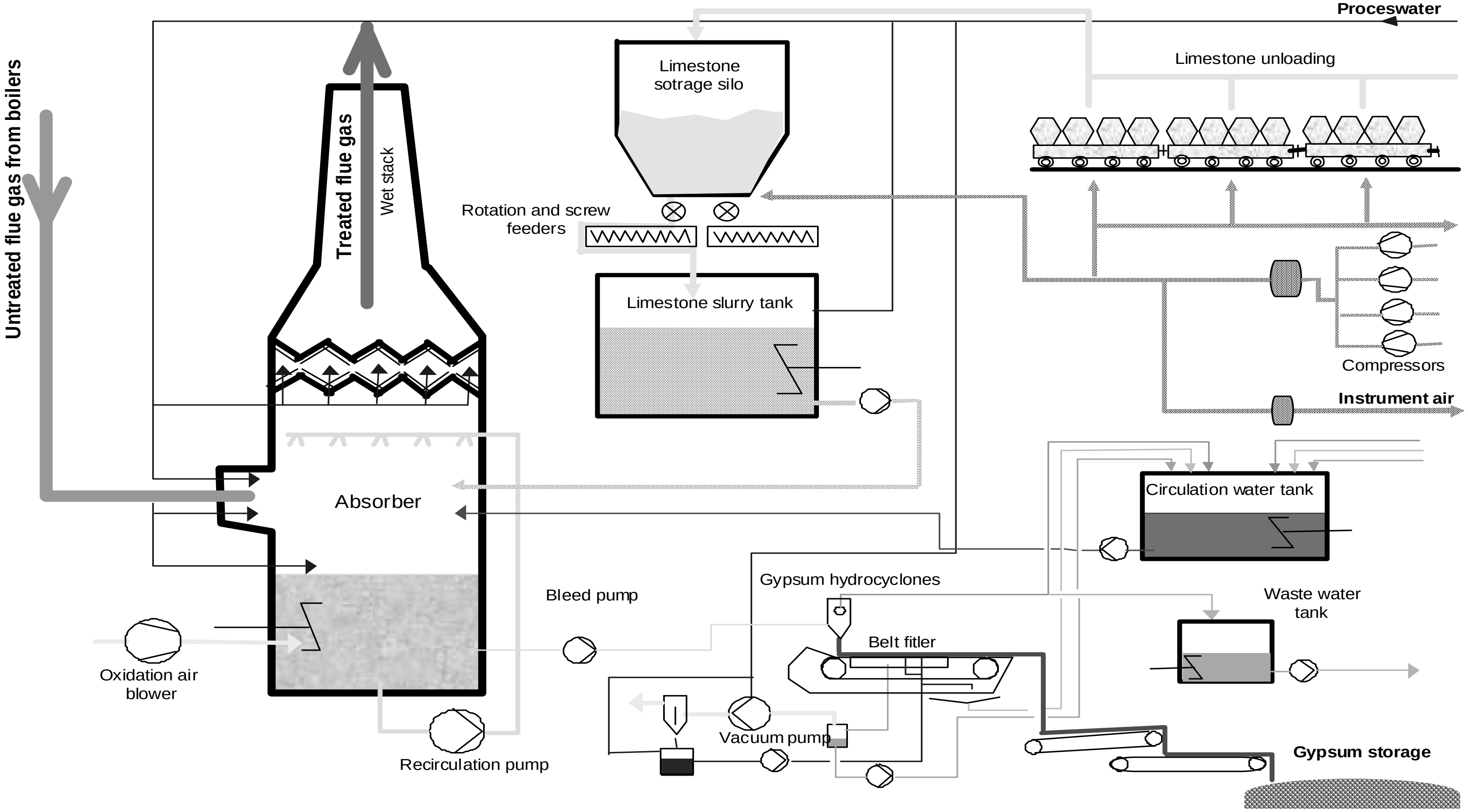


Figure 2

GENERAL LAYOUT

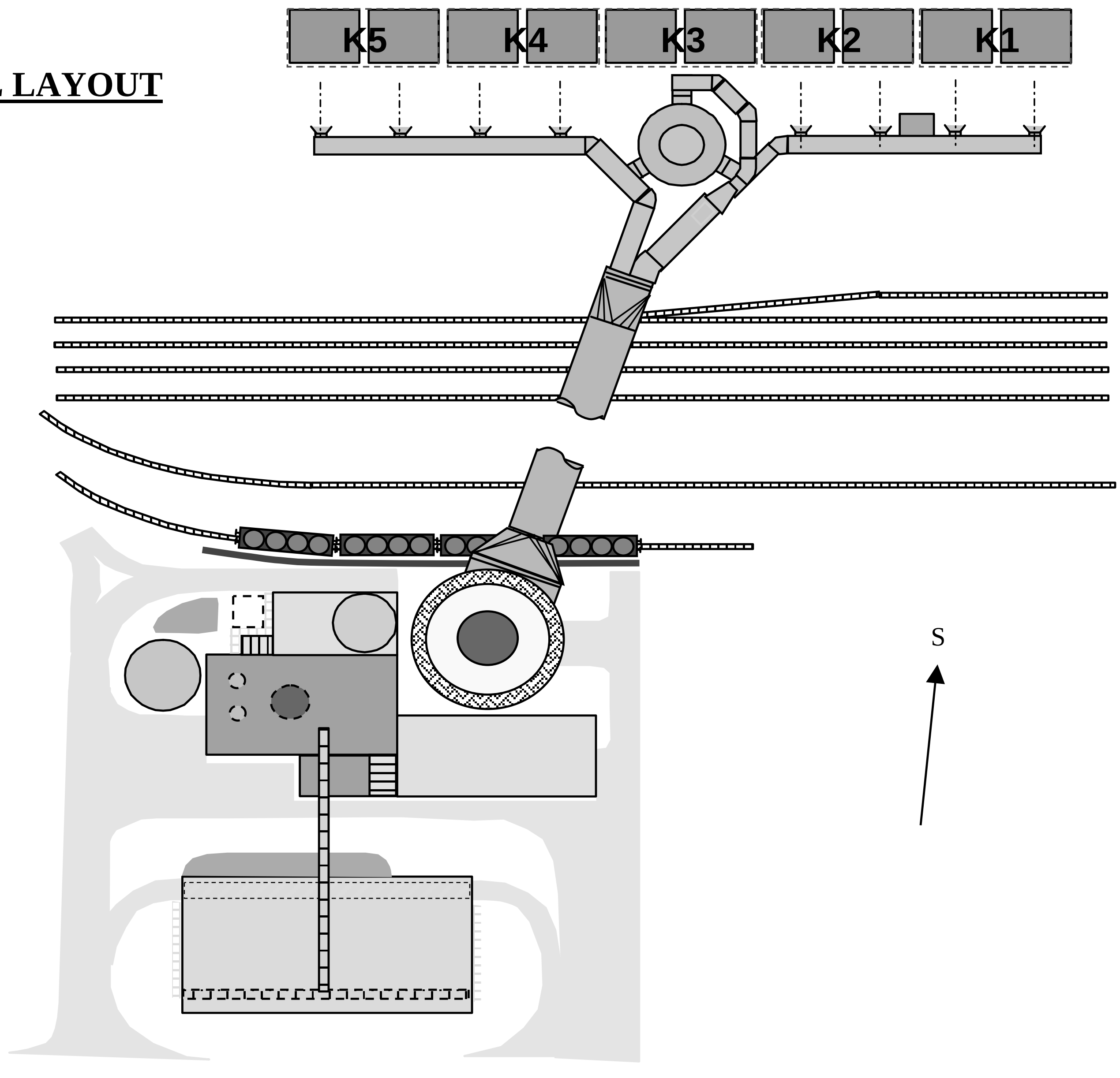
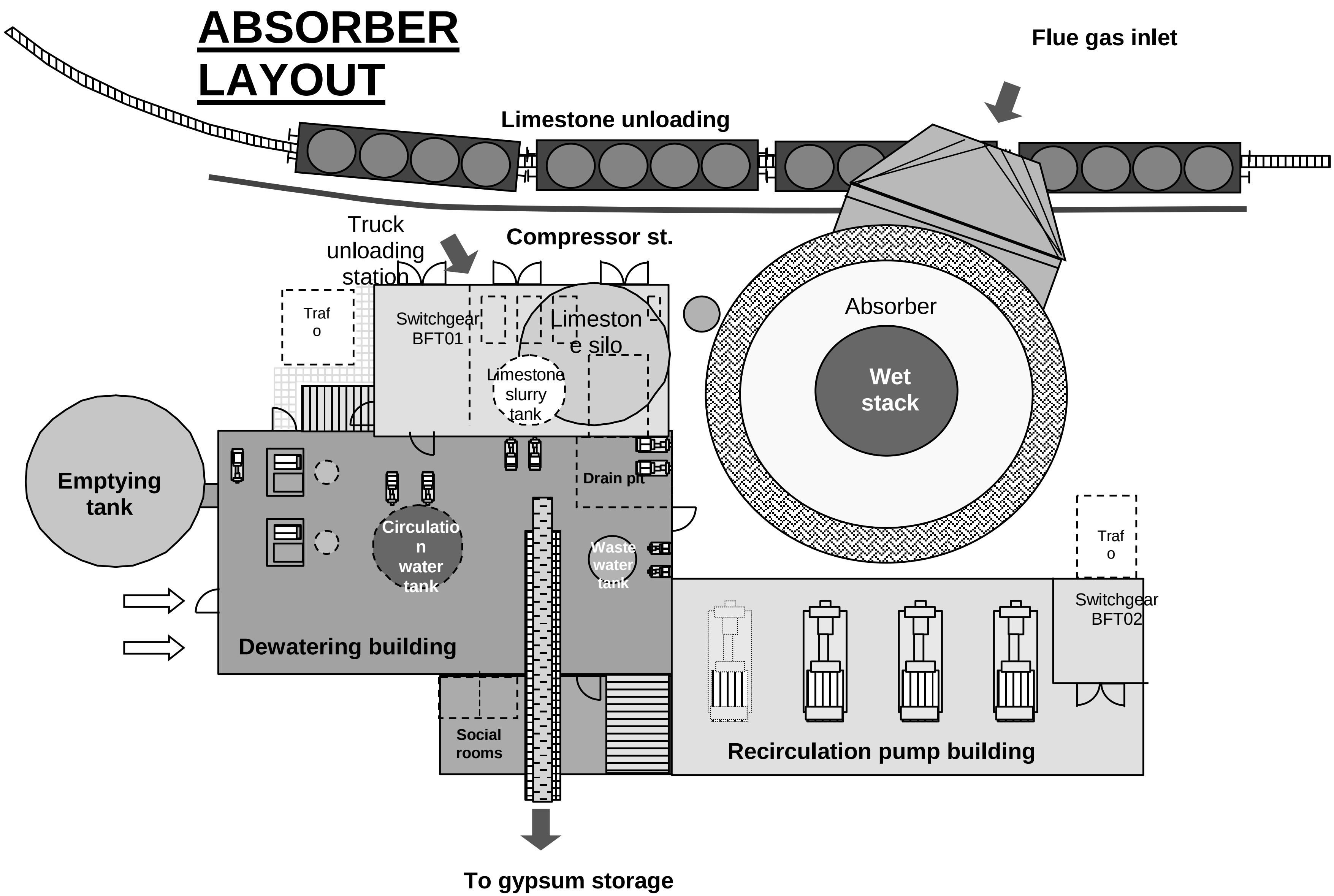


Figure 3


ABSORBER LAYOUT
Flue gas inlet
Limestone unloading
Truck unloading station
Compressor st.
Traf o
Switchgear BFT01
Limestone silo
Limestone slurry tank
Absorber
Wet stack
Emptying tank
Drain pit
Circulation water tank
Waste water tank
Traf o
Switchgear BFT02
Dewatering building
Social rooms
Recirculation pump building
To gypsum storage