Table 12.2.2 (cont'd)

(b) PROJECTED PROFIT & LOSS
(1000DOL.)

PROJECT : THE INTEGRATED STEEL PLANT PROJECT IN THAILAND
CASE NO : (B)

PAGE= 2-2
DATE= AUG/28/1979

CALENDAR YEAR	11	12	13	14	15	16	17	18	19	20
PROJECT YEAR	6	7	8	9	10	11	12	13	14	15
SALES	508329.	508329.	508329.	508329.	508329.	508329.	508329.	508329.	508329.	508329.
VARIABLE COST	234516.	234516.	234516.	234516.	234516.	234516.	234516.	234516.	234516.	234516.
PRODUCTION FIXED COST	36173.	36173.	36173.	36173.	36173.	36173.	36173.	36173.	36173.	36173.
DEPRECIATION & AMORTIZ. (#1)	86457.	86457.	86457.	86457.	86457.	79574.	79574.	79574.	79574.	79574.
PRODUCTION COST FOR SALES	270689.	270689.	270689.	270689.	270689.	270689.	270689.	270689.	270689.	270689.
LONG TERM LOAN INTEREST	49298.	39439.	29579.	19719.	9860.	0.	0.	0.	0.	0.
SHORT-T LOAN & DEPOSIT INTER.	1438.	1438.	1438.	1438.	1068.	264.	106.	105.	105.	105.
GENERAL ADMINIST. EXPENSES	2280.	2280.	2280.	2280.	2280.	2280.	2280.	2280.	2280.	2280.
BUSINESS TAX FOR SALES	7625.	7625.	7625.	7625.	7625.	7625.	7625.	7625.	7625.	7625.
TOTAL COST	417786.	407927.	398067.	388207.	377979.	360432.	360274.	360273.	360273.	360273.
OPRATING INCOME	90543.	100402.	110262.	120122.	130350.	147897.	148055.	148056.	148056.	148056.
NON-OPERATING REVENUES	0.	0.	0.	0.	0.	0.	0.	0.	0.	93987.
NON-OPERATING EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	93987.
ORDINARY INCOME	90543.	100402.	110262.	120122.	130350.	147897.	148055.	148056.	148056.	148056.
EXTRAORDINARY PROFITS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EXTRAORDINARY LOSSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NET INCOME BEFORE TAXES	90543.	100402.	110262.	120122.	130350.	147897.	148055.	148056.	148056.	148056.
(LOSS FORWARD)	-79205.	-79205.	-79205.	40916.	0.	0.	0.	0.	0.	0.
(TAXABLE INCOME)	-79205.	-79205.	-79205.	40916.	130350.	147897.	148055.	148056.	148056.	148056.
RESERVE FOR TAXES	0.	0.	0.	6137.	19552.	22185.	22208.	22208.	22208.	22208.
NET INCOME AFTER TAXES	90543.	100402.	110262.	113985.	110797.	125712.	125847.	125848.	125848.	125848.
PROV. OF LEG. RETAINED EARNINGS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISPOSABLE INCOME AFTER TAXES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(NOTES) (#1) INCLUDES										
"DEPRECIATION"	79574.	79574.	79574.	79574.	79574.	79574.	79574.	79574.	79574.	79574.
"AORTIZ. OF T/A & TRAIN. FEE"	6235.	6235.	6235.	6235.	6235.	0.	0.	0.	0.	0.
"AORTIZ. OF INITIAL ORG. EXP."	647.	647.	647.	647.	647.	0.	0.	0.	0.	0.

Table 12.2.3 Projected Cash Flow (Case A)

(D) PROJECTED CASH FLOW
(1000 DOL.)

PROJECT : THE INTEGRATED STEEL PLANT PROJECT IN THAILAND
CASE NO : (A)

PAGE= 4-1
DATE= AUG/28/1979

CALENDAR YEAR	1	2	3	4	5	6	7	8	9	10
PROJECT YEAR	-5	-4	-3	-2	-1	1	2	3	4	5
** APPLICATIONS **										
INVEST.PAY. FOR CONSTRUCTION	44500.	177000.	271000.	316000.	399078.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF OTHER INV.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTEREST PAY. DURING CONST.	1935.	9894.	25590.	47288.	68646.	0.	0.	0.	0.	0.
TOT.ACQUISITION OF FIX.ASSETS	46435.	186894.	296589.	363288.	467723.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.REPAY. (*1)	0.	0.	0.	0.	0.	140881.	109552.	109552.	109552.	109552.
TOTAL REPAY.OF FIXED LIABILI.	0.	0.	0.	0.	0.	140881.	109552.	109552.	109552.	109552.
IN-OR-DECREASE OF CASH	0.	0.	0.	0.	0.	1969.	1505.	228.	27.	0.
IN-OR-DECREASE OF DEBTORS	0.	0.	0.	0.	0.	28861.	22058.	3347.	396.	0.
TAX PAYMENT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC.OF OTHER LIQ.ASSET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC. OF INVENTORIES	0.	0.	0.	0.	46589.	-17719.	14761.	1590.	179.	-9.
SHORT-T LOAN REPAYMENT	0.	0.	0.	0.	0.	0.	0.	20373.	22815.	23094.
TOT.IN-OR-DEC.OF CURR.ASSETS	0.	0.	0.	0.	46589.	13110.	38324.	25539.	23416.	23085.
TOTAL APPLICATIONS	46435.	186894.	296589.	363288.	514312.	153991.	147876.	135091.	132968.	132637.
** RESOURCES **										
INCREASE OF CAPITAL STOCK	1500.	47000.	72000.	84000.	107500.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.BORROW.(*2)	43000.	130000.	199000.	232000.	331329.	31329.	0.	0.	0.	0.
BORROWING OF L-T LOAN INTER.	1935.	9894.	25590.	47288.	75484.	0.	0.	0.	0.	0.
TOT.INC.OF CAP.& FIX.LIABIL.	46435.	186894.	296590.	363288.	514313.	31329.	0.	0.	0.	0.
DISPOSAL INCOME AFTER TAXES	0.	0.	0.	0.	0.	-111975.	-17342.	5357.	16727.	26569.
DEPRECIATION & AMORTIZATION	0.	0.	0.	0.	0.	87358.	87358.	87358.	87358.	87358.
FIXED ASSETS REMOVED	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.IN-OR-DEC.OF RESERV.FUNDS	0.	0.	0.	0.	0.	-24618.	70015.	92715.	104085.	113927.
IN-OR-DEC.OF CREDITORS	0.	0.	0.	0.	0.	19549.	14941.	2267.	268.	0.
IN-OR-DEC.OF OTHER CUR.LIAB.	0.	0.	0.	0.	0.	3937.	3009.	457.	54.	0.
RESERVE FOR TAXES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORT TERM LOAN BORROWING	0.	0.	0.	0.	0.	0.	20373.	22815.	23094.	23085.
TOT.IN-OR-DEC.OF CUR.LIABILI.	0.	0.	0.	0.	0.	23486.	38324.	25539.	23416.	23085.
TOTAL RESOURCES	46435.	186894.	296590.	363288.	514313.	30197.	108339.	118254.	127500.	137012.
(NOTES)										
(*1) INCL."DEBT F.CONST.REPAY"	0.	0.	0.	0.	0.	31329.	0.	0.	0.	0.
(*2) INCL."DEBT F.CON.BORROW."	0.	0.	0.	0.	31329.	0.	0.	0.	0.	0.

Table 12.2.3 (cont'd)

(D) PROJECTED CASH FLOW
(1000DOL.)

PROJECT : THE INTEGRATED STEEL PLANT PROJECT IN THAILAND
CASE NO : (A)

PAGE= 4-2
DATE= AUG/28/1979

CALENDAR YEAR	11	12	13	14	15	16	17	18	19	20
PROJECT YEAR	6	7	8	9	10	11	12	13	14	15
** APPLICATIONS **										
INVEST.PAY. FOR CONSTRUCTION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF OTHER INV.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTEREST PAY. DURING CONST.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.ACQUISITION OF FIX.ASSETS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.REPAY. (*1)	109552.	109552.	109552.	109552.	109552.	0.	0.	0.	0.	0.
TOTAL REPAY.OF FIXED LIABILI.	109552.	109552.	109552.	109552.	109552.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF CASH	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF DEBTORS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TAX PAYMENT	0.	0.	0.	0.	0.	141.	13021.	13137.	13138.	13138.
IN-OR-DEC.OF OTHER LIQ.ASSET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC. OF INVENTORIES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORT-T LOAN REPAYMENT	23085.	23085.	23085.	23085.	23085.	22944.	10064.	9948.	9947.	9947.
TOT.IN-OR-DEC.OF CURR.ASSETS	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.
TOTAL APPLICATIONS	132637.	132637.	132637.	132637.	132637.	23085.	23085.	23085.	23085.	23085.
** RESOURCES **										
INCREASE OF CAPITAL STOCK	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.BORROW.(*2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BORROWING OF L-T LOAN INTER.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.INC.OF CAP.& FIX.LIABIL.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISPOSAL INCOME AFTER TAXES	30619.	40479.	50339.	60198.	69917.	73787.	74444.	74450.	74450.	74450.
DEPRECIATION & AMORTIZATION	86457.	86457.	86457.	86457.	86457.	79574.	79574.	79574.	79574.	79574.
FIXED ASSETS REMOVED	0.	0.	0.	0.	0.	0.	0.	0.	0.	93987.
TOT.IN-OR-DEC.OF RESERV.FUNDS	117076.	126936.	136796.	146655.	156374.	153362.	154019.	154024.	154024.	248011.
IN-OR-DEC.OF CREDITORS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC.OF OTHER CUR.LIAB.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RESERVE FOR TAXES	0.	0.	0.	0.	141.	13021.	13137.	13138.	13138.	13138.
SHORT TERM LOAN BORROWING	23085.	23085.	23085.	23085.	22944.	10064.	9948.	9947.	9947.	9947.
TOT.IN-OR-DEC.OF CUR.LIABILI.	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.	23085.
TOTAL RESOURCES	140161.	150021.	159880.	169740.	179459.	176446.	177103.	177109.	177109.	271096.
(NOTES)										
(*1)INCL."DEBT F.CONST.REPAY"	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(*2)INCL."DEBT F.CON.BORROW."	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 12.2.4 Projected Cash Flow (Case B)

(O) PROJECTED CASH FLOW
(1000DOL.)

PROJECT : THE INTEGRATED STEEL PLANT PROJECT IN THAILAND
CASE NO : (B)

PAGE= 4-1
DATE= AUG/28/1979

CALENDAR YEAR	1	2	3	4	5	6	7	8	9	10
PROJECT YEAR	-5	-4	-3	-2	-1	1	2	3	4	5
** APPLICATIONS **										
INVEST.PAY. FOR CONSTRUCTION	44500.	177000.	271000.	316000.	399078.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF OTHER INV.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTEREST PAY. DURING CONST.	1935.	9894.	25589.	47288.	68645.	0.	0.	0.	0.	0.
TOT.ACQUISITION OF FIX.ASSETS	46435.	186894.	296589.	363288.	467723.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.REPAY. (*1)	0.	0.	0.	0.	0.	140881.	109552.	109552.	109552.	109552.
TOTAL REPAY.OF FIXED LIABILI.	0.	0.	0.	0.	0.	140881.	109552.	109552.	109552.	109552.
IN-OR-DECREASE OF CASH	0.	0.	0.	0.	0.	2242.	1708.	256.	30.	0.
IN-OR-DECREASE OF DEBTORS	0.	0.	0.	0.	0.	32864.	25047.	3747.	443.	0.
TAX PAYMENT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC.OF OTHER LIQ.ASSET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC. OF INVENTORIES	0.	0.	0.	0.	46589.	-17719.	14761.	1590.	178.	-9.
SHORT-T LOAN REPAYMENT	0.	0.	0.	0.	0.	0.	0.	21134.	23677.	23968.
TOT.IN-OR-DEC.OF CURR.ASSETS	0.	0.	0.	0.	46589.	17387.	41516.	26727.	24328.	23959.
TOTAL APPLICATIONS	46435.	186894.	296589.	363288.	514312.	158268.	151068.	136278.	133880.	133511.
** RESOURCES **										
INCREASE OF CAPITAL STOCK	1500.	47000.	72000.	84000.	107500.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.BORROW.(*2)	43000.	130000.	199000.	232000.	331329.	31329.	0.	0.	0.	0.
BORROWING OF L-T LOAN INTER.	1935.	9894.	25590.	47288.	75484.	0.	0.	0.	0.	0.
TOT.INC.OF CAP.& FIX.LIABIL.	46435.	186894.	296590.	363288.	514313.	31329.	0.	0.	0.	0.
DISPOSAL INCOME AFTER TAXES	0.	0.	0.	0.	0.	-79205.	39887.	65812.	77564.	87406.
DEPRECIATION & AMORTIZATION	0.	0.	0.	0.	0.	87358.	87358.	87358.	87358.	87358.
FIXED ASSETS REMOVED	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.IN-OR-DEC.OF RESERV.FUNDS	0.	0.	0.	0.	0.	8152.	127244.	153170.	164922.	174764.
IN-OR-DEC.OF CREDITORS	0.	0.	0.	0.	0.	22260.	16965.	2538.	300.	0.
IN-OR-DEC.OF OTHER CUR.LIAB.	0.	0.	0.	0.	0.	4483.	3417.	511.	60.	0.
RESERVE FOR TAXES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORT TERM LOAN BORROWING	0.	0.	0.	0.	0.	0.	21134.	23677.	23968.	23959.
TOT.IN-OR-DEC.OF CUR.LIABILI.	0.	0.	0.	0.	0.	26744.	41516.	26727.	24328.	23959.
TOTAL RESOURCES	46435.	186894.	296590.	363288.	514313.	66225.	168760.	179896.	189250.	198723.
(NOTES)										
(*1) INCL."DEBT F.CONST.REPAY"	0.	0.	0.	0.	0.	31329.	0.	0.	0.	0.
(*2) INCL."DEBT F.CON.BORROW."	0.	0.	0.	0.	31329.	0.	0.	0.	0.	0.

Table 12.2.4 (cont'd)

(D) PROJECTED CASH FLOW
(1000DOL.)

PROJECT : THE INTEGRATED STEEL PLANT PROJECT IN THAILAND
CASE NO : (B)

PAGE= 4-2
DATE= AUG/28/1979

CALENDAR YEAR	11	12	13	14	15	16	17	18	19	20
PROJECT YEAR	6	7	8	9	10	11	12	13	14	15
** APPLICATIONS **										
INVEST.PAY. FOR CONSTRUCTION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF OTHER INV.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTEREST PAY. DURING CONST.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.ACQUISITION OF FIX.ASSETS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.REPAY. (*1)	109552.	109552.	109552.	109552.	109552.	0.	0.	0.	0.	0.
TOTAL REPAY.OF FIXED LIABILI.	109552.	109552.	109552.	109552.	109552.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF CASH	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DECREASE OF DEBTORS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TAX PAYMENT	0.	0.	0.	0.	6137.	19552.	22185.	22208.	22208.	22208.
IN-OR-DEC.OF OTHER LIQ.ASSET	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC. OF INVENTORIES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORT-T LOAN REPAYMENT	23959.	23959.	23959.	23959.	17821.	4406.	1774.	1751.	1751.	1751.
TOT.IN-OR-DEC.OF CURR.ASSETS	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.
TOTAL APPLICATIONS	133511.	133511.	133511.	133511.	133511.	23959.	23959.	23959.	23959.	23959.
** RESOURCES **										
INCREASE OF CAPITAL STOCK	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
L-T LOAN & D.F.C.BORROW.(*2)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BORROWING OF L-T LOAN INTER.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOT.INC.OF CAP.& FIX.LIABIL.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DISPOSAL INCOME AFTER TAXES	90543.	100402.	110262.	113984.	110797.	125712.	125846.	125848.	125848.	125848.
DEPRECIATION & AMORTIZATION	86457.	86457.	86457.	86457.	86457.	79574.	79574.	79574.	79574.	79574.
FIXED ASSETS REMOVED	0.	0.	0.	0.	0.	0.	0.	0.	0.	93987.
TOT.IN-OR-DEC.OF RESERV.FUNDS	176999.	186859.	196719.	200441.	197254.	205286.	205421.	205422.	205422.	299408.
IN-OR-DEC.OF CREDITORS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
IN-OR-DEC.OF OTHER CUR.LIAB.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RESERVE FOR TAXES	0.	0.	0.	6137.	19552.	22185.	22208.	22208.	22208.	22208.
SHORT TERM LOAN BORROWING	23959.	23959.	23959.	17821.	4406.	1774.	1751.	1751.	1751.	1751.
TOT.IN-OR-DEC.OF CUR.LIABILI.	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.	23959.
TOTAL RESOURCES	200958.	210818.	220678.	224400.	221213.	229245.	229379.	229381.	229381.	323367.
(NOTES)										
(*1)INCL."DEBT F.CONST.REPAY"	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
(*2)INCL."DEBT F.CON.BORROW."	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

i. Case A

Table 12.2.3 indicates that fund shortages will continue into the fourth year after commissioning, and the fifth year will see a fund surplus for the first time. In the subsequent years, the fund position will improve year after year. Particularly, from the eleventh year when the repayment of long-term loans is to be completed, the fund position will be substantially improved.

ii. Case B

Table 12.2.4 shows that there is a substantial shortage of funds in the first year after commissioning, but a fund surplus will develop from the second year onward.

12.3 Financial Analyses

Some analyses on the results of financial projections are made as follows:

(1) Profits and Losses by Type of Products

Profits and losses of the products to be marketed by the new company are given by type of products in Tables 12.3.1 and 12.3.2 for Cases A and B, respectively. These figures represent average profits and losses in a normal operating year.

Although business taxes are exempted for 5 years after commissioning, those for the subsequent years, regarded as normal operating years, were added to costs. Capital costs (depreciation cost plus interest) were calculated using the annuity method.

(2) Break-even Point Analysis

Break-even points, which have been described in Chapter 11 are given for each case in Table 12.3.3.

Table 12.3.1 Sales Profit – Case A

(Unit: dollars/t)

	Production (1,000 t)	Sales price	Cost					Profit	Profit amount (mill. dollars)	Remarks
			Production cost	Business tax for sales	General administration cost	Interest	Total			
HR coil	425	*1 351	286.3	*2 5.3	1.8	*3 42.8	336.2	14.8	6.3	
HR sheet	199	376	295.1	5.6	1.9	45.9	348.5	27.5	5.4	
CR coil	54	416	338.4	6.2	2.2	52.6	399.4	16.6	0.9	
CR sheet	121	441	370.0	6.6	2.2	53.8	432.6	8.4	1.0	
CRC for tin plate	80	476	397.9	7.1	2.4	58.1	465.5	10.5	0.8	
CRC for GI sheet	224	489	371.9	7.3	2.5	59.6	441.3	47.7	10.7	
Total	1,103	406	325.1	6.0	2.1	49.6	382.8	23.2	25.1	

Note: 1. Sales price level is set to substitute import of flat products including CIF price, normal custom tariff and other charges.

2. Business tax for sales is charged by assuming normal taxation year.

3. Annuity method is applied to calculate interest.

Table 12.3.2 Sales Profit – Case B

(Unit: dollars/t)

	Production (1,000 t)	Sales price	Cost					Profit	Profit amount (mill. dollars)	Remarks
			Production cost	Business tax for sales	General administration cost	Interest	Total			
HR coil	425	*1 406	286.3	5.3	1.8	42.8	336.2	69.8	29.7	
HR sheet	199	431	295.1	5.6	1.9	45.9	348.5	82.5	16.4	
CR coil	54	471	338.4	6.2	2.2	52.6	399.4	71.6	3.9	
CR sheet	121	496	370.0	6.6	2.2	53.8	432.6	63.4	7.7	
CRC for tin plate	80	531	397.9	7.1	2.4	58.1	465.5	65.5	5.2	
CRC for GI sheet	224	544	371.9	7.3	2.5	59.6	441.3	102.7	23.0	
Total	1,103	461	325.1	6.9	2.1	49.6	383.7	77.3	85.9	

Note: 1. Sales price is revised by assuming protective custom tariff.
2. Other assumptions are same as Table 12.3.1.

The table indicates that an operating level of 966,000 tonnes will be required to achieve a break-even point in Case A, while, in Case B, fixed costs can be recovered at an operation level of 749,000 tonnes because of increased sales prices.

The operation rate at the break-even point is 87.6% in Case A and 67.9% in Case B.

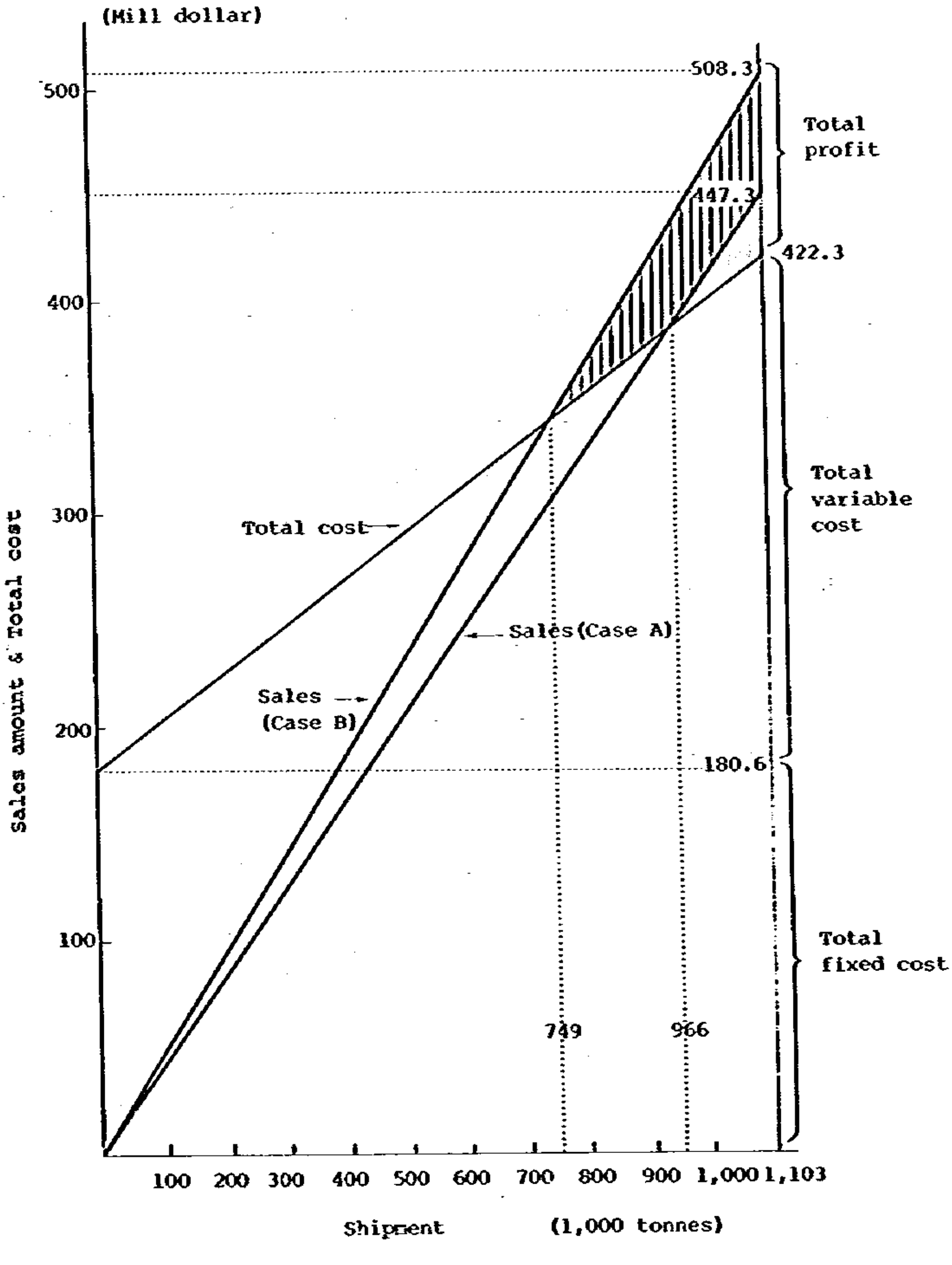

Fig. 12.3.1 Break-even Point Analysis

(3) Internal Rate of Return on Investment

i. Calculation of return on investment ratio by the discounted cash flow method

In evaluating the profitability of investment, the discounted cash flow (DCF) method was employed.

In this study, ROI (return on investment) and ROE (return on equity) were calculated from the above mentioned cash flow statement on the assumption that the period of this project is 20 years for the sake of calculation purpose (5 years for the construction period, 15 years after commissioning).

ii. Calculation results

The results of calculation are shown below. According to this table, ROI is 6.25% and ROE is 5.59% in Case A. In Case B, ROE as calculated by setting ROI at 10% is 14.08%.

(%)

	Case A	Case B
ROI	6.25	10.00
ROE	5.59	14.08

CHAPTER 13

EFFECT ON THE NATIONAL ECONOMY

CHAPTER 13 IMPACT ON ECONOMY AND SOCIETY

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CHAPTER 13 IMPACT ON ECONOMY AND SOCIETY

13.1 General

Economic development plans are implemented by the vast majority of the Asian nations. Rolling mostly on a five-year basis, they are intended to reform the traditional economy and promote modernization and industrialization.

In general, a significant increase in the national income of developing nations is realized when industrial production comes to carry greater weight in the national production. Economic and social development calls for changes in the traditional economy and society. Industrialization plays an important role in generating these changes. Evidently, rapid industrialization generally constitutes a driving force in the process of accelerated economic development. Industry itself is capable of exerting a great influence on agriculture and other economic sectors. Further, it tends to have a dynamic impact upon the entire social institution through changes in the general life style and the pattern of consumption. It is because of this that developing nations on the whole take up industrialization as means of economic progress and give priority to it in their economic development efforts.

In the promotion of industrialization in developing nations, the steel industry is identified as a foundation on which to build modern industrial complexes and hence is entitled to an important place in the industrialization plans.

It deserves the treatment also because of the fact that no other industry can match it in the magnitude of the linkage effect upon the national economy. See Table 13.1.1.

The effect of the steel industry is characterized by the creation of employment opportunities as well as by the cumulative effect of creating various other new industries. Besides, the steel industry offers a technological foundation for overall industrial development through the propagation of various types of technology and the elevation of the general technological standards.

The proposed integrated steel plant in Thailand that assures an effective utilization of domestic natural gas resources and an addition of higher value to these will open the way to the substitution of steel products imports and hence to a significant saving of foreign currency. To be located in the heart of a new industrial zone, it will have a favourable effect on regional development leading to homogeneous economic development and regional distribution of the population. At the same time, the successful development and expansion of the steel industry, a typical key industry, will generate confidence in industrial development and afford a clear vista into the future. And the people of younger generation full of new and high spirits will gain great confidence along with improvements in the educational system. The impact will then be extensive both socially and educationally going beyond the matter of a specific industry, the steel industry.

Such is the character of the steel industry. However, attention is called to a number of points in promoting the development. Being a typically capital intensive industry, the steel industry requires huge capital outlays to develop it. It also requires an extensive and systematized technology. It is suited to the economies of scale when it comes to the scale of production. Thus, the expansion of production up to a certain level will serve to reduce the unit cost. It does not necessarily mean, however, that the larger the scale of production, the

Table 13.1.1 Industrial Interdependence, Forward and Backward Linkage (Examples of Italy, Japan and U.S.A.)

Sectors	Forward linkage	Backward linkage
Intermediate manufacture (backward and forward linkage both high)		
Iron and steel	66	78
Non-ferrous metal	61	81
Paper and products	57	78
Petroleum products	65	68
Coal products	63	67
Chemicals	60	69
Textiles	67	57
Rubber products	51	48
Printing & publishing	49	46
Final manufacture (backward linkage high, forward linkage low)		
Grain mill products	89	42
Leather and products	66	37
Lumbre and wood products	61	38
Apparel	69	12
Transport equipment	60	20
Machinery	51	28
Non-metallic mineral products	47	30
Processed foods	61	15
Shipbuilding	58	14
Miscellaneous industries	43	20
Intermediate primary production (forward linkage high, backward linkage low)		
Metal mining	21	93
Petroleum and natural gas	15	97
Coal mining	23	87
Agriculture and forestry	31	72
Electric power	27	59
Non-metallic minerals	17	52
Final primary production (backward and forward linkage both low)		
Transport	31	26
Trade	16	17
Fishing	24	36
Services	19	34

Note: (a) Ratio of interindustry purchases to total production (%)
(b) Ratio of interindustry sales to total demand (%)

Source: A.O.Hirschman "Strategy of Economic Developement" P. 106 - 107

Original source: Chenery and Watanabe "International Comparisons" PN better it is. It means that it is important to select from among various possibilities the optimal one to meet with the economic and industrial development of Thailand.

Such being the case, the proposed integrated steel plant designed to utilize the natural gas produced at home has great significance along with the strategic goals of the Thai government set for the steel industry in Thailand.

The effect of the steel plant in terms of the saving of foreign currency and the creation of employment will be discussed in length in the following sections.

13.2 Saving of Foreign Currency

The saving of foreign currency was calculated taking into consideration the effect of import substitution. That is to say, it was calculated on the basis of a comparison between the possible amount of foreign currency required in case the proposed integrated steel plant is not constructed and that in case the mill is constructed.

According to the calculation, as much as 425,832,000 dollars will be saved per year. On the other hand, the principal production equipment and facilities (certain types of infrastructure will be included depending on the case) will have to be paid for in foreign currency. By directing the foreign currency thus saved annually to investment, the first stage of investment will be recoverable in 8.09 years. The estimates are shown in Table 13.2.1.

It was assumed that the investment of 1,063,225,000 dollars financed by borrowings from abroad will be repaid over a 10-year period at an average annual rate of 106,323,000 dollars.

In the meantime, the expenses for the preparation of operation, expenses for personnel training, fees for technical guidance for operation, consulting fees, etc. will have to be paid in foreign currency. For this reason, the mention of 8.09 years to recover investment is no more than an indication of the import-

Table 13.2.1 Foreign Currency Saving Effect

	Item	First stage			Remarks
		Volume (t/y)	Price ($/t)	Amount (1,000 $)	
Saving of foreign currency					
	Ⓐ	1,103,000	386	425,832	
Outflow of foreign currency Ⓔ Note 1	Import of ore Import of pellet Import of scrap Sub-materials Variable supplies Return of foreign currency	365,000 1,400,000 132,000		8,204 51,364 19,765 6,446 41,812 106,323	
	material interest			24,566 35,933	For maintenance Note 2
	Ⓑ			294,413	
Foreign currency saving effect					
	Ⓒ = A – B			131,419	
In investment foreign currency	Main production facilities			1,063,225	
	Ⓓ			1,063,225	
Payout period	D/C		8.09 yrs		( ) Excluding infrastructure

Note 1: Engineering and consulting cost and overseas training cost may be paid in foreign currency, though not included in this Table.

Note 2: It is assumed that all construction capital and running capital are borrowed foreign currency.

ance of foreign currency saving. Be that as it may, the trade balance which is expected to deteriorate while the construction is under way will start to improve several years thereafter.

In case the demand in the steel market is not tight in Thailand, it is possible that Thai steel products can be exported to the neighboring countries, though export possibilities were not considered in Table 13.2.1. If exported, a significant contribution will be made to the improvement of the trade balance. The domestic production of firebricks, sulphuric acid, rolls, casts and moulds will be possible accompanying the development of heavy and chemical industries in Thailand. This is another factor which contributes significantly to the improvement of the trade balance. If the saying that "demand is the mother of supply" holds true, the existence of an integrated steel plant will have an psychological impact on the promotion of business cycles for the creation of supporting industries.

Integration is not confined to the steel mill. It can be applicable to all associated industrial sectors.

13.3 Effect of Employment

A key industry, such as the steel industry, generates what is termed as "forward linkage effect" which signifies a great effect of product utilization or activities induced by the supply to the market of processed products. It also generates "backward linkage effect" which signifies demand from the said industry for products and services made available by other industries. As shown in Table 13.1.1, the steel industry comes to the top surpassing all other industries including services. In other words, the steel industry ranks among the top industries in the creation of new industries and employment. As for the creation of employment, the lack of reliable data and the absence of the latest imput-output table made it impossible to land at the number of employment opportunities created either by the forward linkage effect or by the backward linkage effect.

Such being the case, it was not possible to calculate the number of employment opportunities created by the proposed integrated steel mill. Should the empirical estimate that the steel industry creates an equal number of employment opportunities in other sectors prove true, the proposed integrated steel mill will provide 4500 inside jobs and 2500 outside jobs in the second stage of construction. These figures do not include construction and infrastructure-related workers. All in all, approximately 100,000 jobs are expected to be created by the steel mill project. And with the steel plant in the center, the area will grow into a new and prosperous industrial zone in Thailand.

13.4 Effect of Technological Transfer

Being an industrial complex, the steel industry requires supporting industries to assure its full development. Further, it is an industry capable of creating many new industries in the process of its own development.

The steel industry itself is in need of various types of technology ranging in fields from metallurgy to mechanics, electricity, chemistry, resources, and, depending on cases, to civil engineering technology. And in recent years, it has been a mounting need for incorporating electronic engineering technologies. Such tendency holds particularly true when it concerns the construction and operation of an integrated steel mill. It has a significant effect in making these various kinds of technology spread and take roots in the country.

In this connection, it is important that these technologies be understood, acquired and utilized over a long period of time by the people of the recipient country, the people of Thailand in this case. Technologies will be transferred from advanced nations to Thailand, and specifically to Thai engineers, in the process of the construction and operation of the new integrated steel plant.

In making these technologies take roots in Thailand, the existence and the kind of steel technology and the extent of its availability in the country as a whole constitute a very important point. It is known that Thailand has electric furnace steelmaking and rolling technology which is representative of the Asian region and that steel mills are operated by Thai engineers. What is important under these circumstances is how to join the existing technology in Thailand or these Thai steel engineers and the various types of technology required for the new integrated steel plant. This is a vital factor in making strategic decisions on technological transfer. It is judged that Thailand is already in possession of the technological foundation.

Such being the case, it is expected that the introduction of technology concerned with the construction and operation of an integrated steel plant, itself a modern and comprehensive operation, will make valuable contributions to the accelerated improvement of steel technology in Thailand and that the induced technology will be instrumental in upgrading the technological standards of other industries through its extensive rippling effect.

Actions by the Royal Thai Government to effectuate the consolidation of the infrastructure for such technological transfer are imperative. These actions should be directed to the consolidation of educational and training institutions, promotion of industrial standardization and improvement of product standards, etc.

13.5 Impact on Environment

(1) Atmospheric Environment

The steel plant uses a large quantity of natural gas which contains sulphur to some extent. In order to prevent the life of the catalyzer in the gas reformer from being degraded, the DR plant which is the biggest gas consumer in the steel plant is equipped with a desulphurization system for natural gas. The desulphurization system functions to reduce the H_2S content in gas from 1.5 g/Nm^3 which is the assumed content in raw gas to 0.001 g/Nm^3. As the DR plant consumes 77% of the total amount of a gas to be used at the steel plant, it is deemed that nearly 77% of the H_2S in the entire gas used at the steel plant is removed by this desulphurization.

Next to the DR plant, the hot strip mill reheating furnace accounts for about 12% of the total gas consumption as the steel plant following the DR plant. In order that waste gas be dispersed effectively in the air, the reheating furnace stack is designed to be 60 m high above the ground. When the dispersion rate of SOx in the waste gas from hot strip mill reheating furnace is calculated by means of the Bosanquet-Sutton formula which is generally used for waste gas dispersion, it will result as shown in Table 13.5.1. The derived result is based on a 3-minute pattern, and it will be about 0.0015 ppm (at the wind velocity of 6 m/sec) when expressed in terms of a 1-day basis. Table 13.5.2 shows examples of the environmental control criteria for SOx enforced in various countries. Compared with the severest value of the criteria, the derived value of the SOx in the waste gas from the hot strip mill reheating furnace is less than 10% which is a very small value. The steel plant will thus affect the SOx value only but very little in the surrounding environment, so there would be no significant problem arising from the derived SOx value.

In electric arc furnace operation, oxidized iron fume is generated from the hot metal surface during melting and refining. The fume is lead through a duct to a dust collector where it is collected in a bag-filter and then exhausted into the air. With the bag-filter, dust concentration is reduced from 5 g/Nm^3 of entry gas to 0.03 g/Nm^3 of discharge gas, so a rate of removal is about 99.5%. Such a dust collector is generally used for today's electric arc furnace systems, but care must be paid in the operation and handling so that suction of outside air to the dust collector duct must be minimized.

At the time of charging scraps and discharging molten steel, dust is not sucked into the dust collector. The dust generated in those occasions is intermittent and dust concentration is low, but the dust is very conspicuous because it is emitted from the top of the steelmaking shop. To cope with the problem, it is designed in this steel plant project, to provide the shop with an roof dust collector. With this dust collector, the atmosphere in the house is exhausted outside through a electro-static dust collector provided atop the electric arc furnace building. The provision of this collector can almost perfectly prevent dust from escaping outside from the house. Provision of this collector may require about 5% of the total cost of an electric arc furnace equipment, and 0.5% of the total power consumption for operation.

Table 13.5.1 SOx Diffusion for Hot Mill Furnace (2nd stage)

Waste gas volume	10^3 Nm^3/h · stack	67	(wet base)
No. of stack		3	
Height of stack	m	60	
Top dia. of stack	m	2.5	
Waste gas temp.	°C	480	
SOx concentration in waste gas	ppm vol.	63	
Wind velocity	m/sec	3.1,	6.0
Results of calculation:			
Maximum SOx concentration on ground (Cmax)	ppm	0.004,	0.012
Distance of Cmax point	m	13,000,	4,500
Effective height of stack	m	280,	109

Table 13.5.2 Environmental Criteria for SOx

(Unit: ppm, mean value in a day)

Brazil	0.02
Canada { desirable	0.06
Canada { max. permissive	0.11
Japan	0.04
New Zealand	0.15
United States	0.14

(2) Waste Water

With regard to the drainage system in the steel plant, cooling water for general purposes will be fully circulated. The acidic effluent from the cold rolling mill will be chemically neutralized, then coagulated and sedimented in a sedimentation basin and then discharged. The effluent thus sedimented is colorless and transparent, but as it contains dissolved solid, it is undesirable to reuse it for circulated cooling water, but can be uninterruptedly discharged into the sea.

Dissolved solid has proximate concentration as shown in Table 13.5.3 and contains no specifically harmful substance. The total amount of effluent will be about 6,000 m^3/d at the 2nd stage.

Table 13.5.3 Characteristics of Wastes after Neutralization & Coagulation

pH	6.5 ~ 9.0
S.S.	0 ~ 3 ppm
T.Fe	<1 ppm
Cl^-	100 ~ 150 ppm
Ca	200 ppm

As the effluent from cold rolling mill contains rolling lubricant, it will be subject to oil separation before disposal. This separation is performed by a colloidal air separator (CAS) wherein the oil is coagulated with addition of a coagulant, floated up to the surface together with the air bubbles by generating micro-air bubbles by pneumatic dissolving under pressure and by reducing the pressure, and then separated from the water.

Table 13.5.4 shows an example of the composition of effluent from cold rolling mill after treatment by the CAS process. As the oil concentration before treatment by the CAS process ranges from 3,000 to 5,000 ppm, a rate of oil removal by the process is 99.8%.

Table 13.5.4 Characteristics of Wastes after CAS Treatment

pH	8 ~ 9	
Oil	4 ~ 8	ppm
S.S.	5 ~ 20	ppm
T.Fe	0 ~ 6	ppm
$C\ell^-$	300	ppm
Ca	400	ppm

(3) **Waste Heat Emission**

In addition to the waste gas and effluent referred to above, the steel plant emits waste heat. Most waste heat emitted is exhausted as a sensible heat in the waste gas from stacks, and some as moisture through the circulated cooling water at the cooling tower, and even as a sensible heat in effluent. Table 13.5.5 shows the summary of the amounts of these waste heats at the 2nd stage. Hypothetically comparing these waste heat amounts with those from a 1,300 MW thermal power station (equivalent to the South Bangkok power station), the total amount of waste heats from the proposed steel plant will be equal to about one-third of that from the power station.

Table 13.5.5 Heat Exhaust from the Steel Plant (2nd stage)

(Unit: mill kcal/h)

Exhaust fume from stacks	220	To atmosphere
Radiation from furnaces	110	
Evaporation in water cooling tower	160	
Radiation from intermediate products	80	
Waste water from cold rolling shop	10	To ocean
Total	580	

(4) Forestation

As the proposed steel plant is to be located on the existing flat land along the coast, land grading will not involve the clearing and grubbing of trees and plants on the hillside. To a certain extent, the beach will be reclaimed by dredging the water channel. Therefore, the steel plant will give no influence to the existing forest and plants. The existing mountains and rivers can also be conserved as they are featuring.

As the steel plant location is along the coastal area, no effluent from it will be discharged into the nearby rivers, but discharged directly into the sea. With these advantages, the steel plant will give no influence at all to the river ecosystem.

(5) Pollution Control Cost

Although the steel plant thus emits some discharges into the air and the sea, provision of various control measures will result in very small influence to the environment. The total equipment cost for these pollution control facilities in the 1st stage will be about $13 million, and the total annual operation cost will be about $1.6 million, the cost shared per tonne of product being estimated to be about 3 dollars. These pollution control facilities include those generally used for current steel plants and also those generally not used yet, such as the roof dust collector.

In implementing the steel plant project, the owner will be required to prepare and submit to the National Environment Board an Environmental Impact Statement (EIS) covering the influence of the steel plant construction and operation on the surrounding environment.

CHAPTER 14

RECOMMENDATIONS

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CHAPTER 14 RECOMMENDATIONS

14.1 Provision of Incentives

In the present study, various studies are made to permit the profitability of the project to be evaluated and the studies being based on the current prices as of April, 1979. It is recommended that the contents of these studies be closely examined for effective utilization in implementing the construction of the steel plant. For the following items, it is necessary that the Royal Thai Government backs up the management by giving incentives aggressively.

(1) Tax Incentives

i. Custom duties and business taxes

Incentives more favourable than those available by the Investment Promotion Act should be given to the following items:

a. Construction machinery, materials, services, etc.
b. Raw materials and other materials required for operation
c. Sale proceeds of the products manufactured by the new steel plant

ii. Corporate income tax

Following incentives should be granted to the new steel plant:

a. Introduction of "Tax Holiday"

b. Designation of "Promoted Zone"

iii. Protective measures

Protective measures such as import license system, protective duties against competition by imported products should be taken.

(2) Utility Prices

Provision of incentives to following utility prices.

a. Electric power charge

b. Natural gas charge

c. Water charge, etc.

(3) Tariffs

Establishment of preferential tariff for both sea and land transportation.

i. Ports and harbours

The following should apply to the imports (raw materials, processed materials, supplies and equipment) and the exports (products).

a. Import duties: None

b. Port charges: Less than 50% of standard charges, provided that wharfage and berthage are free. (See Note *)

Note*: The sea berths and products quays are to be constructed and depreciated by the steel plant. Thus, the port charges are limited to towage, pilotage, etc.

ii. Roads:

For all the incomings (raw materials, processed materials, supplies and equipment) and outgoings (products), any tariff should be free.

iii. Railways:

For all the incomings (raw materials, processed materials, supplies and equipment) and outgoings (products), any tariff should be less than 50% of the standard.

iv. Sattahip port:

The condition (i) shall apply.

(4) Funds

Assistance should be given to the procurement and financing of funds required for the construction and operation of the steel plant.

(5) Encouragement of Domestic Industries

Steel making related industries should be fostered and domestic production of raw materials and other necessary materials should be encouraged.

14.2 Improvement of Infrastructure

(1) Land

Expropriation, buying-up, and compensation to inhabitants and landowners.

Procurement of land (417.5 ha) necessary for the steel plant.

(2) Port Facilities

The raw materials receiving berths and products shipping quays shall be constructed, maintained, managed and depreciated by the steel plant. Aside from these, pilotage, towage, customs clearance, quarantine service, maintenance of channels and basins, construction and maintenance of breakwaters and navigation aids, and other various port administrative activities should be undertaken by the Royal Thai Government to keep the port functions in working order.

(3) Railway

i. Railway siding

It is necessary to construct a railway siding as connected to the main line planned by SRT. The construction, operation and maintenance of the track and signaling facilities within the steel plant premises should be left to the hands of SRT.

(4) Town Development

i. City construction

The steel plant will prepare up to 1,500 houses for the employees. It is expected that people of more than 100,000 will live around the steel plant, and the houses, schools, hospitals, markets, temples, recreation facilities should be available for them.

They also necessitate water, electricity and gas, sewerage, transport, telecommunication facilities, fire prevention facilities, police system, civic centre, banking services, and other institutional facilities. Namely, the Royal Thai Government should lead the construction of a city with a population of 100,000.

14.3 Guarantee for Supply of Utilities

The supply of the utilities (natural gas, electric power and water) is essential to the operation of the steel plant. These utilities have to be supplied stably and steadily from the test run stage of the steel plant to the future. Concerning the supply requirements, the utilities should be supplied as far as the steel plant premise by the public service in accordance with the requirements given in Table 14.3.1.

Table 14.3.1 Requirement for Natural Gas, Power and Water

	1st stage		2nd stage	
	Annual consumption	Peak demand	Annual consumption	Peak demand
Natural gas	$527,400 \times 10^3$ Nm^3 or 17.2×10^{12} BTU	80,000 Nm^3/h 70×10^6 SCFD	$841,600 \times 10^3$ Nm^3 or 27.5×10^{12} BTU	120,000 Nm^3/h 110×10^6 SCFD
Electric power	$1,577 \times 10^6$ kWh	240 MW (In 230 kv, 450 MVA x Double Circuits)	$2,480 \times 10^6$ kWh	360 MW
Industrial water	14.2×10^6 m^3	50,000 m^3/day	21.7×10^6 m^3	70,000 m^3/day
Potable water	720×10^3 m^3	2,200 m^3/day	530×10^3 m^3	3,200 m^3/day

(1) Electric Power

Concerning specifically the supply of electric power, the EGAT will be required to identify the short-circuit capacity of power supply at the phase of equipment planning for the steel plant. This is necessary because the size of flicker control system to be provided on the steel plant compound will vary with such short-circuit capacity.

(2) Gas

What is the most important about natural gas is that as the steel plant will use natural gas as a reductant, natural gas must be kept supplied in sufficient amount as long as the steel plant continues to exist.

Considering the future, more natural gas will be used in gas-fired power generation, other industries will accelerate energy substitution to natural gas, private gas consumption will have to increase, and the supply to the Thai South Area will also have to be increased. Taking all those prospects into consideration, it will be necessary that the NGOT develops to produce more natural gas in the Gulf of Thailand.

(3) Water

In order that a stable amount of water be secured even in the time of rainfall ranking second worst in the past decade as registered in the Thai hydrological data, a plan to construct and utilize reservoirs must be established. In particular it is necessary to clarify the rights between the water for the steel plant and that for irrigation, and these rights must be protected without friction. The water transmission facilities to the steel plant should be equipped with a diesel generator serving as an emergency power source during power failure.

14.4 Surveys Relating to the New Steel Plant

Basic surveys include the following.

(1) Topographic and Hydrographic Surveys

A topographic map is required for an area of about 800 to 1,200 ha (400 ha x 2 to 3).

It should be drawn to a scale of 1 to 1,000 (or 1 to 2,000). Both the survey of neighbouring structures and the aerial mapping are required together with sounding, to cover a tract including offshore waters.

(2) Soil Investigations

Boring should be made at a minimum of 20 locations (10 ashore and 10 offshore). The boring depth should be about MSL −30 m where a hard layer is expected. Subsoil profile and mechanical properties should also be clarified to some extent.

(3) Water Quality Analysis

The water quality of Bang Phra reservoir should be analyzed. The subjects of analysis should include such characteristics as pH range, hardness, metals, and turbidity.

(4) Surveys of Natural Resources

Although using the raw materials of Thai origin would be natural from the Thai national policy, much of the raw materials will have to have dependence on import as the current status is indicated through surveys and developments of natural resources.

As iron ore to be used as main raw material, and manganese ore to be used as raw material for ferroalloy have already been identified as to their reserves, it would be expected that their detailed surveys are carried out for development. Although it is assumed by the study that limestone and fluorite can be procured at home, a detailed development plan or a detailed procurement plan of these ores must be established before start-up of the steel plant.

(5) Analysis of Natural Gas Composition

The sulphuric matters (hydrogen sulphide, carbon disulphide, mercaptan, etc.) adversely affect the catalyst which is the content of the reforming furnace tube, and obstruct the productivity, so they have to be removed.

On the sulphuric matters, the hydrogen sulphide can be removed comparatively with ease, but removal of the other components require provision of a special system, and its construction cost is very expensive. The use of ordinary reforming furnace can hardly reform heavy hydrocarbon, and the desulphurization system is also adversely affected by the heavy hydrocarbon, so it has to be removed if it is contained substantially. Thus, urgent survey of the impurities in the natural gas should be carried out.

14.5 Recruitment of Competent Labour Force

The number of employees required for operation of the new integrated steel plant will be as many as about 3,700. Considering that

a. the estimated unemployment in Thailand is 5 to 6%,

b. unemployment sharply increases during those period when agriculture, forestry and fishery, are inactive because of drought or some other reasons,

c. about 80% of current employees are engaged in agriculture, forestry and fishery, and

d. population increases at a high rate of about 3% per annum, Thailand has a large labour force surplus. However, what is important, among all others is how to secure competent managing staff, engineers and skilled workers. Operation of the steel plant requires more operators of furnaces and mills and cranes as such who must have high skills than those required by other industries.

To secure such competent labour force, the following must have been considered by the Royal Thai Government:

a. Provision of professional education at universities and colleges for metallurgy, civil engineering, and mechanical and electrical engineering, etc.

b. Provision of professional training schools and training centres.

14.6 Establishment of the Project Promotion Organization

For the purpose of realization of this project in the earliest possible time, it is desired to establish as soon as possible the project promotion organization which will have a right and authority to execute the project.

14.7 Improvement of Statistical Data

The statistical data currently available in Thailand are not necessarily well compiled. It is desired to improve the quality and expand the scope of these data to effectively promote the type of study as being conducted.

CHAPTER 15

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CHAPTER 15-1

RAW MATERIAL RECEIVING AND HANDLING FACILITIES

15.1 Raw Material Receiving and Handling Facilities

Receiving flow of raw materials is mainly divided into two routes:

a. Sea route by vessel or carrier

b. Land route by railway trucks

The former route covers iron ores, scrap, ferroalloys, aluminium, and carburizing material, and the latter burnt lime, fluorite, etc.

(1) Main Raw Material Receiving and Handling Facilities

As described under Section 5.6 (1), iron ores, scrap and part of ferroalloys are unloaded from the carriers at the raw material receiving berth. Iron ores are discharged from holds by travelling unloaders, then they are transported by belt conveyors, and stacked in the ore stock-yard. From there, they are sent out by reclaimers in accordance with the need of the DR plant (Refer to Figs. 15.1.1 and 15.1.2).

Scrap is discharged by derricks with electromagnets mounted on scrap carriers themselves, and by shore cranes equipped with electromagnets from general bulk carriers.
Scrap is temporarily placed on the berth, and eventually transported to the scrap yard by lorries. In consideration of the operation rate of the berth, scrap will be discharged at the berth built for receiving iron ores at the 1st stage, but an exclusive berth for scrap will be built at the 2nd stage (Refer to Table 15.1.1).

Some ferroalloys in bulk (e.g. Fe-Mn) may be discharged at the ore berth. Materials arriving in a small consignment, such as a several-hundred-tonne consignment of Fe-Si, aluminium or carburizing material, will be discharged at the nearby general commercial port, and from there, they will be barged to the product berth or to the scrap berth where they will be discharged by shore cranes. From the berths, they will be transported to the sub-material warehouse. Finally, they will be sent to the steelmaking shop as required.

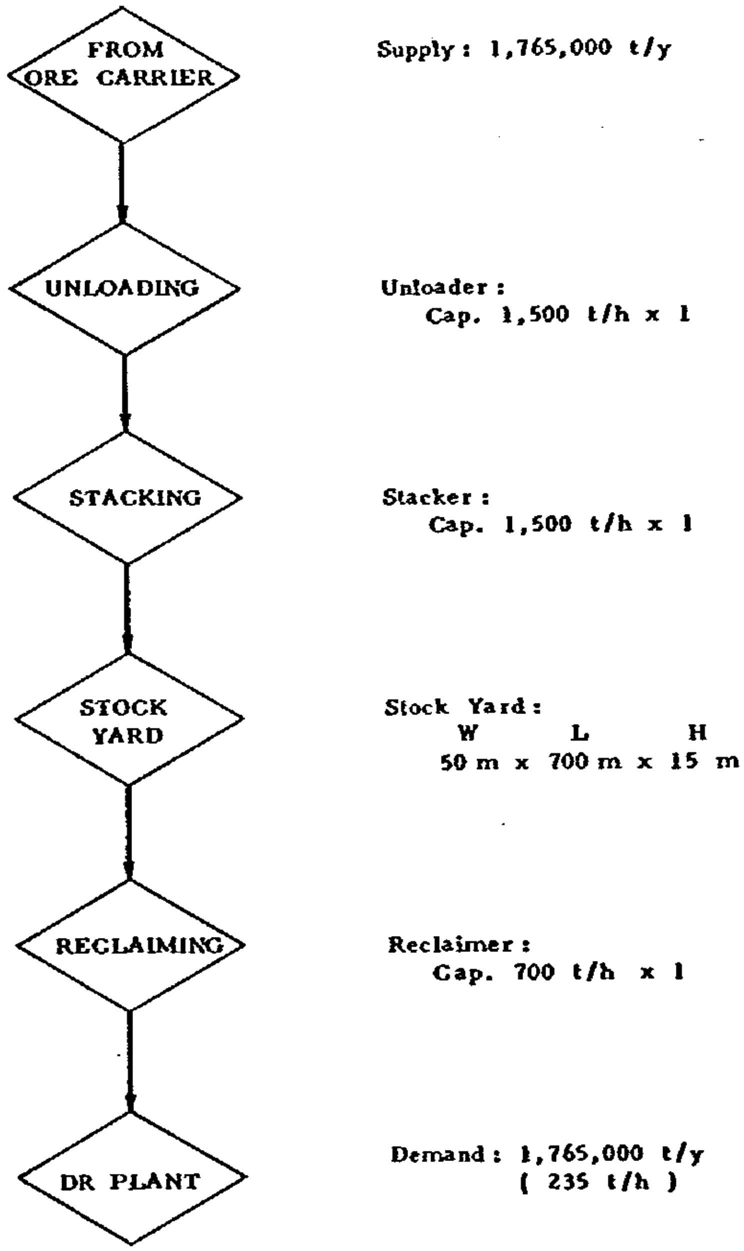


Fig. 15.1.1 Flowchart of Raw Material Handling (1st Stage)

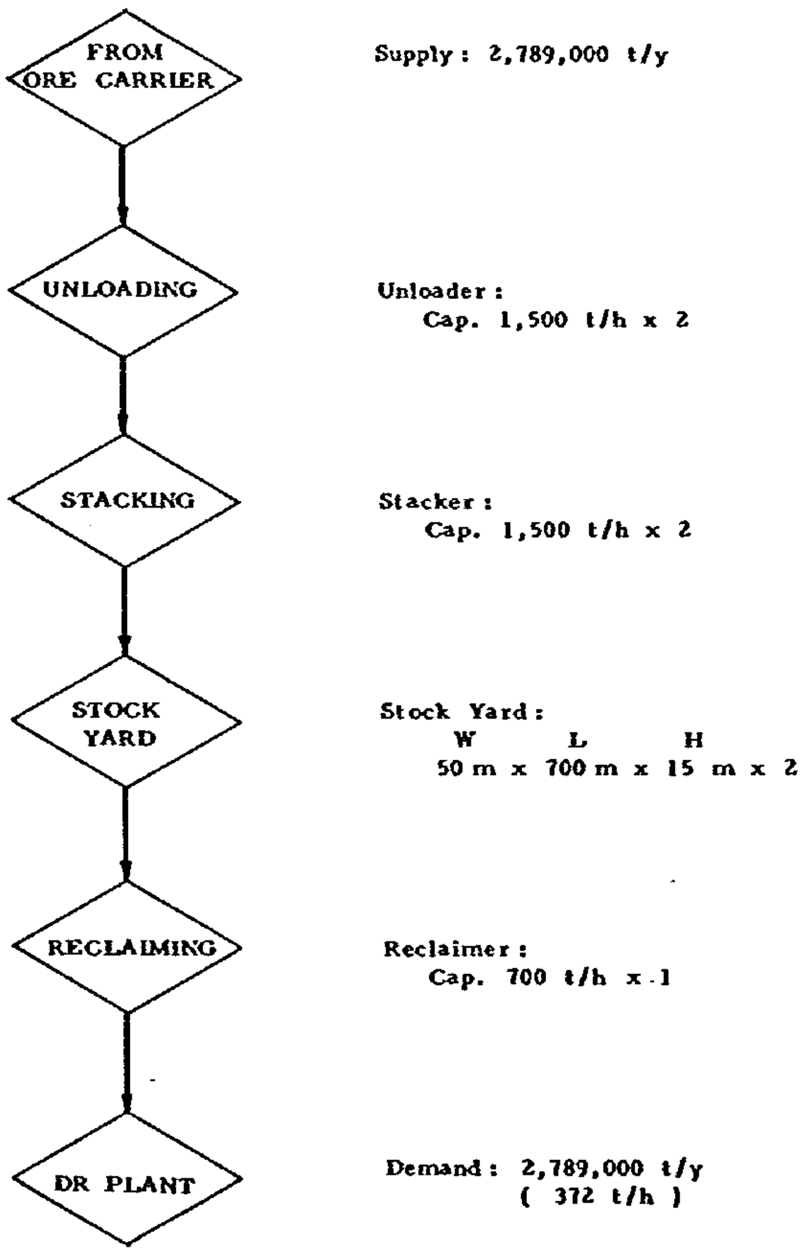


Fig. 15.1.2 Flowchart of Raw Material Handling (2nd Stage)

The major raw material equipment and facilities are given in Table 15.1.2. And, Figs. 15.1.3 and 4 show simplified sketches of the unloader, the stacker, the reclaimer and stock yards.

Table 15.1.1 Capacity Calculation of Berth

Items	1st Stage			2nd Stage		
	Iron Ores		Scrap	Iron Ores		Scrap
	From Austr. and India	From Brazil and Sweden		From Austr. and India	From Brazil and Sweden	
Applicable Vessels (DWT)	50,000 ~ 100,000 (80,000)	150,000	25,000	50,000 ~ 100,000 (80,000)	150,000	25,000
Quantity to Be Unloaded (t/y)	765,000 (11 vessels/y)	1,000,000 (7 vessels/y)	139,000 (7 vessels/y)	989,000 (13 vessels/y)	1,800,000 (13 vessels/y)	208,000 (10 vessels/y)
Rate of Unloading (t/d)	25,000	25,000	2,500	50,000	50,000	2,500
Days Required per Vessels* (d/v)	3.5	6.3	8.7	2.0	3.4	8.7
Yearly (Monthly Max.) Rate of Operation (%)	10.5(11.7)	12.1(21.0)	16.7(29.0)	7.1(13.3)	12.1(22.7)	23.8(33.3)
	22.6(32.7)			19.2(36.0)		
	39.3(61.7)			43.0(69.3)**		

Notes: * Including 0.5 day for other miscellaneous working than days actually required for unloading.

** If rate of operation exceeds 70%, congestion will occur.

Table 15.1.2 List of Raw Material Receiving and Handling Equipment and Facilities

Item	1st stage	2nd stage	Total
1,500 t/h Unloader	1 Unit	1 Unit	2 Units
1,500 t/h Stacker	1 Unit	1 Unit	2 Units
700 t/h Reclaimer	1 Unit	–	1 Unit
35 t Crane	2 Units	–	2 Units
Ore stockyard 150 m x 700 m	1 Unit	1 Unit	2 Units
Scrap yard and slag disposal area	1 Unit	–	1 Unit
Sub-materials receiving and handling facilities	1 Set	–	1 Set
Warehouse for sub-materials	1 Bldg.	–	1 Bldg.

(2) Sub-material Receiving and Handling Facilities

Burnt lime and fluorite are to be loaded on to railway trucks (loading capacity of 20 tonnes) at mine sites, and transported by State Railway of Thailand to sub-material receiving facilities at the project. The railway trucks are of the bottom discharging type. Sub-materials of three trucks can be discharged simultaneously there. Discharged sub-materials are to be stored in six bins, each having a capacity of 30 tonnes. From the bins, the sub-materials are discharged as required through bottom chutes, and sent out to following processes. Burnt lime is directly sent through surge bins to the steelmaking shop by belt conveyor, and fluorite is stored in a surge bin, from which it is transported to the steelmaking shop by lorries as required. Fig. 15.1.5 shows layout of sub-material receiving and handling facilities.

(3) Stockyard and Warehouse

Stockyards have been designed for approx. three months' supply of imported iron ores, scrap, ferromanganese, etc. and a warehouse is installed to be enough for approx. three months' supply of sub-materials such as ferrosilicon, aluminium, and carburizing material.

(4) Organization and Personnel

Organization and personnel for the raw material receiving and handling is shown in Table 15.1.3.

Table 15.1.3 Personnel for Raw Material Receiving and Handling

Manager	Group	Assist. manager	Engineer	Clerk	Foreman	Skilled worker	Semi-skilled worker	Unskilled worker
	Unloader					6 (12)	–	3 (6)
	Stacker					6 (12)	–	3 (6)
	Reclaimer and crane	1 (1)	2 (2)	1 (1)	3 (3)	4 (4)	–	4 (4)
						6 (6)	–	6 (6)
1 (1)	Panel Control					3 (3)	3 (3)	–
	Sub-material handling					2 (2)	6 (6)	6 (6)
	Scrap trimming	1 (1)	1 (2)		2 (2)	2 (2)	4 (6)	4 (6)
	Warehouse			1 (2)		–	–	–
1 (1)		2 (2)	3 (4)	2 (3)	5 (5)	29 (41)	13 (15)	26 (34)
			Total		81 (105)			

Note: Figures in ( ) show the number of personnel at the 2nd stage.

(Assist. manager for Reclaimer and crane covers Unloader through Panel Control; Assist. manager for Scrap trimming covers Sub-material handling through Warehouse.)

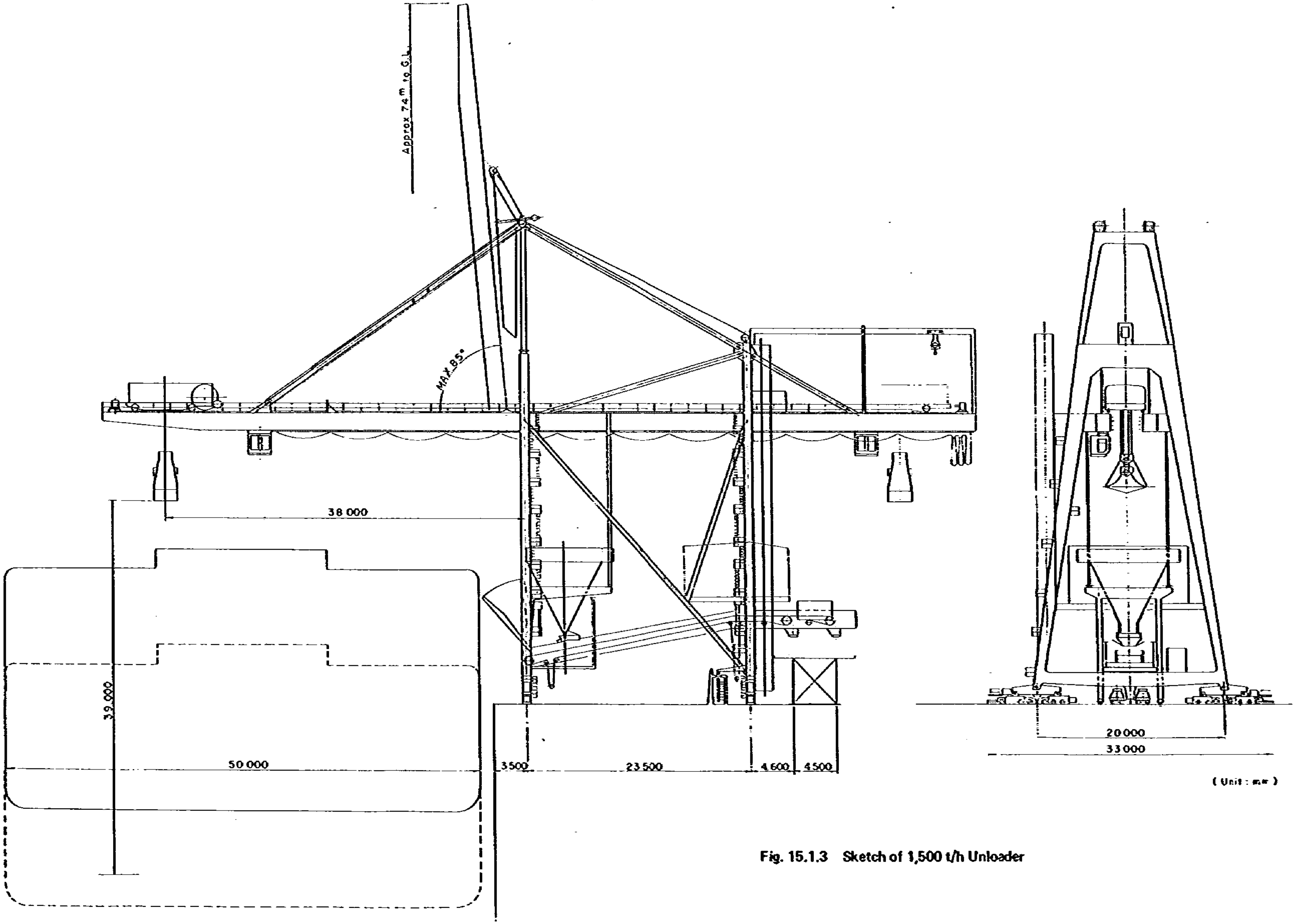


Fig. 15.1.3 Sketch of 1,500 t/h Unloader

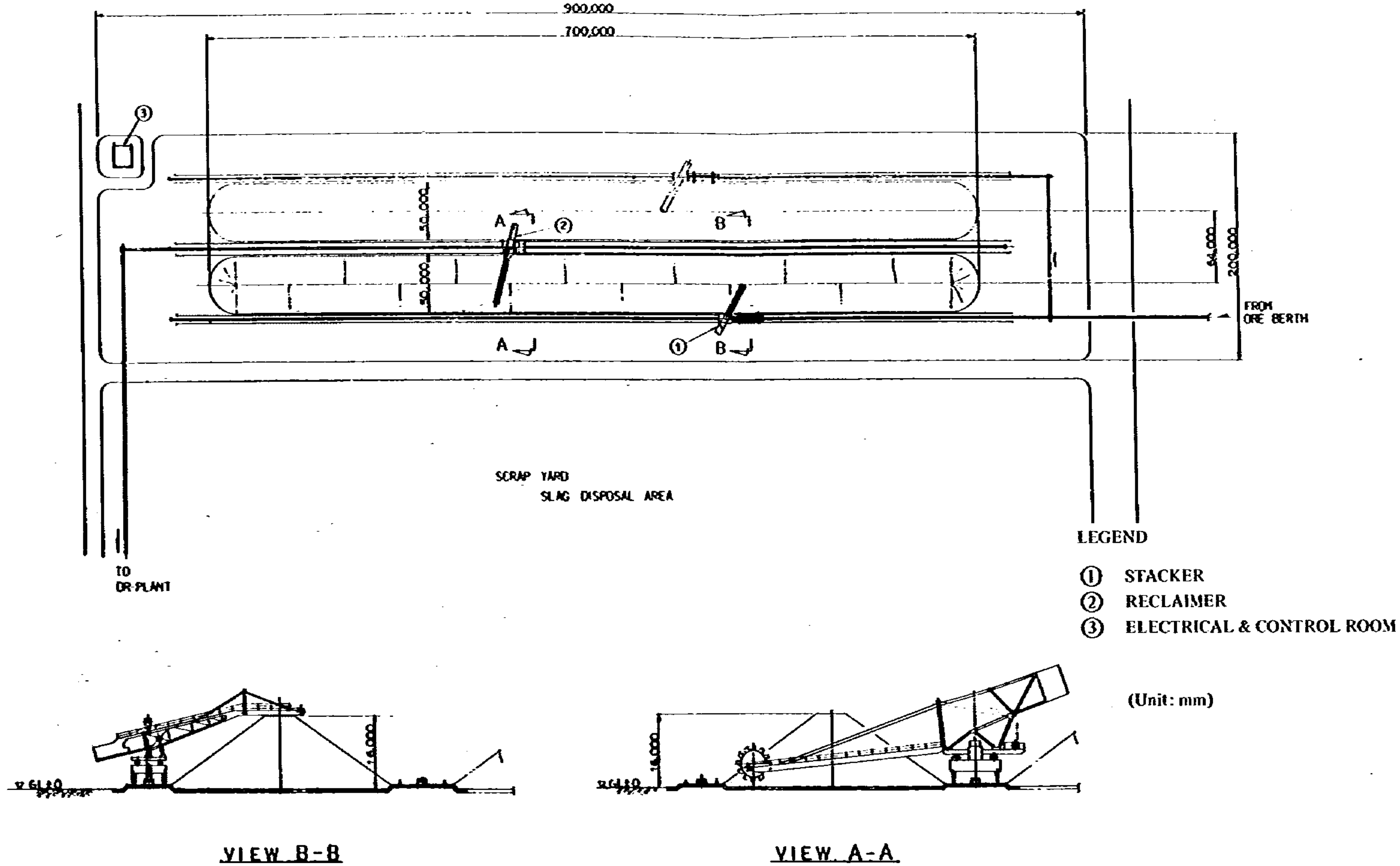


Fig. 15.1.4 Layout of Raw Material Receiving and Handling Facilities

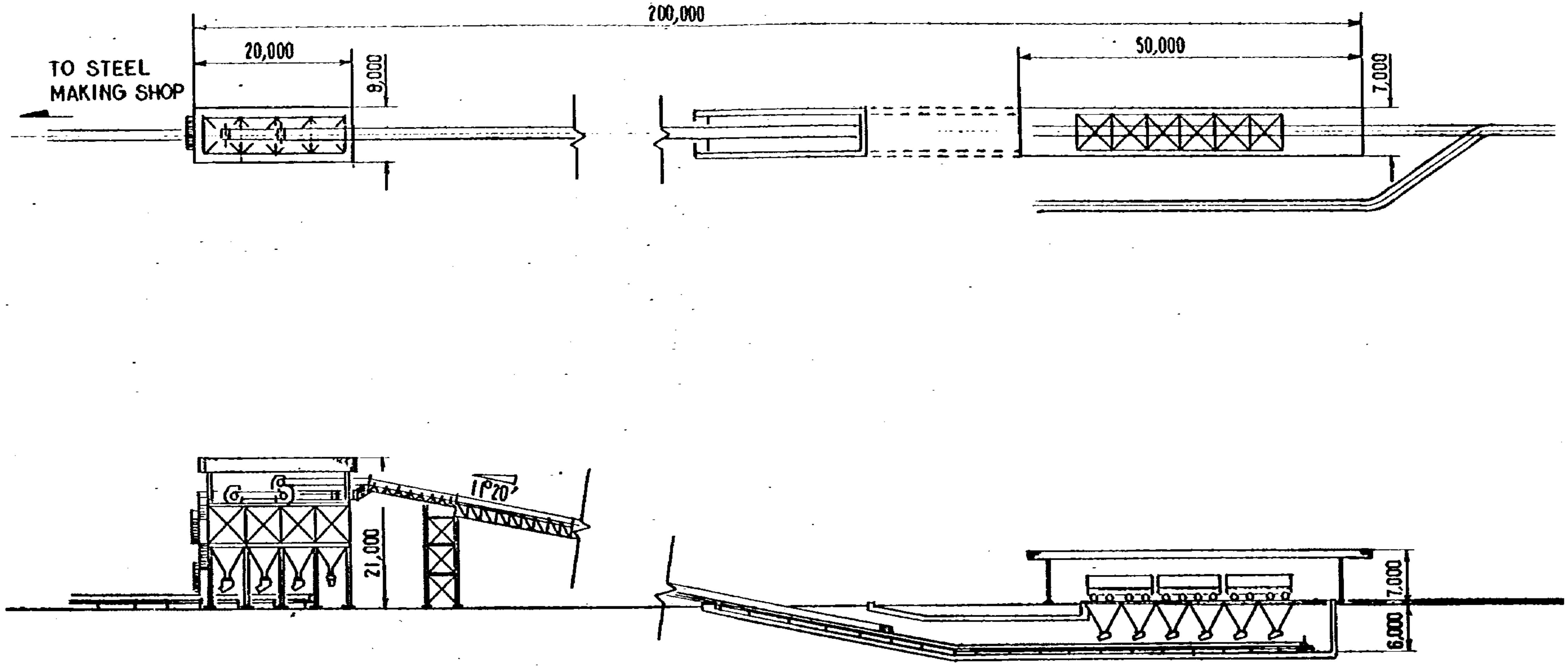


Fig. 15.1.5 Layout of Sub-material Receiving and Handling Facilities

CHAPTER 15-2

DIRECT REDUCTION PLANT

15.2 Direct Reduction Plant

(1) Selection of Process

At present, four types of direct reduction furnaces are in industrial use; the rotary kiln, the shaft furnace, the fluidized bed furnace, and the static bed furnace. In these furnaces, either solid or gaseous reducing agents are used. Most rotary kilns use solid reducing agents but other types of direct reduction furnaces usually use gaseous reducing agents. Solid reducing agents are mainly coal and coke, while gaseous reducing agents are mostly H_2 and CO, mainly obtained from natural gas by reaction with steam or CO_2.

The direct reduction (DR) processes to be examined here are limited to those which can utilize the natural gas obtainable from the off-shore gas field in the Gulf of Thailand, and are further limited to those gas reduction processes based on the use of shaft furnace and static bed furnaces. Fluidized bed furnaces have been used to only a very limited extent as industrial plants, and there is no prospect of future technological development. For this reason, the fluidized bed furnace process has been excluded from the present study.

i. Shaft furnace process

In the shaft furnace process, the iron oxide is fed into the furnace from the top, and progressively descends. Hot reducing gas is introduced into the furnace from the bottom. It rises through the burden, preheats the charge, and supplies the heat necessary for reduction. Of the many shaft furnace processes, the Midrex process, the Armco process, the Purofer process, and the Nippon Steel Corporation (NSC) process will be described here.

a. Midrex process

This process was initially developed by a division of Midland Ross

Corporation in 1965. After extensive industrialization tests, two plants were built at Portland, Oregon. Each plant had a yearly production capacity of 200,000 tonnes. This process is now the property of Midrex Corporation of the U.S.A. The commissioning years and production capacities of all Midrex process plants in operation as of 1978 are as follows:

U.S.A.	Gilmore	1969	2 x 200,000 t/y
U.S.A.	Georgetown	1971	400,000
W. Germany	Hamburg	1972	400,000
Canada	Sidbec I	1973	400,000
Argentina	Dalmine	1976	330,000
Venezuela	Sidor	1977	360,000
Canada	Sidbec II	1977	600,000
Qatar	QASCO	1978	400,000
Argentina	Acindar	1978	400,000

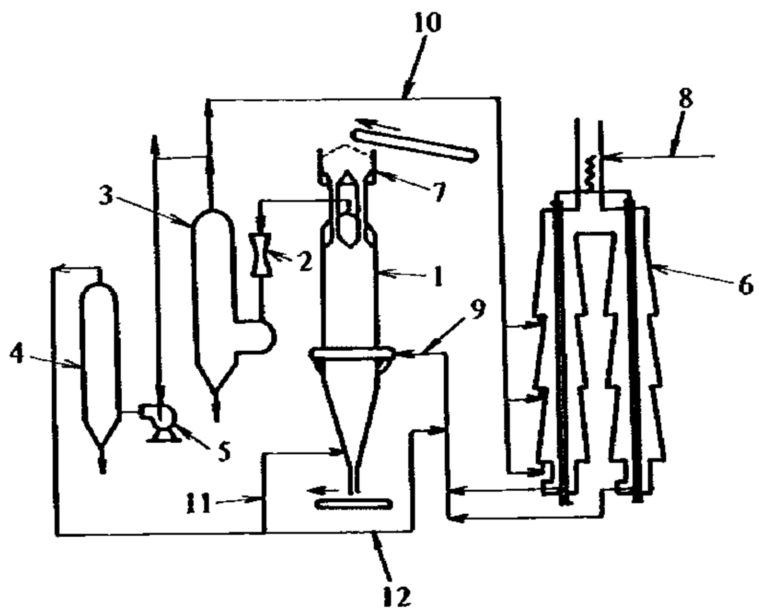
The features of this process are that the top gas of the reduction furnace is used as the reforming agent for natural gas, that the reduction and cooling processes take place in a single shaft furnace, and that part of top gas from the reduction zone is used as the cooling agent. Fig. 15.2.7 shows a simplified flowsheet of this process.

The top gas discharged from the shaft furnace is cooled and cleaned of dust in a venturi scrubber, pressurized, and mixed with fresh natural gas. The resulting mixture is preheated by the exhaust heat of the gas reformer, and then, sent to the gas reformer where it reacts to become reducing gas. The reducing gas thus obtained is at 950 – 1000°C. Part of this gas passes through the cooler, which regulates the temperature of the gas blown into the furnace through the tuyere. The reducing gas, after entering through the tuyere, rises through the charge in the shaft furnace and reduces the charge. It escapes at the top of the furnace. The shaft furnace is basically cylindrical at the reduction zone and conical at the cooling zone. Iron oxide is charged through a charging device known as an "octopus". As the charge descends through the furnace, it passes through the reduction zone, and then through the cooling zone at the lower part of the furnace. Cooling gas is introduced into the cooling zone through a distributor. Here, it cools the reduced material, and is discharged through off-take ducts. This gas is cooled and cleaned of dust, then recirculated. The cooling zone is provided with a burden feeder and the discharge rate of reduced iron is controlled by means of "wiper bar". Both the charging and discharging devices are sealed with seal gas to prevent the leakage of reducing gas.

b. Armco process

This process has been developed by Armco Steel since 1962, and the first commercial plant with a yearly production capacity of 330,000 tonnes was completed at Houston Texas in 1972. However no plant has been built on the basis of this process since then.

This process features a special method of utilizing discharge gas. Of the discharge gas of the reduction furnace, 60% is used as a heat source in the gas reformer, and the remainder is used to cool the reduced iron and to adjust the temperature of the reducing-gas blown into the tuyere. Figure 15.2.1 shows a simplified flow sheet of this process. In the gas reformer, special catalysts are used to keep the steam content of the obtained reducing gas at a sufficiently low level for direct introduction into the shaft furnace. The shaft furnace charge is introduced into the furnace from the top through charging pipes. Furnace top gas getting mixed with the charge in the charging pipes is extracted by a steam ejector, and is sent into the top gas lowering piping. Below the tuyere is a conical cooling section, the bottom of which is connected to the discharge pipe. This discharge pipe is also provided with a steam ejector similar to the one for the charging pipes. The discharge rate of reduced iron is controlled by the discharge conveyor.



1) Shaft furnace
2) Venturi scrubber
3) Top gas cooler
4) Compressed gas cooler
5) Top gas compressor
6) Reformer
7) Hopper
8) Steam + Natural gas
9) Reforming gas
10) Top gas
11) Cooling gas
12) Temp. control gas

Fig. 15.2.1 Flow Sheet of Armco Process

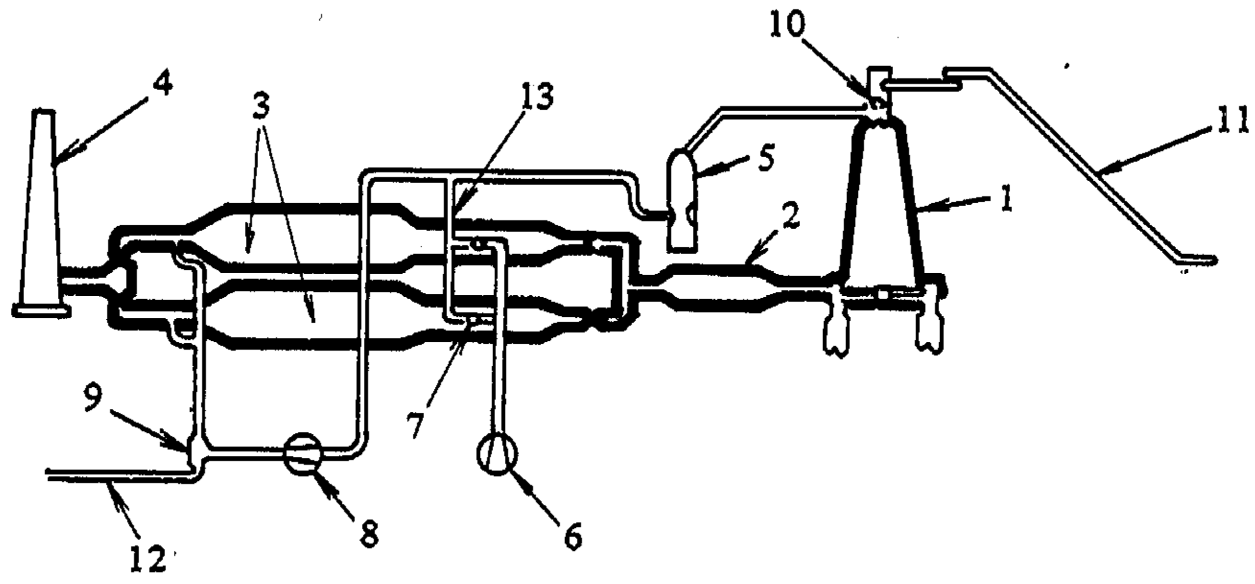
c. Purofer process

This process has been developed by Hüttenwerk Oberhausen AG since 1961. A pilot plant with a yearly production capacity of 150,000 tonnes was completed in 1970 for further experiments. At present, one 350,000 t/y plant (using fuel oil) is in operation at Cosigua, Brazil, and one 330,000 t/y plant (using natural gas) is in operation at Nisic, Iran.

The characteristic features of this process using natural gas are as follows. The charge is reduced and cooled in completely separate systems, and the reduced iron is discharged at high temperature. The hot reducing gas is produced alternately in two gas reformers.

Figure 15.2.2 shows a simplified flow sheet of this process. The top gas flowing out of the shaft furnace is cooled and cleaned of dust in a venturi scrubber. It is then sent to the first reformer, where it is burnt with air to heat the reformer. The burnt exhaust gas is discharged through a stack. When the first gas reformer has been sufficiently heated, the gas flow is switched to the second gas reformer, and the mixture of natural gas and air or top gas is passed through the first reformer. Here, partial oxidation or contact catalytic reaction produces reducing gas.

The charge enters the shaft furnace through a bell type charging device. On the bottom plate of the shaft furnace, there are two discharge ploughs. The ploughs are moved horizontally, alternately rightward and leftward, by hydraulic force. These discharge reduced iron at approx. 800°C. The hot iron is either sent directly to the steelmaking shop, or hot-briquetted and cooled for sales.



1) Shaft furnace
2) Temp. control chamber
3) Reformer
4) Stack
5) Scrubber
6) Combustion air blower
7) Burner
8) Top gas circulating blower
9) Gas mixing chamber
10) Double lock
11) Conveyor
12) Natural gas
13) Top fuel gas

Fig. 15.2.2 Flow Sheet of Purofer Process

d. NSC process

This process has been developed by Nippon Steel Corporation since 1969, and a model plant with a production capacity of 150,000 t/y was completed in 1976 at the Hirohata Works for further reginement.

The main features of this process are as follows;

– the gas pressure in the reduction furnace is higher than other processes, and therefore the furnace volume is smaller comparatively,
– top gas is recycled, but does not pass through the reformer tubes, and,
– kerosene and coal can be used as materials for reducing gas, as well as natural gas.

Figure 15.2.3 shows a simplified flow sheet of this process applied to natural gas.

In view of the high gas pressure in the shaft furnace, a double valve sealing system is employed for the top charging system of the shaft furnace. The charged material is supported by a table at the lower reduction zone. At the bottom of the shaft furnace, a swing type scraper discharges the reduced iton into a cooling vessel at a uniform descending speed. This cooling vessel is separate from the furnace, and the contents are cooled by either reducing gas or inert gas. The reducing gas is obtained from natural gas by reaction with steam. The top gas is cooled by heat exchanger and dust is removed. Part of the top gas is reheated after CO_2 and H_2O have been removed from it. The heated top gas is mixed with reducing gas which has been reformed with steam, and is injected into the shaft furnace.

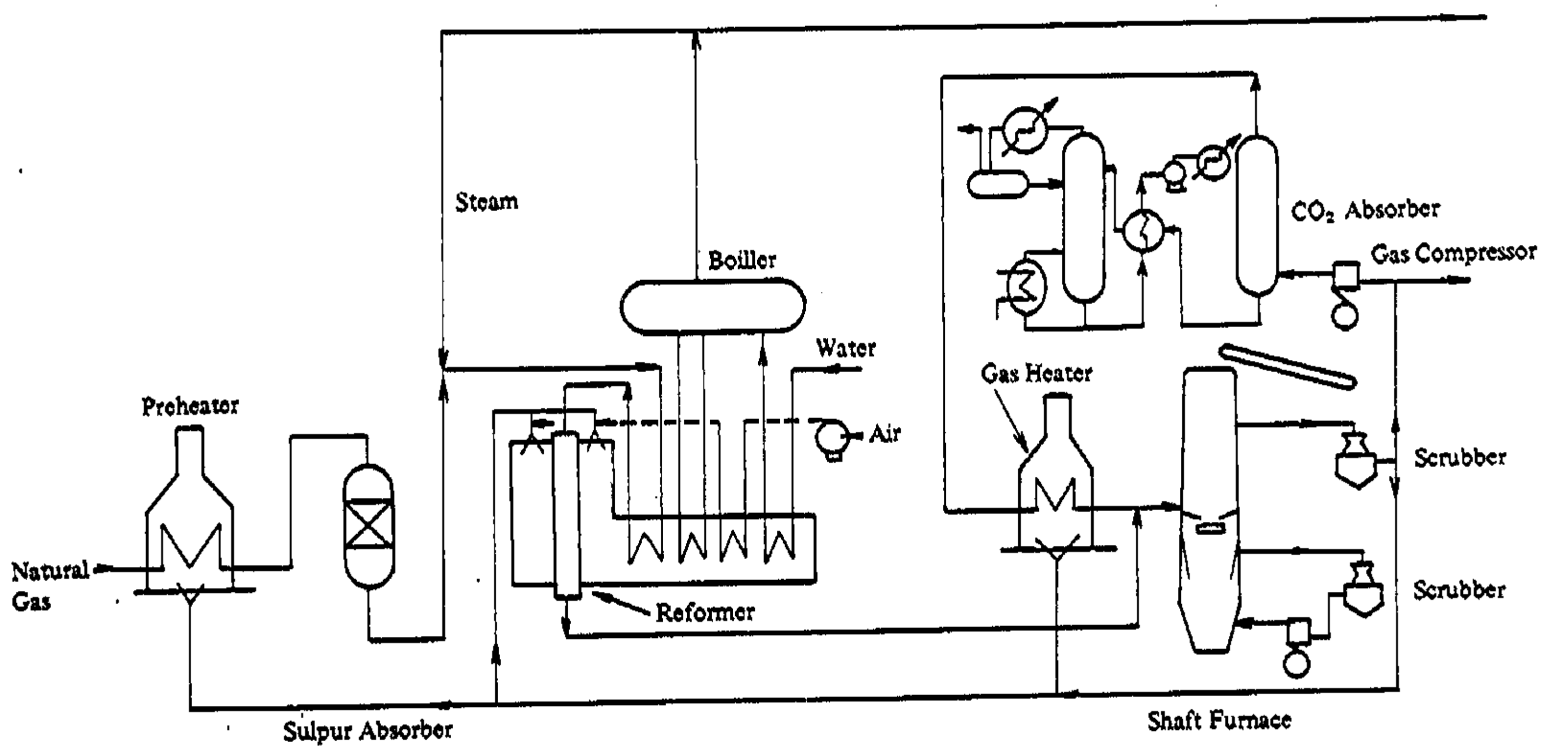


Fig. 15.2.3 Flow Sheet of NSC Process

ii. Static bed furnace process

In static bed furnaces, the charge remains stationary during the reducing process, and charges are processed in batches. As reducing gas flows through the charge, its H_2O and CO_2 contents progressively increase, its reducing capacity progressively decreases, and the matallization rate differs with the height of the furnace. These are inherent shortcomings of all static bed furnaces.

a. HyL process

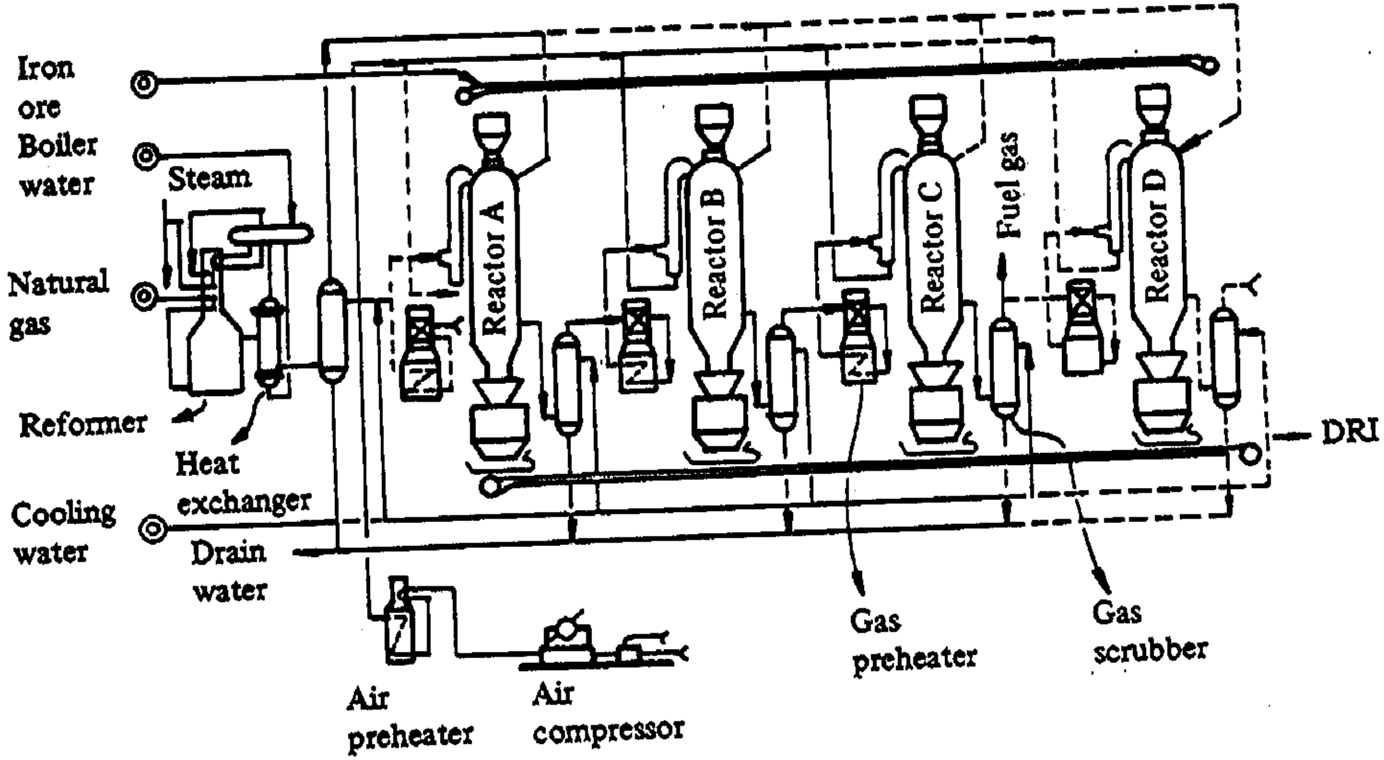
This process was developed by Hojalata y Lamina S.A. in the 1950's. The first plant based on this process was a 95,000 t/y plant built in 1957 at Monterrey, Mexico. At present, the licensing rights of this process are held by Pullman Inc., U.S.A. As of 1978, the following plants based on this process have been in operation:

Mexico	Hylsa	1957	95,000 t/y
Mexico	Hylsa	1960	270,000
Mexico	Tamsa	1967	235,000
Mexico	Hylsa	1969	315,000
Brazil	Usiba	1974	300,000
Mexico	Hylsa	1974	420,000
Venezuela	Sidor	1976	420,000
Mexico	Hylsa	1977	700,000
Indonesia	Krakatau	1978	500,000

A plant based on this process always includes one gas reformer and four reactors. Natural gas is reformed with steam to form reducing gas, which is then cooled at high speeds in a cooler to remove excess water content. This reducing gas is first sent to a "cooling" reactor. Here, it flows through the hot charge, which has been reduced in a "final reduction" reactor to a high metallization state. Thus, the reduced iron in the hot charge is cooled and the gas heated. Then, the heated reducing gas is passed through a preheater, further a heater, and is sent to the "final reduction" reactor. After reducing the charge in this reactor, the gas has its water content lowered in a cooler. Then, it is sent through the preheater and the heater, sent through the "primary reduction" reactor, and then discharged. This discharge gas is used as fuel. The above operation cycle is repeated. In each reactor, charge flow from charging to discharging, takes approximately 12 hours. Steps include discharging and charging, cooling, final reduction, and primary reduction, each lasting for 3 hours. Figure 15.2.4 shows a simplified flow sheet of this process.

iii. Comparison of various processes

Table 15.2.1 compares the processes described. As can be seen from this table, these processes have advantages and disadvantages respectively, as well as problems to be solved. This study adopts the Midrex process, which has the largest number of plants in operation and accounts for the largest total iron production, as the basis for technical and economic study, but no decision has been made as to the process to be finally adopted in this project. For eventual submission of tenders for this project, all these factors should be fully taken into consideration when selecting the most advantageous process.



Reactor –A: Cooling process
–B: Reduction process
–C: Reduction process
–D: Discharge/charge process

Fig. 15.2.4 Flow Sheet of HyL Process

Table 15.2.1 Comparison of Selected Processes Using Natural Gas

	Process	Midrex	Armco	Purofer	NSC	HyL
Characteristics of process	Features	The top gas recirculated as the oxidizing agent in the gas reformer. The cooling gas for the lower part of the shaft furnace independently recirculated.	Part of the top gas used as cooling gas in the DR furnace. This gas mixed with the reducing gas produced by steam reforming in the lower part of the reduction zone.	Partially oxidized gas and a part of the top gas mixed to form reducing gas.	Furnace pressure higher than other shaft furnaces. Top gas recirculated which removed CO_2 gas.	The four, static-bed furnaces switched over, in rotation, to repeat the four processes of pre-reudction, final reduction, cooling and discharge-charging.
	Advantages	Low overall energy consumption. Very stable product quality. Low water consumption.	The process simple.	Permissible limits for sulphur in the ore and natural gas not severe.	High productivity, high-stability of operation and quality, due to high pressure furnace. Permissible limit for sulphur in ore not severe.	Operation procedure simple.
	Disadvantages	The permissible limit of sulphur in the material comparatively strict. The product has high reoxidizing tendency.	Low metallization. High re-oxidation tendency of the product. High tendency of uneven temperature distribution in the DR furnace.	Reducing gas composition fluctuates. Maintenance complicated. The discharge mechanism inherently prone to adhesion of fused materials.	Maintenance should be taken notice due to high pressure operation.	Total energy consumption high. Product quality fluctuates.
Reduction furnace	Type Tuyere temperature Tuyere pressure	Shaft type 760 – 900°C 0.7 – 1.3 kg/cm g	Shaft type 760 – 800°C 1.4 kg/cm g	Shaft type 900 – 1,000°C 2.5 kg/cm g	Shaft type 850°C 3.2 – 3.8 kg/cm g	Report type static bed furnace 1,000 – 1,200°C 2.4 – 6.0 kg/cm g
Reformer	Type Process Reforming temperature	Tube box type Reforming with top gas (CO_2 and H_2O) 960°C	Tube box type Steam reforming 870°C	Hot stove type Regenerating with top gas 840 – 1,400°C	Tube box type Steam reforming 880°C	Tube box type Steam reforming 840°C
Unit consumption	Natural gas Power Water	2.8 Gcal/t-DRI 120 – 140 kWh/t-DRI 0.1 – 1.5 m^3/t-DRI	3.2 Gcal/t-DRI 40 kWh/t-DRI 1.8 m /t-DRI	3.3 Gcal/t-DRI 100 kWh/t-DRI 2.5 m /t-DRI	2.9 Gcal/t-DRI 120 kWh/t-DRI 1.5 – 2.5 m /t-DRI	4.2 Gcal/t-DRI 6 kWh/t-DRI 2.5 m /t-DRI
Product quality	Metallization Reoxidization tendency	92 – 95% Yes	90% Yes	95% Almost absent	93 – 95% Not much	85 – 90% Not much

(2) Conditions for Equipment Plan

i. Basic concept

The proposed DR plant will receive oxide pellets and iron ore lump from the raw material stock yard and produce DRI at the following rates for supply to the steelmaking shop for the subsequent process:

1st stage : 1,211,000 tonnes/year

2nd stage : 1,912,000 tonnes/year

For this DR plant, the following main facilities are planned.

	1st stage	2nd stage
DR facilities	2	3
Briquette facilities	1	2
H_2S removal facilities	1	2

ii. Site conditions of DR plant

The plant site is to be located immediately east of the raw material stock yard. It is to be 440 m from east perimeter to west perimeter and 400 m from north perimeter to south perimeter and surrounded by roads 30 to 100 m in width. Within the site, the steelmaking shop is to be built to the south of adjacent to the DR plant and the sub-material yard and the warehouse are to be to the west.

In addition to these main facilities, auxiliary facilities such as material stock bins, DRI stock bins, water treatment facilities, sludge pond, dust collector, central control room, electric room, site office, and the personnel quarters are to be built.

The site is to be sufficiently large to accommodate not only the facilities to be erected in the 2nd stage, but also extra DR plant which will eventually be built to supply DRI to steel bar and rod mills and outside electric arc furnace steel manufacturers. (This means that with all these facilities completed, the total DRI production capacity will be approx. 2.4 million tonnes per year.)

iii. Production plan

Basically, the production plan of the proposed plant is as shown in Table 15.2.2. During the first year, iron production will be approx. 65% of full capacity, and during the second year, this will be increased to 95% as shown in Fig. 6.6.1. To initiate the personnel to the operation, only pellets will be used as raw material during the first year. Approx. 20% lump ore will be mixed from the second year.

Table 15.2.2 Basic Design Data of DR Plant (1st Stage)

DRI production	1,211,000 t/y
Average production rate	3,876 t/d
Operation	24 hours, 3 shifts
Plant availability	7,500 h/y, 312.5 d/y
Total Fe of DRI	91.0 %
Metallization, nominal	93 %
Carbon content, nominal	1.5 %
Iron oxide feed from ore yard	1,765,000 t/y
	5,648 t/d
Iron oxide screen undersize (–3 mm)	89,000 t/y
Iron oxide fine dust	7,000 t/y
Iron oxide to DR furnace	1,669,000 t/y

iv. Material flow

The proposed plant layout is shown in Fig. 15.2.5. The pellets and lump ore received from the raw material stockyard will be temporatily stored in ore storage bins (day bins) classified by material types. Each of the bins will be sufficient to hold 1,000 tonnes of material. The total of six bins roughly corresponds to one day's consumption. From the bins, ore will be discharged in predetermined quantity, screened to remove fines (–3 mm), and lifted to the furnace top. The screened fines can be marketed as material additives for cement manufacturing industries.

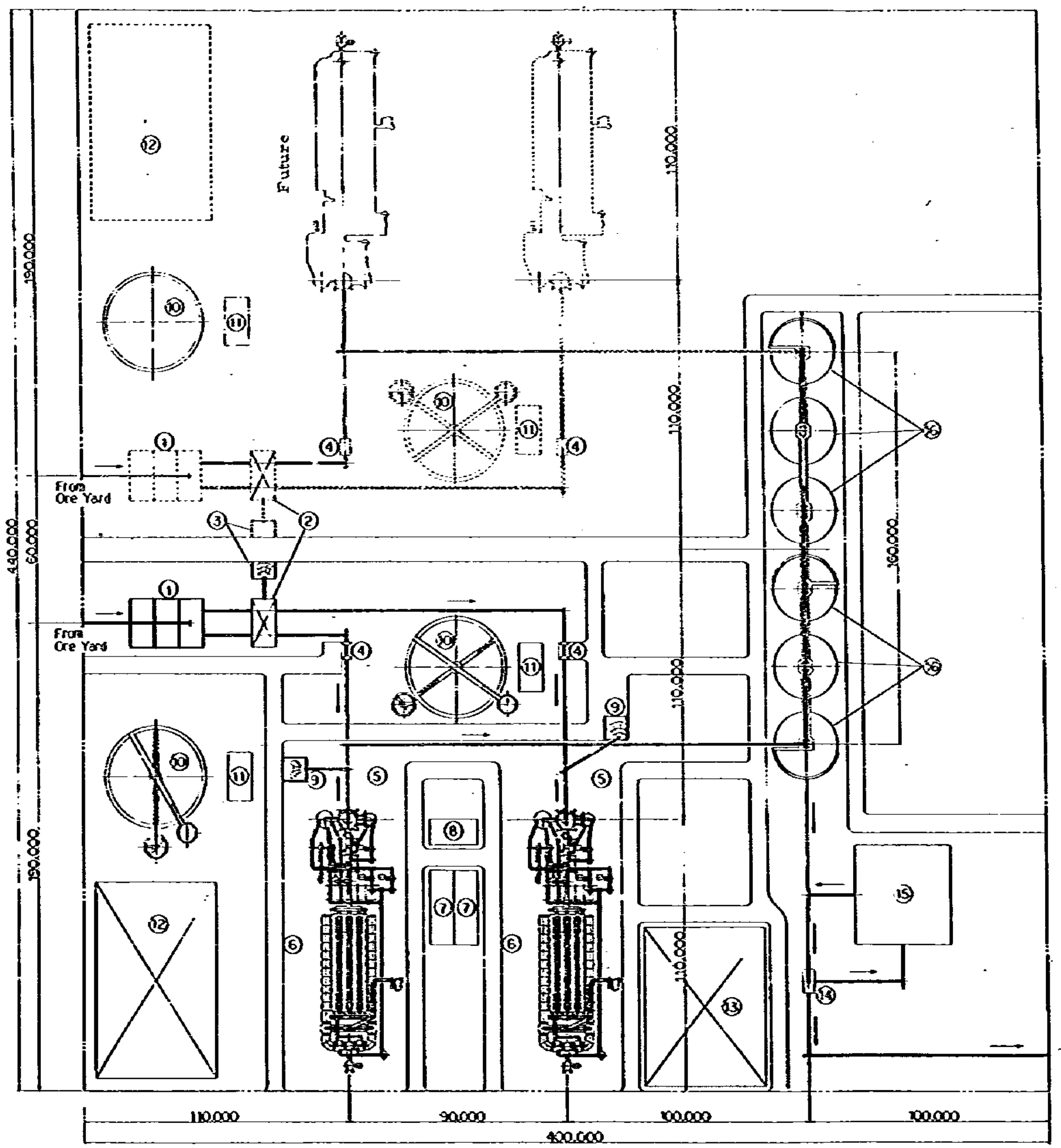
The DRI discharged from the DR furnace will pass to the product storage bins, for storage with inert gas atmosphere. Each of these bins will be able to store 6,000 tonnes of DRI, the total of six bins corresponding to approx. 10 days of steelmaking material for use in the electric arc furnace.

From the storage bins, DRI will be taken out, and screened to remove fines. Fines will be processed into briquettes, and by means of conveyor, are sent to the steelmaking shop together with the DRI remaining on the screen.

Fig. 15.2.6 shows the material flow for the 1st stage.

(3) Outline of DR Process

The Midrex process reduces iron oxides in the form of pellets and lump to DRI suitable for steelmaking, at high reduction rates. The reduction process consists of the chemical removal of oxygen from the iron oxides by continuous flow of reducing gas. The reduced iron will be subsequently carburized in the same furnace.



LEGEND

1. Oxide Day-Bin
2. Oxide Screening Station
3. Oxide Fines Pile
4. Remet Hopper
5. Direct Reduction Furnace
6. Reformer
7. Electrical/Control Room
8. Site House
9. Remet Pile
10. Clarifier
11. Cooling Tower / Pump Station
12. Sludge Pond
13. H_2S Removal Facilities
14. Product Screen
15. Briquetting Facilities
16. Product Silo

———	1st Stage
- - - - -	2nd Stage
— - —	Future

Fig. 15.2.5 Layout of DR Plant

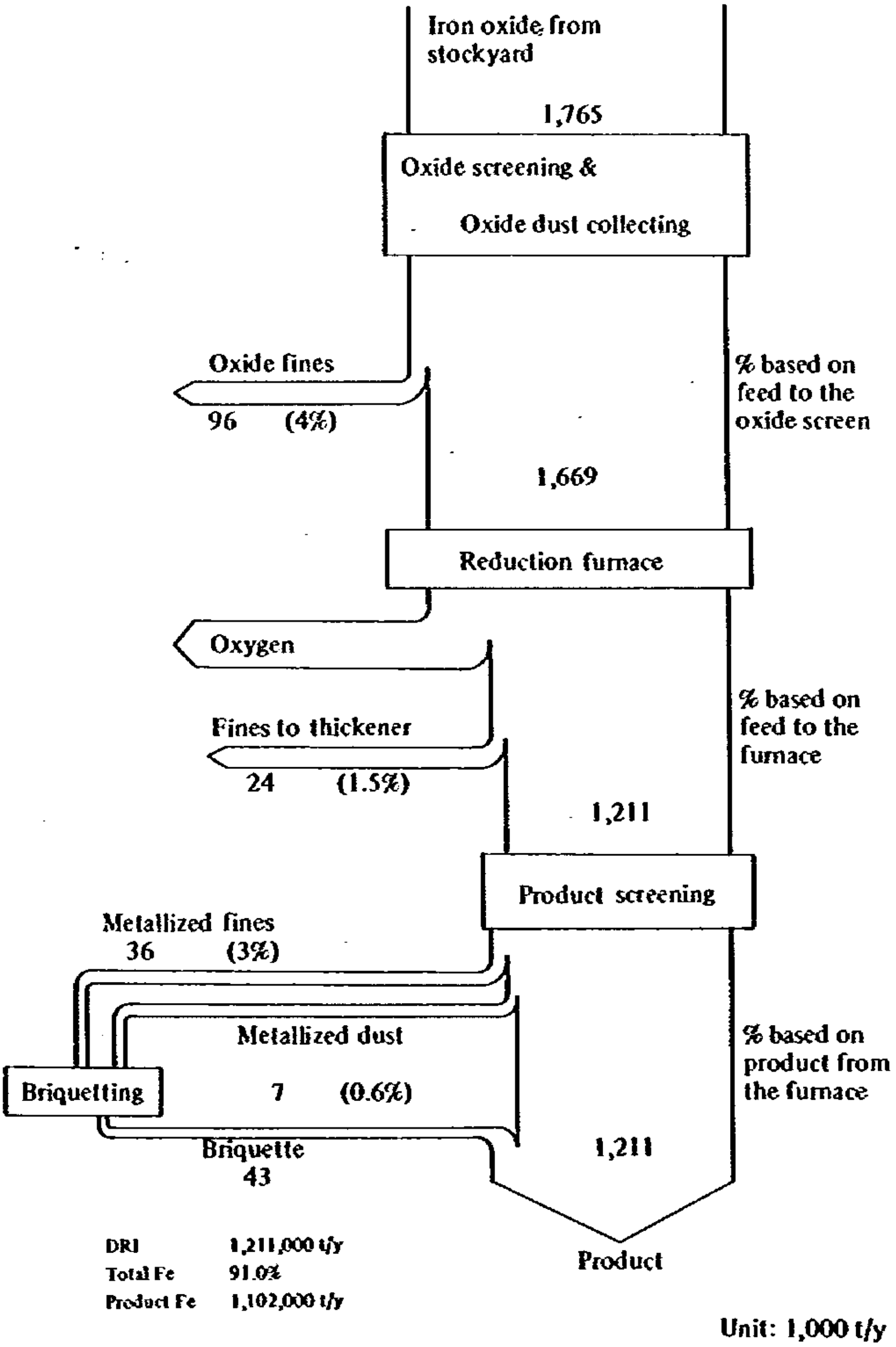


Fig. 15.2.6 Material Flow of DR Plant (1st Stage)

The reduction process takes place below the fusing point of the materials in the furnace. The reducing gas, consisting of hydrogen and carbon monoxide, is generated in a gas reformer, its composition and temperature being properly adjusted before it enters the DR furnace. The reducing gas rises through the furnace, and heats the descending iron oxides to the reducing temperature. Hydrogen and carbon monoxide in the gas remove oxygen from the iron oxides to yield products at high reduction rates. The main chemical reactions involved in the Midrex process are as follows:

a. Reduction $Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

b. Carburization $3Fe + 2CO \rightarrow Fe_3C + CO_2$

c. Reforming $CH_4 + H_2O \rightarrow CO + 3H_2$

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$

The top gas discharged from the DR furnace carries much powder dust. This gas is cleaned of the dust in a top gas scrubber, and cooled. The cooled gas is mostly used as process gas. For this it is compressed by compressors, mixed with natural gas, preheated in a preheater, and sent to the gas reformer. The remainder of the gas is used as a fuel to heat the gas reformer.

The reformed gas temperature is controlled by a direct-contact reformed gas cooler.

In the lower part of the DR furnace, cooling gas recirculates to cool the product before discharge. After bearing the cooling zone, the cooling gas is cleaned and cooled in a cooling zone scrubber, and then pressurized to be sent again to the cooling zone of the DR furnace.

Fig. 15.2.7 shows the flow sheet of the Midrex process.

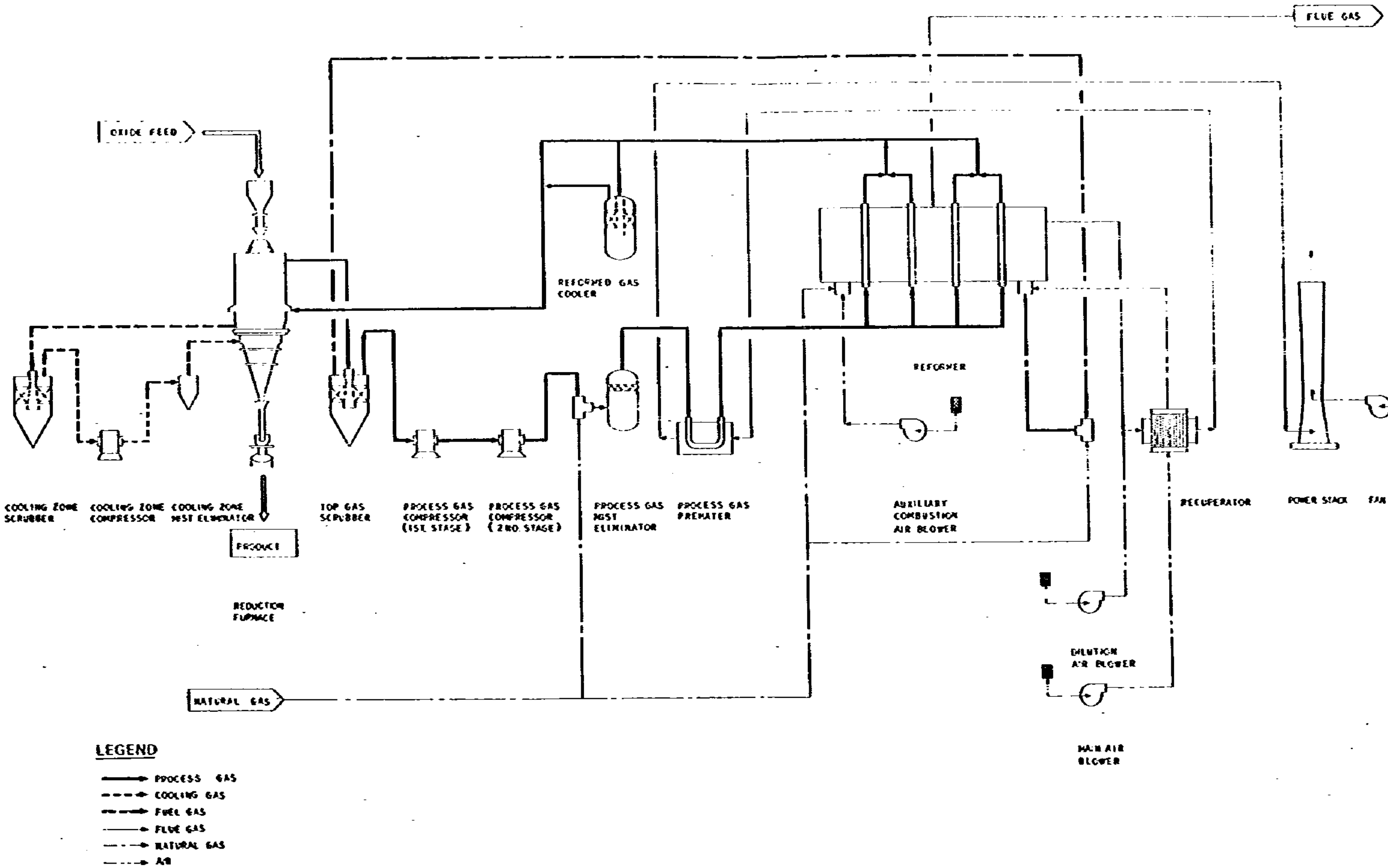


Fig. 15.2.7 Flow Sheet of Midrex Process

(4) Outline of Gas Desulphurization Process

The composition of the natural gas to be obtained from the gas wells in the Gulf of Thailand is shown in Table 8.1.1. However sulphur content is not clear. When reforming natural gas with steam and CO_2, sulphur content in the gas has an adverse effect on the catalyst in the tubes in the gas reformer, and reduces the reforming efficiency when the sulphur content is above several ppm. For this reason, the proposed plant will be provided with a desulphurization facility. The main considerations for this desulphurization facility are as follows:

It is assumed that the natural gas produced from the Gulf of Thailand contains approx. 1,000 ppm of sulphur in the form of hydrogen sulphide, and not in any other form such as organic sulphide.

The Stretford process is the most suitable process to reduce hydrogen sulphide to below 1 ppm. A combination of the amine process and the zinc oxide process is also possible, but high installation cost makes it unsuitable for this project. This study uses technical and economic data for the Stretford process.

Outline of Stretford process is as follows. Natural gas from the on-site gas pressure reducing facility is introduced into the bottom of the absorber tower. In the tower, the gas makes contact with Stretford solution and H_2S is removed to a level below 1 ppm. The natural gas treated in the absorber tower is then washed in a scrubber and Stretford solution removed. Its mist content is then removed in a mist separator. After all these treatments, the natural gas is sent to the DR plant.

Stretford solution with absorbed H_2S remains in reaction tanks for approx. 10 minutes, and during this time, the HS^- ion in Stretford solution completely changes into free sulphur by the catalytic action of vanadium.

Thereafter for the purpose of separation from Stretford solution, elememtal free sulphur contained in Stretford solution is concentrated as sulphur slurry by air floatation in oxidizer. Such sulphur slurry is transferred to slurry tank.

Stretford solution in oxidizer is regenerated by air, and is transferred to balance pit, thereafter is recycled to the top of absorber by pump.

The main reactions involved in the Stretford process are as follows:

$HS^- + 2V^{5+} + CO_3^{--} \rightarrow S + 2V^{4+} + HCO_3^-$

$2V^{4+} + Na_2ADA + 2HCO_3^- \rightarrow 2V^{5+} + Na_2ADA - H_2 + 2CO_3$

$Na_2ADA - H_2 + 1/2\ O_2 \rightarrow Na_2ADA + H_2O$

The sulphur slurry in the slurry tank is pumped to a filter press where it is compressed into sulphur cakes. The filtrate of the Stretford solution returns to the balance pit. Fig. 15.2.8 shows a simplified flow sheet of Stretford process.

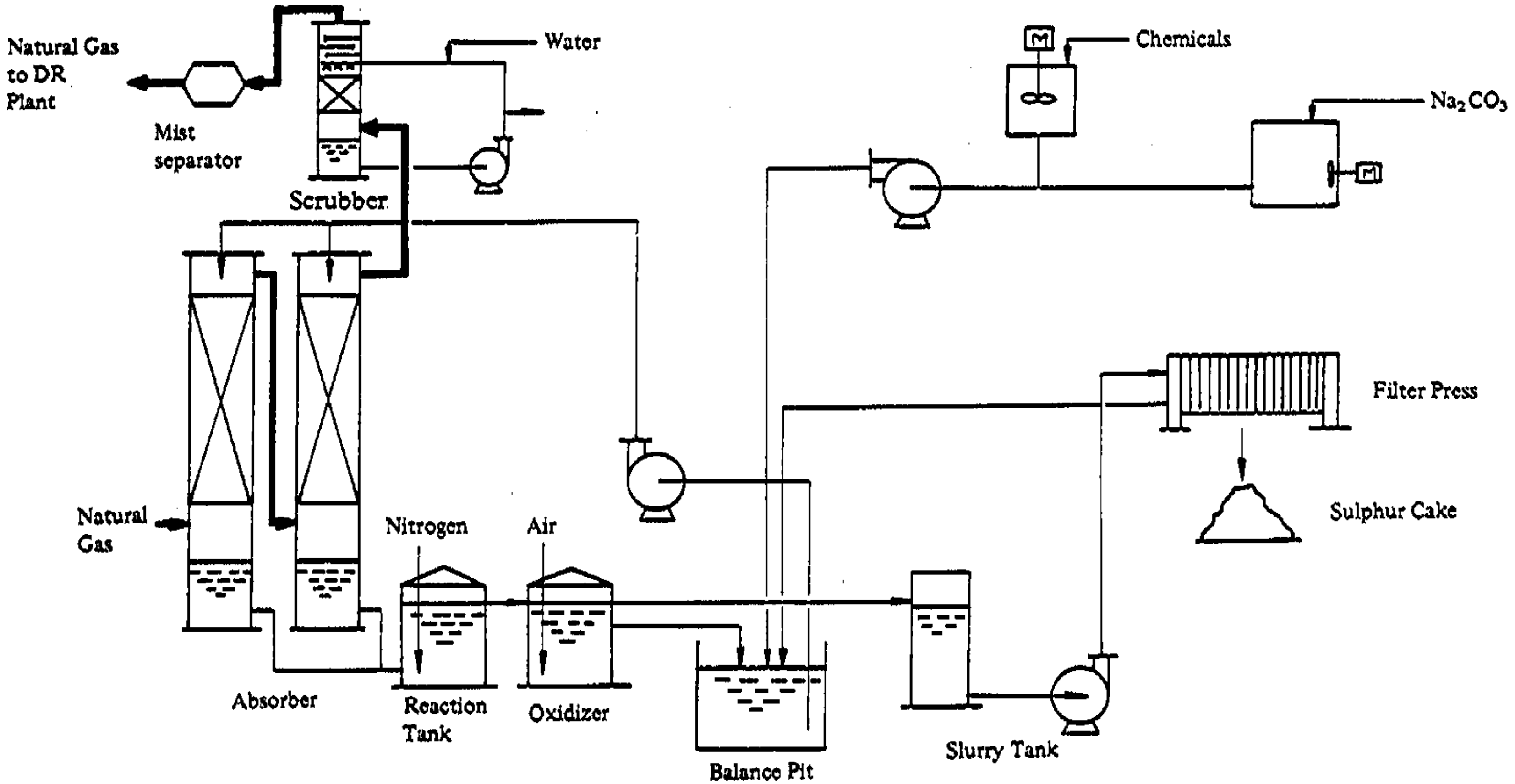


Fig. 15.2.8 Flow Sheet of Desulphurizing Process (Stretford Process)

(5) Unit Consumption

Table 15.2.3 shows the material quantities required to produce a tonne of DRI.

Table 15.2.3 Unit Consumption of DRI

	Item	Unit consumption
1	Iron oxide (pellets)	1.156 t
2	Iron oxide (lump)	0.301 t
3	Nautral gas (8,233 Kcal-Net/Nm^3)	340.13 Nm^3 (2.8 Gcal – Net)
4	Electric power	142.03 kWh
5	Industrial water (make-up)	1.5 m^3
6	Compressed nitrogen	0.25 Nm^3
7	Compressed air	9.0 Nm^3
8	Others (reagents for water treatment and desulphurization, etc.)	1.93 US$

(6) Main Equipment List

The main facilities for DR plant is given in Table 15.2.4.

(7) Organization and Personnel

i. Organization

The organization of DR plant is planned as follows:

DR plant
- Operation group
- Supplies group
- Office work group

Table 15.2.4 Main Equipment List

Equipment	Q'ty	Description
1 Direct reduction furnace	2 (3)	Shaft furnace (Nominal capacity 600,000 t/y each) equipped with charge hopper, slide gates, burden feeders and wiper bar
2 Reformer	2 (3)	200 mm dia. tubes with catalyst
3 Top gas scrubber	2 (3)	Venturi and packed tower type
4 Cooling zone scrubber	2 (3)	– ditto –
5 Reformed gas cooler	2 (3)	Packed tower type
6 Seal gas cooler	2 (3)	– ditto –
7 Preheater	4 (6)	Shell & tube type heat exchanger
8 Recuperator	4 (6)	Shell & tube type heat exchanger
9 Stack	2 (3)	Height: approx. 50 m
10 Process gas compressor	8 (12)	Positive displacement type Rotary lobe compressors
11 Cooling zone compressor	2 (3)	Positive displacement type Rotary lobe compressors
12 Main air blower	2 (3)	Centrifugal air blower
13 Auxiliary air blower	2 (3)	Centrifugal air blower
14 Dilution air blower	2 (3)	– ditto –
15 Seal gas compressor	4 (6)	Rotary lobe compressors

Note: Figures in ( ) are for the 2nd stage.

Table 15.2.4 (cont'd)

Equipment	Q'ty	Description
16 Mist eliminator	6 (9)	For process gas, cooling gas & seal gas each 2
17 Piping system	2 sets (3)	Including valves and fittings
18 Dust collection system	2 sets (3)	Composed of cyclones, venturi scrubbers, fans and dust storage bin
19 Briquetting system	1 set (2)	Capacity: 20 t/h
20 Water system	2 sets (3)	Composed of clarifier, cooling towers and pumps
21 Electrical and instrumentation system	2 sets (3)	Max. capacity: 33 MVA
22 Product storage bin	6 (6)	Capacity: 6,000 t equipped with feeders
23 Oxide day bin	6 (9)	Capacity: 1,000 t equipped with feeders
24 Material handling system	2 (3)	Composed of screens, belt scales and belt conveyors
25 H_2S removal facility	1 set (2)	Stretford process

ii. Personnel

Personnel requirements for the proposed plant are shown in Table 15.2.5. This plan is based on a 3-shift per day system.

Table 15.2.5 Personnel for DR Plant

Super-intendent	Group	Assist. super-intendent	Engineer	Clerk	Foreman	Skilled worker	Semi-skilled worker	Unskilled worker
1 (1)	Operation	1 (1)	6 (6)		3 (3)	6 (9)	18 (27)	27 (42)
	Supplies	1 (1)		1 (1)	1 (1)	–	4 (5)	4 (5)
	Office			1 (1)				
1 (1)		2 (2)	6 (6)	2 (2)	4 (4)	6 (9)	22 (32)	31 (47)
				Total	74 (103)			

Note: Figures in ( ) show the number at personnel of the 2nd stage.

CHAPTER 15-3

STEELMAKING SHOP

15.3 Steelmaking Shop

(1) General

i. Basic plans for the steelmaking shop:

The steelmaking shop receives the DRI as raw material from the preceding DR plant and produces in

1st stage ....1,295,000 tonnes per year

2nd stage.......2,044,000 tonnes per year

on molten steel base. The following equipment are planned as main facilities for supplying slab to the hot strip mill.

	Electric arc furnace	Continuous casting machine
1st stage	4 units	2 units
2nd stage	6 units	3 units

ii. Features of the steelmaking shop

In planning the construction of the steelmaking shop, an attention was paid to facilitate with the modern equipment so as to realize high productivity and economy along with stable operation.

a. Large type ultra high power (UHP) electric arc furnaces (EAF) are to be installed for high efficiency production.

b. A continuous casting process is to be employed to expect a fully continuous casting operation for higher quality of products and economy.

c. The whole steelmaking shop area is divided into 6 yards and arranged in a clearly defined layout so that obstacles for production operation which may be caused by the largeness of the shop with four large types of EAF (6 EAF in the 2nd stage) and two continuous casting machines (3 CCM in 2nd stage) can be avoided.

d. To rationalize the transportation of raw materials and products, DRI is transported to the shop by means of a belt conveyor system, and slab as semi-finished product are transported by a slab car directly to the hot strip mill. Both systems are operated automatically by remote control.

e. Special attention is paid on environmental protection and pollution control and sufficient equipment for the purpose is installed to make the shop ultra-modern.

f. For the purpose of future expansion of production beyond the 2nd Stage construction, EAF and CCM facilities are secured.

For the details of each facility and equipment, refer to the relevant section in this chapter.

iii. Location of the steelmaking shop

The steelmaking shop is located almost at the centre of the steel plant. The shop's area with about 700m in the east-west direction and about 500m in the north-south direction is surrounded by the road with 50 to 100m width. Across the road of the north-south direction, the DR plant is located on the north side, and the hot strip mill on the south side.

In the area of the steelmaking shop, there is a main building, to begin with, which has about 39,000m^2 (in the 2nd stage, it will be about 53,000m^2). Other facilities and buildings which are related to the steelmaking shop include scrap preparation yards, dust collectors, electricity rooms, water treatment system, brick warehouse, offices, workers' stations, etc.

In addition to the 2nd stage expansion as planned, the shop is well prepared with space for additional EAF and CCM, etc. for a further expansion purpose in the future.

iv. Basic production programme and main equipment of the steelmaking shop:

Basic production programme of the steelmaking shop is shown in Table 15.3.1.

Table 15.3.1 Production Programme of Steelmaking Shop

(Unit: tonnes)

		1st stage	2nd stage
Main raw materials	DRI	1,211,000	1,912,000
	(Fe. conversion)	(1,102,000)	(1,740,000)
	Scrap	276,000	435,000
Products	Molten steel	1,295,000	2,044,000
	As cast slab	1,230,000	1,942,000
	Surface conditioned slab	1,205,000	1,903,000

The main facilities are shown in Table 15.3.2.

Table 15.3.2 Main Facilities of Steelmaking Shop.

		1st stage	2nd stage
Melting, refining	UHP EAF	150 t/heat x 4 units	150 t/heat x 6 units
Casting	Slab CCM	2 strands x 2 units	2 strands x 3 units

v. Type of steel

Low carbon steel for hot strip and cold strip mills is planned to be produced.

(2) Material Flow in the Steelmaking Shop

The main material flow at the 1st stage of the steelmaking shop is shown Fig. 15.3.1.

(3) Organization and Personnel for the Steelmaking Shop

The organization is as follows:

Steelmaking Shop
- EAF Group
- CCM Group
- Crane Group
- Furnace repairing Group
- Office work Group

Personnel for the steelmaking shop are shown in Table 15.3.3.

The working system in the steelmaking shop is based on the three-crew/three-shift system. Details of working system are referred to in Table 9.1.4.

(4) Layout of the Steelmaking Shop

The layout plan of the entire steelmaking shop is shown in Fig. 15.3.2 and that of the facilities in Fig. 15.3.3.

Table 15.3.3 Personnel for Steelmaking Shop

Sup't	Group	Ass't. mgr.	Engi-neer	Clerk	Fore-man	Skilled worker	Semi-skilled	Un-skilled	Sub-total of group
	EAF	1 (1)	2 (2)	1 (1)	6 (6)	28 (36)	35 (46)	74 (96)	147 (188)
	CCM	1 (1)	2 (2)	2 (2)	3 (3)	24 (36)	6 (9)	11 (17)	49 (70)
1	Crane	1 (1)		1 (1)	3 (3)	20 (21)	43 (50)	20 (23)	88 (99)
	Furnace repairing	1 (1)			1 (1)	4 (5)	10 (13)	7 (9)	23 (29)
	Office work	1 (1)		3 (5)					4 (6)
1		5 (5)	4 (4)	7 (9)	13 (13)	76 (98)	94 (118)	112 (145)	311 (392)
Total					312 (393)				

Note: Figures in ( ) shows the number of personnel of the 2nd stage.

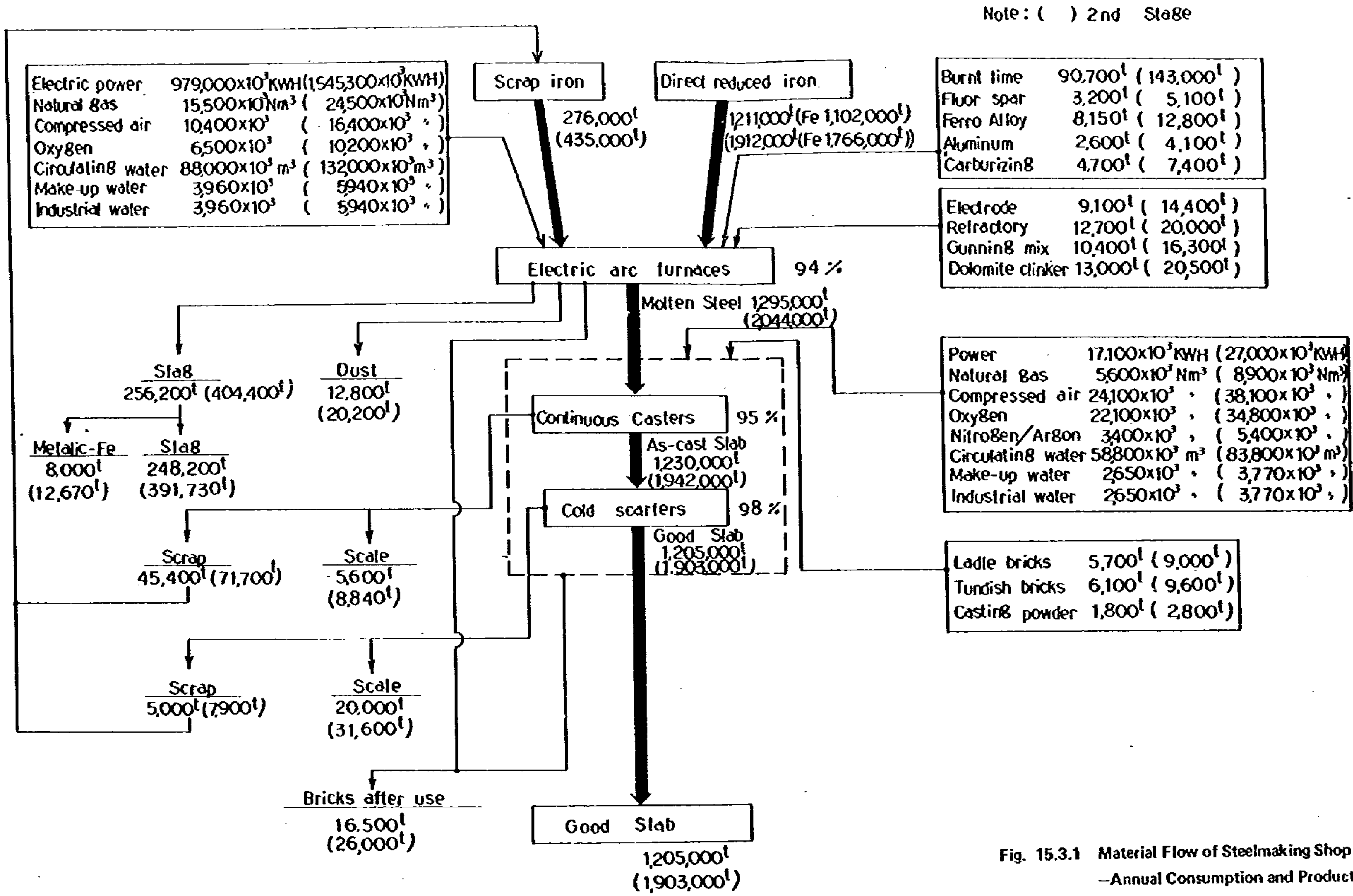


Fig. 15.3.1 Material Flow of Steelmaking Shop
—Annual Consumption and Production—

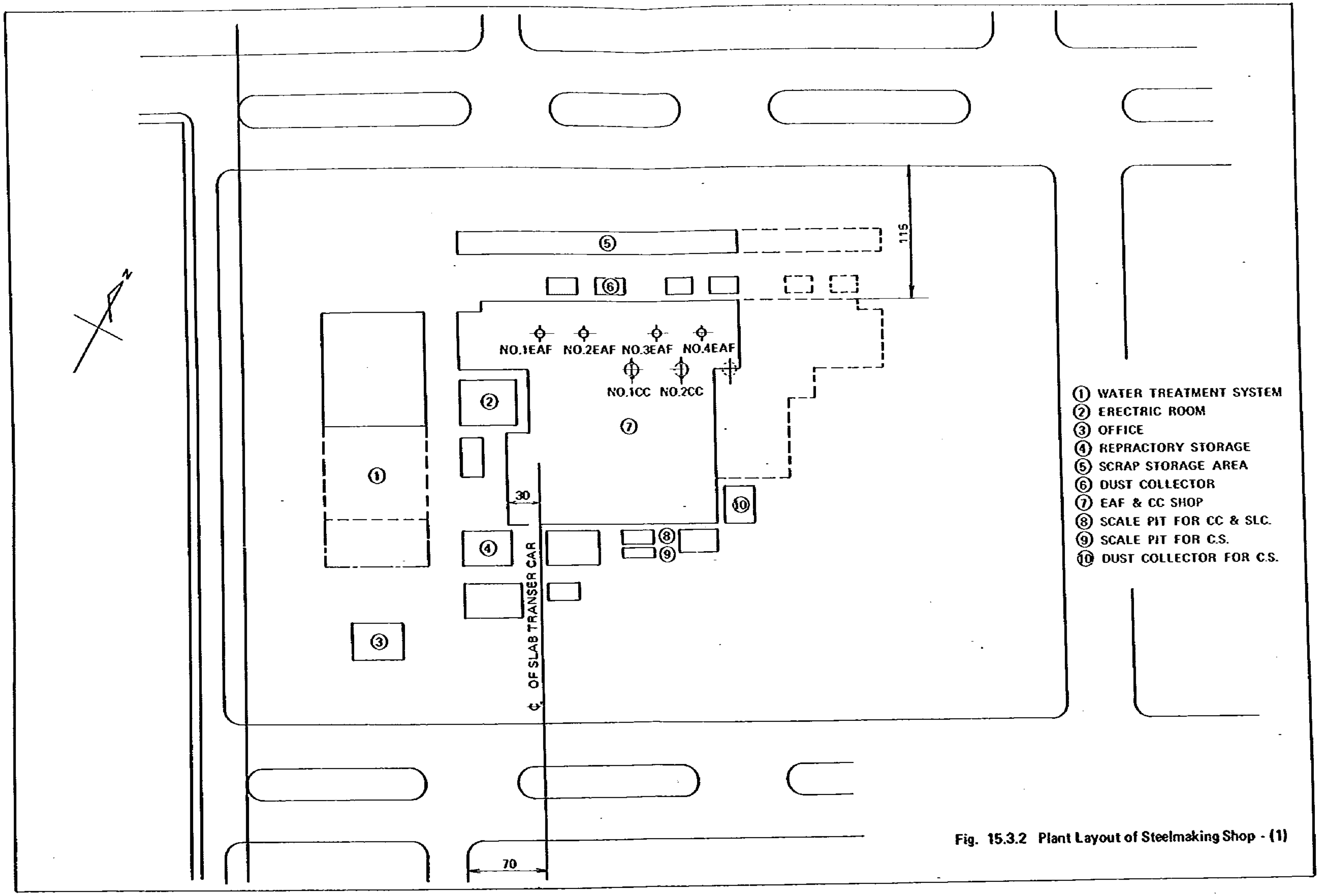


Fig. 15.3.2 Plant Layout of Steelmaking Shop - (1)

(5) Electric Arc Furnace in General

In accordance with the production plans mentioned previously, for the 1st stage of the steelmaking shop, four UHP EAF with a capacity of 150 t/heat required for the production of 1,295,000 tonnes/year of molten steel will be constructed. Transformer capacity for the furnaces will be 75,000 kVA, sufficient to meet the melting capacities called for in the production plan. Further construction of two 150 t/heat UHP EAF will be necessary to realize the 2nd stage production target of 2,044,000 tonnes/year of molten steel.

The main materials will be scrap and DRI produced in the DR plant in the preceding process. Scrap will consist of purchased scrap and the so-called "return scrap" generated in the steel plant. The DRI is transported from the DR plant to the steelmaking shop by a belt conveyor system to be stored in the storage hopper in front of the EAF. The DRI can be continuously charged into the furnace by drawing out the specified amount from the storage hopper, being weighed and transported by the conveyor.

The scrap is carried by a truck from the scrap yard to the scrap preparation yard in the steelmaking shop, where it is loaded onto a charging bucket by means of a crane equipped with a magnet, and after being weighed on a built-in scale it is hoisted up by the charging crane in front of the EAF to be charged from the furnace top.

The sub-materials are transported by a truck from the sub-materials yard to the receiving bunker and are then brought up by conveyor to the storage hopper in front of the furnace. From this hopper, the specified amount is charged, after being automatically weighed, by a conveyor. The burnt lime, which is used as sub-material in large amount is transported by a belt conveyor from the unloading yard of the freight cars. This belt conveyor merges with the belt conveyor for the DRI and from this point onwards, a single conveyor is used alternately to transport the DRI and the burnt lime to the steelmaking shop.

In addition, the transportation and actual charging into the furnace of the DRI and sub-materials are planned to be automatically remote controlled.

After the melting and refining, the molten steel is tapped into a ladle, and, as will be described later, is poured into a continuous casting machine to be formed into slab.

The slag discharged from the EAF is received in slag pots, transported by self-loading trucks to the slag yard outside the steelmaking shop where it is discarded after cooling, crushing and removal of any steel which had overflowed into the slag.

The waste gas generated in the EAF are drawn into a bag filter from the furnace top where dust is collected. In addition, the plan provides for the installation of an electrostatic precipitator equipped at the top of the inside roof of the building to collect dust contained in the gas which escapes from the furnace top during the charging of the scrap or at tapping time.

(6) Conditions for EAF Plan

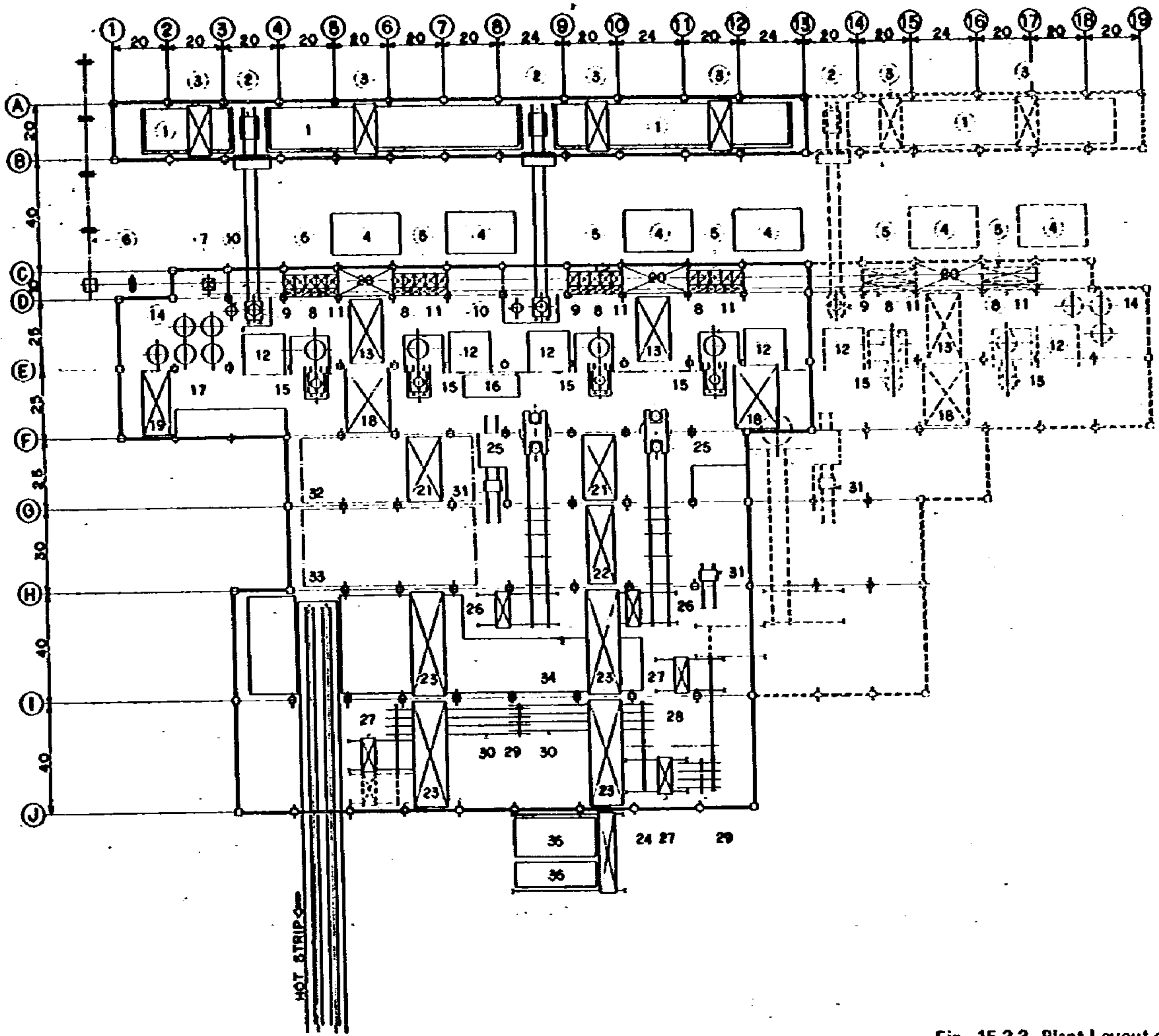
i. Production

The production of molten steel from the EAF is designated as follows:

1st stage	1,295,000 tonnes/year
2nd stage	2,044,000 tonnes/year

ii. Blending ratio of main raw materials and production yield

The standard blending ratio of the main raw materials of the charge and standard yield for both the 1st and 2nd stages given below in Table 15.3.4



1 SCRAP STORAGE AREA
2 SCRAP WEIGH SCALE
3 SCRAP CHARGING CRANE (15 T)
4 DUST COLLECTOR
5 SPONGE IRON AND LIME STORAGE BUNKER
6 SPONGE IRON AND LIME BELT CONVEYER
7 FERRO ALLOY RECEIVING BUNKER
8 FERRO ALLOY STORAGE BUNKER
9 SCRAP BUCKET TRANSFER CAR
10 SCRAP BUCKET
11 ELECTRIC ARC FURNACE
12 TRANSFORMER ROOM
13 FURNACE CHARGING CRANE (75 T/20 T)
14 ROOF REPAIRING AREA
15 LADLE TRANSFER CAR
16 LADLE PREPARING AREA
17 LADLE REPAIRING AREA
18 HOT METAL LADLE CRANE (240 T/40 T)
19 LADLE REPAIRING CRANE (75 T/20 T)
20 CONTROL ROOM
21 O.H.C (70 T/20 T)
22 O.H.C (45 T)
23 O.H.C (75 T)
24 O.H.C (75 T)
25 No. 1, 2 C.C.M
26 CRANE (TONGS)
27 CRANE (MAGNET)
28 COLD SCARFER
29 SLAB TURNER
30 PARTIAL SCARFER
31 TRANSFER CAR
32 TUNDISH REPAIRING AREA
33 MACHINE REPAIRING AREA
34 SLAB COOLING BED
35 SCALE PIT FOR CC & SL.C
36 SCALE PIT FOR C.S

Fig. 15.3.3 Plant Layout of Steelmaking Shop – (2) (Scale 1/1,000)

Table 15.3.4 Main Materials Blending Ratio and Production Yields

		1st stage		2nd stage	
		t/year	%	t/year	%
Main raw materials	DRI (Fe)	1,102,000	80.0	1,740,000	80.0
	Scrap	276,000	20.0	435,000	20.0
Total		1,378,000		2,175,000	
Molten steel	Steel tapped (yield as against main raw materials)	1,295,000	(94.0)	2,044,000	(94.0)
Slab	As cast slab (yield as against steel tapped)	1,230,000	(95.0)	1,942,000	(95.0)
	Slab after surface conditioned (yield as against as cast slab)	1,205,000	(98.0)	1,903,000	(98.0)

iii. Annual working days:

The EAF is to be operated continuously, with 300 annual working days. The non-working time is based on the assumption given in Table 15.3.5.

Table 15.3.5 Non-working Time of EAF

	Frequency & time	Annual total hours
Roof change	Once/100 heats x 3 h	87 h
Sidewall repair	Once/120 heats x 25 h	601 h
Overhaul repairs	Once/2 years x 7 days	84 h
Periodical repairs	Once/week x 8 h	417 h
Waiting (adjusting) time	1.7% x 8,760 h	149 h
Accidents and troubles	1.83% x 8,760 h	160 h

iv. Determination of capacity and number of furnances

For the determination of optimum furnace capacity, the factor that should first be considered is coordination with the succeeding casting method, i.e.. between the EAF and processing capacity of the CCM and its cycle time. At the same time, ease of operation, economic aspects and productivity should also be regarded as of great importance.

In the present plan, to meet the 1st stage requirements of 1,294,000 tonnes/year of molten steel production, four furnaces, each with a capacity of 150 tonnes/heat with a furnace transformer of 75,000 kVA, will be constructed. This plan is based on consideration of the following factors:

a. Melting time:

Theoretically, the melting time of DRI is:

$$\frac{120\ \text{t/heat} \times 650\ \text{kWh/t} \times 60\ \text{min/h}}{75{,}000\ \text{kVA} \times 1.2 \times 0.65 \times 0.95} = 84.2\ \text{min/heat}$$

In the same manner, melting time of scrap will be:

$$\frac{30\ \text{t/heat} \times 450\ \text{kWh/t} \times 60\ \text{min/h}}{75{,}000\ \text{kVA} \times 1.2 \times 0.76 \times 0.85} = 13.9\ \text{min/heat}$$

From these figures and after considering the time required for other steelmaking operations, tap to tap time will be 189 min/heat.

b. Number of heats per day:

The number of heats per day will be as follows:

$$\frac{1{,}440\ \text{min/d}}{189\ \text{min/heat}} \fallingdotseq 7.6\ \text{heats/day (per furnace)}$$

c. Daily steel production:

1st stage $\dfrac{1{,}295{,}000\ t}{300\ d} = 4{,}317\ t/d$

2nd stage $\dfrac{2{,}044{,}000\ t}{300\ d} = 6{,}813\ t/d$

d. Number of EAF required:

1st stage $\dfrac{4{,}317\ t}{150\ t \times 7.6\ heats} = 3.79 \fallingdotseq 4$ furnaces

2nd stage $\dfrac{6{,}813\ t}{150\ t \times 7.6\ heats} = 5.98 \fallingdotseq 6$ furnaces

If repair time is subtracted from tap to tap time, the actual steelmaking time is 159 min/heat. Consequently, the annual working ratio will be as follows:

As against chronological time:

$$\frac{159\ min/heat \times 7.6\ heats \times 300\ d}{1{,}440\ min \times 365\ d} \times 100 \fallingdotseq 69\%$$

As against potential working time:

$$\frac{159\ min \times 7.6\ heats \times 300\ d}{1{,}440\ min \times 300\ d} \times 100 \fallingdotseq 84\%$$

The operating conditions of the furnace, as obtained by arranging these data, are given in Table 15.3.6:

v. Type of steel to be produced

The type of molten steel to be produced with the EAF are low carbon steel for hot and cold rolling strips.

Table 15.3.6 Operating Conditions of EAF

		Planned values	
		1st stage	2nd stage
Working time	Number of working days per year	300 d	300 d
	Non-working days (Repair, etc.)	65	65
Working ratio	Actual steelmaking time/total time	70 %	70 %
Tonnes of steel produced	t/heat	150	150
	t/d	4,317	6,813
	t/mon	107,900	170,300
	t/y	1,295,000	2,044,000
Number of taps	heats/d	29	45
	heats/mon	719	1,135
	heats/y	8,633	13,627
Breakdown of steelmaking time	Scrap charging	5 min	5 min
	Melt-down (scrap)	14	14
	Melt-down (DRI)	85	85
	Slag removal	15	15
	Refining	35	35
	Tapping	5	5
	Repairs	30	30
	Tap to tap	189 min	189 min

(7) Description of EAF

i. Layout

The yard for the EAF is composed of, paralleled with the building of the steelmaking shop, the yard for the DRI and sub-materials storage hopper and the EAF yard for the furnace itself. Also, a dust collector will be installed between the storage hopper and the scrap preparation yard.

For the working floor space in front of the furnace, adequate space is allotted centering around the main body of furnace. In order to economize on construction costs, the storage hoppers for the main and sub-materials are housed in a separate building from the EAF yard.

The transfer car rails for the scrap charging bucket are laid along a line so as not to affect the charging operation into the EAF and the loading of the scrap by crane.

To realize rationalization of the equipment, the EAF control room is constructed in a position through which centralized control of the two furnaces can be carried out. Also, the transformer room for the EAF is located in a position where electrical loss is kept to a minimum.

In addition, a repair yard for the furnace roof is allotted at one end of the EAF yard.

In order to prevent interferance of the EAF operation and the CC operation, a ladle preparation yard is prepared between the furnace yard and the CC yard.

The plan is designed so that the shop can be constructed with compact positioning for a high level of workability, with due consideration being given to the addition of the EAF for the 2nd stage, as well as to the possibility of still further expansion. In addition, the layout plan tries to provide easier operation of construction work.

With regard to the details of the layout, reference should be made to Fig. 15.3.3.

ii. DRI equipment

The DRI is transported by a belt conveyor from the DR plant to the steelmaking shop and is supplied to the selected storage hopper by means of a tripper. This hopper has the capacity to store sufficient material for 5.6 heats (400 m^3/furnace) and when the amount stored is reduced to 2 heats, it will be automatically replenished until it is full.

Burnt lime sufficient for 9.5 heats (100 m^3/furnace) is stored in a hopper to which it is transported by means of the same conveyor system as for the DRI.

After completion of the 2nd stage, the working ratio of the conveyor will be 51% so that there is more than sufficient capacity.

The materials can be drawn out in the specified amount from the storage hopper through remote control and can be automatically charged continuously into the EAF by the conveyor.

The ratio of the DRI (Fe content) and scrap is 8:2 with 128t of DRI per heat.

The composition of the DRI is given in Table 15.3.7.

Table 15.3.7 Specification of DRI

Total Fe	91 %
Metallization	93 %
C content	1.5 %

iii. Equipment for scrap

Scrap will be transported by a truck into the scrap preparation yard in the steelmaking shop just to leave it in the yard. This yard will have an area capable of storing scrap for 4 day's use (3,000 m^2). From this yard, it is loaded onto the charging bucket on the transfer car by means of a magnet crane. In this operation, the amount loaded is measured on a weighing machine installed below the car and the weights will be indicated continuously.

After being loaded, the bucket is hoisted and the scrap is charged from the top of the furnace by opening the bottom of the bucket.

Scrap to be used for a heat is 30 tonnes.

iv. Equipment for sub-materials

Sub-materials are burnt lime, fluorite, ferroalloys, and carburizing material; the ferroalloys being of six types including Fe-Mn and Fe-Si. With regard to the burnt lime, reference should be made to the section on DRI. The sub-materilas, with the exception of the burnt lime are transported by trucks from the sub-materials yard outside the steelmaking shop to the underground receiving bunker of the EAF.

One set of machine at the receiving underground bunker is used in common for all types of sub-materials and from this bunker, the materials are transported by a conveyor with a capacity of 100 t/h and are supplied through a tripper into any storage hopper desired. The storage hopper has a capacity for two days' use, and a calculator always keeps track of the amount remaining by subtracting the used amount from the received amount, and when the remainder is reduced to that of 2 days' use, a "Capable of Receiving" indication is issued.

This conveyor is to be used only during the day-time (8 hours) and its working ratio after completion of the 2nd stage is about 70%, and therefore has enough capacity than the requirement.

The specified amount of materials can be drawn out from the storage hopper by setting the specified amount through remote control and can be automatically charged continuously into the EAF through the same conveyor as used for the DRI. The composition of the materials and amounts used are shown in Table 15.3.8.

The chemical compositions are shown in Table 15.3.9.

Table 15.3.8 Specification and Consumption of Raw Materials and Others

	Grain size	Bulk specific gravity	Unit consumption	Used per heat (tonnes, kg/t)	Used per day
DRI	50 mm	1.8	935 kg/t	140t (Fe, 128t)	4,040t (Fe, 3,670t)
Scrap	–	0.6	213	30	920
Burnt lime	10∿40	1.0	70	10.5	300
Fe-Mn	25∿60	3.5	5.6	840 kg/t	24
Fe-Si	40∿100	1.5	0.7	100	3
Fluorite	10∿80	1.5	2.5	370	11
Carburizing material	5∿25	0.5	3.6	540	16
Aℓ	Rod		2	300	7

Table 15.3.9 Chemical Composition of the Sub-materials

Name	Chemical composition
Burnt lime	CaO 90∿94%, SiO_2 3∿4%, Ig-loss 2∿3%
Fe-Mn	Mn 73∿78%, C ≤ 7.3, Si ≤ 1.2, P ≤ 0.40, S ≤ 0.40
Fe-Si	Si 75∿80%, C ≤ 0.2, P ≤ 0.05, S ≤ 0.02
Fluorite	CaF_2 75∿83%
Carburizing material	C 98%

v. EAF equipment

a. Ultra high power

The capacity of the EAF for this plant is 150 t/heat and the Ultra High Power (UHP) system is adopted. Generally, the productivity of an EAF is determined by melt-down time which takes up about 50% of the total time required in the steelmaking operation. Conventional measures to shorten this melt-down time have been to use large furnaces and to increase the amout of electrical power per unit time. The reason for this is that as a high electric power factor (electrical efficiency of 90 ∿ 95%) can be realized through high voltage and low amperage. This method is more advantageous from the standpoint of electrical efficiency. However, if electrical power is increased through this method, the long arcs cause damage to the brick on the sidewalls of the furnace and also create problems of generating flicker due to the excessive variations in the electrical power load. Therefore, considering that

Electrical Power (kW) = Transformer Capacity (kVA) x Power Factor

it can be seen that it is possible to obtain large electrical power by increasing the kVA even if the power factor is decreased. Through UHP operation, even by lowering the power factor (about 70%) to the so-called low power factor, high electrical power operation can be realized, as a low voltage, large current stabilized short-arc can be obtained. Through this method, melt-down is rapid with minimum damage to the refractory material.

In the present plan, a furnace transformer with a capacity of 75,000 kVA is adopted. In addition, tries to achieve an auto-driven device for melting is to be adopted for stable and rapid melting.

b. Electrode

The electrode has a diameter of 610 mm. For electrodes to be used on UHP, those with small electrical specific resistance and coefficient of heat expansion but high shock resistance and mechanical strength are required.

For the electrode hoisting device, after considering operational efficiency, a motor driven wire rope winding system is adopted.

c. Furnace body

The inside diameter of the furnace shell is 7,300 mm. As a large current is charged for a short period of time in the UHP operation, measures for protecting the refractory materials on the sidewall of the furnace are of great importance. For this reason, the present plan calls for large-scale adoption of water-cooled jackets to partly replace refractories not only at the hot spots of the sidewell, but also on other parts of the wall and on the roof cover. This water-cooled jacket method will prolong the life of the furnace wall and roof cover to a considerable extent as compared with the conventional brick method, and a large saving in cost is expected.

Schematic diagrams of the EAF are shown in Fig. 15.3.4 and Fig. 15.3.5.

d. Others

The tilting mechanism of the furnace is electrically operated through the rack and pinion method. The lifting and lowering as well as the rotating movement of the furnace roof cover, and the opening and closing of the door are hydraulicaly activated. All these operations are carried out through remote control from the control room in front of the furnace. Slag discharge from the EAF is effected from the door on the side opposite the steel tapping staut to be collected in the slag pot positioned below the furnace. The slag is then transferred to a self loading truck to be transported to the slag yard outside the steelmaking shop.

The slag transported to the slag yard, is cooled and crushed and a magnet is used to recover the iron content in the slag.

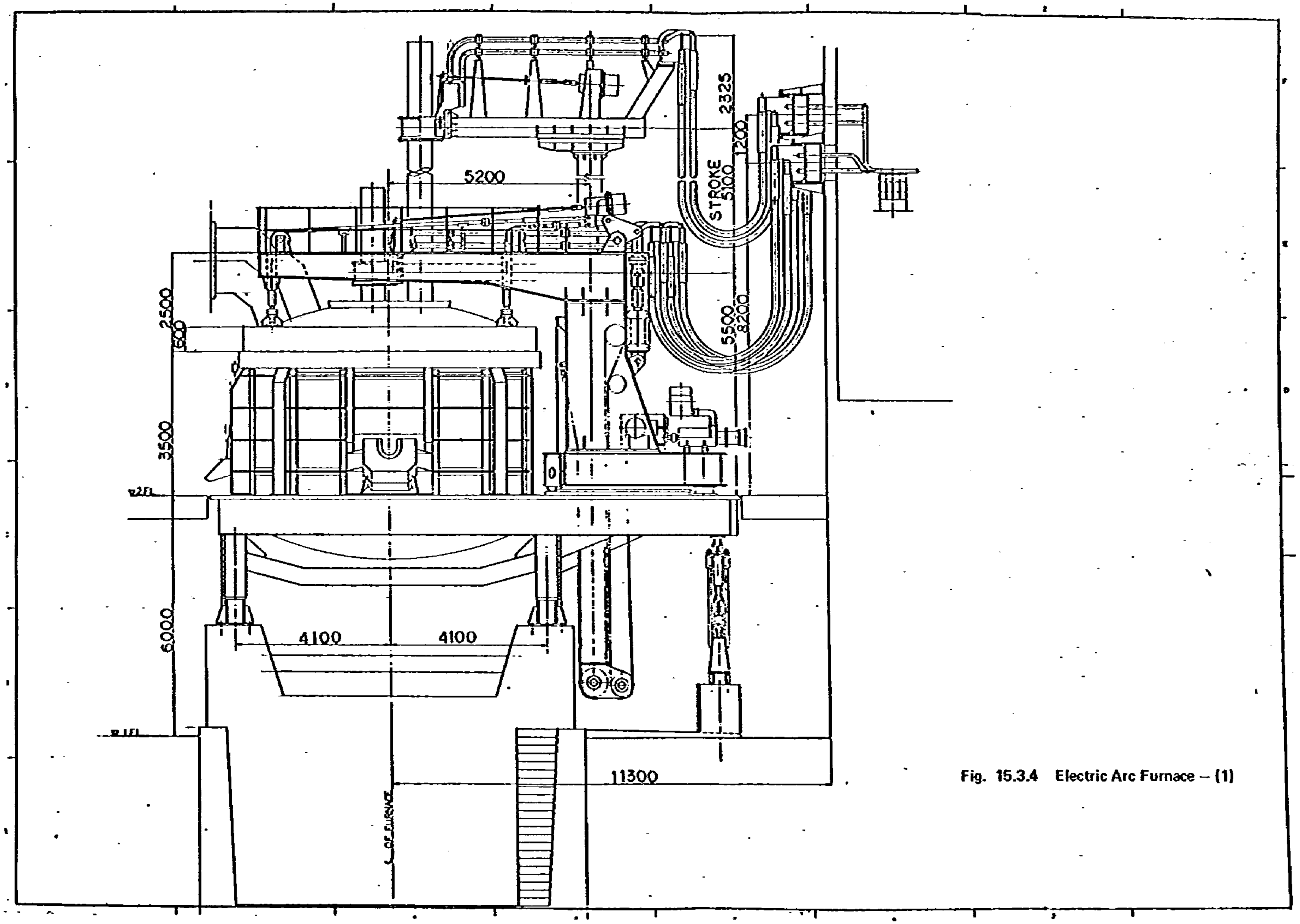
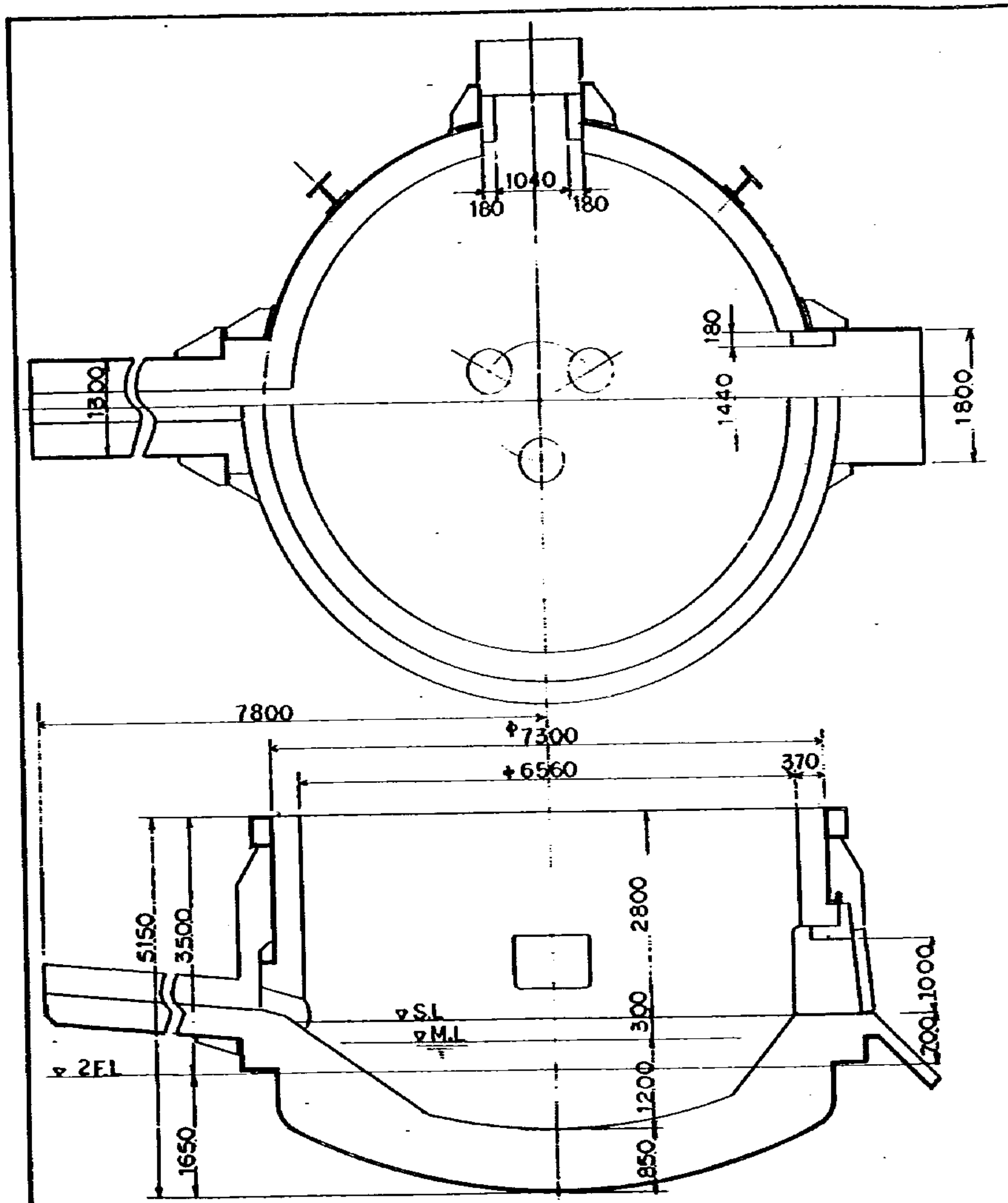


Fig. 15.3.4 Electric Arc Furnace – (1)



Note:
1. Molten Metal Capacity 150 mt
2. Furnace Volume 125 m³
3. Slag Volume 8.5 m³

Fig. 15.3.5 Electric Arc Furnace – (2) (shell refractory outline)

vi. Filcker compensating device

Currents in EAF generally vary repeatedly at irregular intervals and especially at the initial stage of melting, the variations in the current are considerably large. As a preventive measure, an automatic electrode controller is employed to maintain the current at a constant level, but the rapid variations cannot always be prevented. Consequently, in such cases, the voltage drop caused by the power source impedance will vary in conformity with variations in the furnace current, and as the voltage in the bus bar of the supplying transformer station will also change from moment to moment, the brightness of the electric lamps receiving power from the same bus bar will vary accordingly, giving an impression of flickering. This is the "flicker" which is a problem caused by the arc furnace.

In the present plan, a countermeasure is taken by installing a flicker compensating device. For details, reference should be made to the separate section on "Utilities" (electric power).

These voltage variations are connected with the capacity of the power source, flicker become a problem when the power source capacity is small as compared with the transformer capacity of the furnace. It is therefore important that proper servicing of the prime electrical power facilities be undertaken.

vii. Dust collecting equipment

For this EAF equipment, special consideration has been paid to the prevention of environmental pollution by installing three systems for dust collecting equipment for assurance.

In the first system, the discharged gases from the EAF during melt-down and refining are drawn up into ducts at the furnace top and the dust is collected in a bag filter. An independent bag filter will be installed for each furnace, each unit having the capacity to treat 3,000 m^3/min (with gas temperature at 220°C).

The second system processes the gases that cannot be treated through the system mentioned above by drawing into ducts from the furnace top. Such gases are as those generated at the time of scrap charging and during the tapping operation. To trap such gases, an electrical dust collector is installed on the roof of the building. Such a electrical dust collector is installed for two electric furnaces as a set, the volume of gases processed will be 20,000 m^3/min/unit (with discharged gas temperature at 50°C).

The so-called "building dust collectors" conventionally used to date had to process large amount of gases and as a dust collector was usually installed on the ground, a motor with an excessively large capacity was required for the ventilator which used to considerably increase running costs. The electric dust collector is therefore being installed on top of the building to reduce this cost, and to facilitate dust disposal. A dry type is adopted.

The third system processes, through a bag type dust collector, the dust generated by the main and sub-materials when passing through the joining parts of the conveyors or when they are dumped into the storage hopper.

This bag filter is commonly used by each of the EAF and its processing capacity will be 2,000 m^3/min (with gas temperature at 20°C).

viii. Molten steel transporting equipment

The molten steel tapped from the EAF is received by a ladle placed on the steel transport car to be transported to the adjacent ladle yard. The capacity of the ladle is to be 160 tonnes maximum, and a total of 14 ladles will be prepared including those being used, repaired or awaiting their turn.

A "motor driven rotary type nozzle" is installed at the bottom of the ladle in order to increase the stability and reliability of the teeming operation. In addition, the opening and closing of this rotary nozzle of the ladle can be managed by remote control.

Four heating devices are installed to pre-heat the ladles awaiting their turn or to dry the ladle after the interior brick lining has been repaired. The fuel to be used for heating is natural gas.

In addition, ladle repairing facilities and rotary nozzle repairing equipment are installed.

ix. Crane equipment

The crane capacity is determined by the following conditions.

a. Scrap loading crane

(Scrap, max. 7t) + (Magnet 8t) = 15t

b. Scrap charging crane

Considering that scrap is the only main material for the initial stage of operation, and the bulk specific gravity of the scrap to be hoisted is $0.8t/m^3$, the crane capacity will be:

Scrap 44t + Weight of Bucket 27t = 75t

c. Ladle crane

Molten steel (maximum)	160t	240t
Weight of ladle	75t	
Rotary nozzle	2t	
Others	3t	

d. Ladle repair crane

Weight of ladle (after brick laying) 75t

(8) Equipment List of EAF

Table 15.3.10 gives a list of specifications for EAF equipment.

Also, for the layout of the furnace equipment, reference should be made to Fig. 15.3.3 given in the section "Outline of Steelmaking Plant" previously explained.

(9) Operation of EAF

The principal operation of the EAF consists of charging the scrap – melting the scrap – continuous charging and melting of the DRI – slag discharge – refining – tapping – repairing, and this cycle is then repeated, the "tap-to-tap" time being 189 minutes.

A schematic presentation of the flow of these operations is shown in Fig. 15.3.6.

Table 15.3.10 List of Specifications for EAF Equipment

Classi-fication	Name of equipment	No.	Main specifications
1.	Main material equipment		
1	DRI transporting conveyor	1 Set	Transporting capacity: 900 t/h, belt width: 1,050 mm
2	DRI storage hopper	20 Units	Capacity: 100 m^3/unit with supervisory device for remaining amount (including 4 units for raw lime)
3	DRI draw out device	4 Units	Draw out capacity: 100 t/h including specified amount drawing out device, automatic weighing device)
4	Scrap charging bucket	5 Units	Capacity: 55 m^3/unit, clamshell type
5	Scrap charging bucket transporting car	2 Units	Load capacity: 70t, electric selfpropelling
6	Scrap weighing machine	2 Units	Weighing value: max. 50t
2.	Sub-materials equipment		
1	Receiving hopper	1 Unit	Capacity: 15 m^3
2	Transporting conveyor	1 Set	Transporting capacity: 100 t/h, belt width: 600 mm
3	Storage hopper	24 Units	6 types/furnace (18 m^3 x 2 units, 10 m^3 x 2 units, 7 m^3, 5 m^3) with supervisory device for remaining amount.
4	Drawing out device	4 Units	Drawing out capacity: 100 t/h including specified amount draing out device, automatic weighing device. (same conveyor to be used as for DRI).
5	Charging machine	2 Units	Load capacity: 2t, self-propelling
3.	EAF equipment		
1	EAF	4 Units	Capacity: 150t, inside diameter of furnace shell: 7,300 mm, electrode diameter: 610 mm
2	Transformer	4 Units	Capacity: 75,000 kVa
3	Slag pot	15 Units	Capacity: 16 m^3/ladle
4	Slag pot carrier	5 Cars	Load capacity: 50t, self-propelling type
5	Electrode connecting device	2 Units	Tightening torque: 100 ∿ 400 kg-m
4.	Dust collecting equipment		
1	Furnace top suction dust	4 Units	Bag filter type, volume of gas treatment: 3,000 m^3/min/unit (gas temperature 220°C).

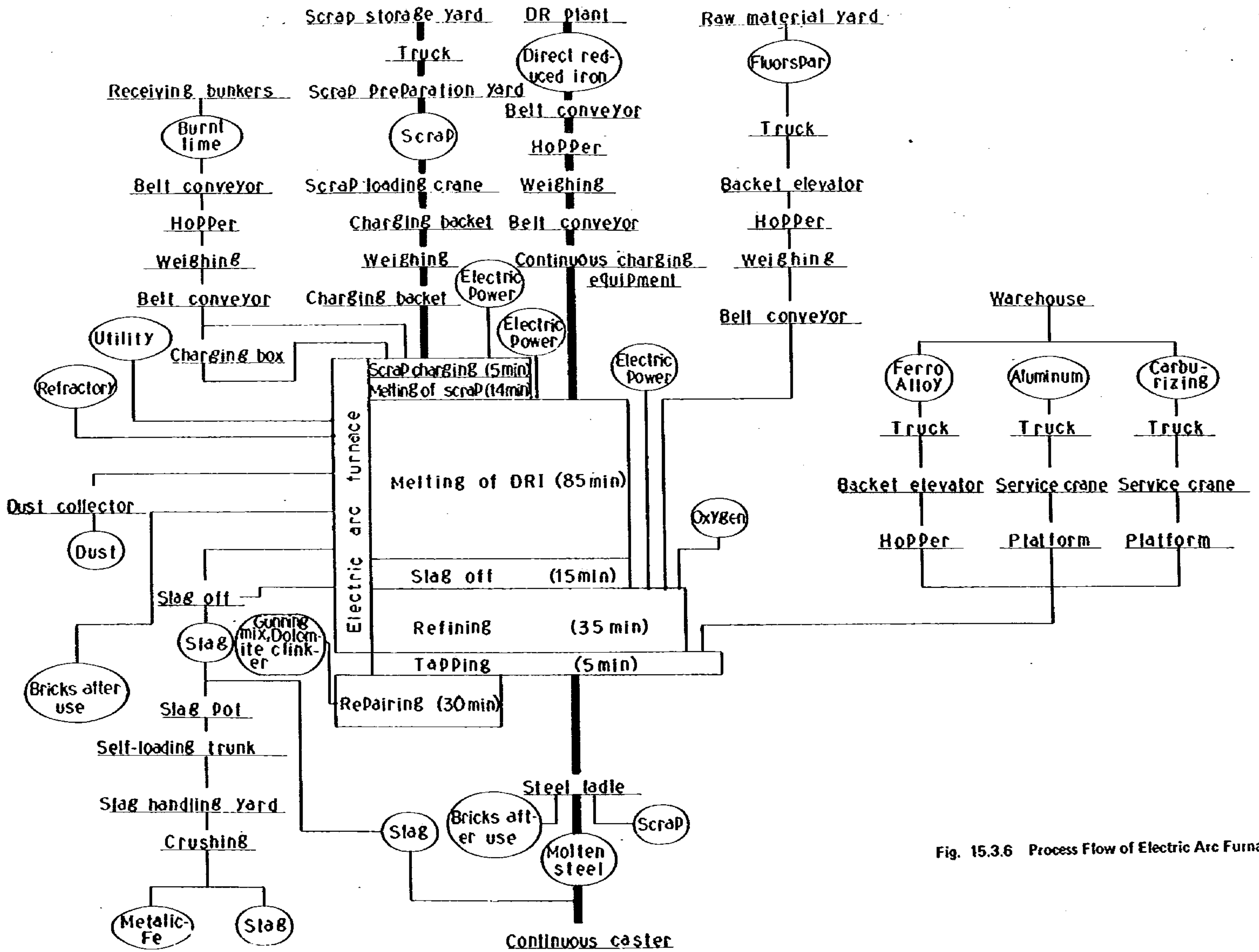


Fig. 15.3.6 Process Flow of Electric Arc Furnace

Table 15.3.10 (cont'd)

Classi-fication	Name of equipment	No.	Main specifications
4. 2	Dust collecting equipment on building	2 Units	Electric dust collector, volume of gas treatment: 20,000 m^3/min/unit (gas temperature 50°C)
3	Dust collector for the auxiliary materials	1 Unit	Bag filter type, volume of gas treatment: 2,000 m^3/min/unit (gas temperature 20°C)
5.	Crane equipment		
1	Scrap loading crane	4 Units	15t x 18m, with lifting magnet
2	Scrap charging crane	2 Units	75t/20t x 22m
3	Ladle crane	2 Units	240t/40t x 22m
4	Ladle repair crane	1 Unit	75t/20t x 22m
6.	Ancillary equipment		
1	Various types of piping	1 Set	O_2 piping, natural gas piping, compressed air piping, cooling water piping, tap and effluent water piping
2	Pneumatic sample transportation equipment	1 Set	Furnace (2 positions), analyzing room
3	Air conditioning equipment	1 Set	
4	Communication equipment	1 Set	
7.	Electrical equipment	1 Set	Power source equipment, shop lighting, power source for cranes
8.	Instrumentation equipment	1 Set	Instrumental power source equipment, molten steel temperature measuring equipment
9	Constructions		
1	Scrap yard	1 Bldg.	20m x 252m, crane rail height 12m
2	Bunker yard	1 Bldg.	10m x 252m, height of eaves 12m
3	EAF yard	1 Bldg.	25m x 252m, height of crane rail 25m
4	Ladle yard	1 Bldg.	25m x 252m, height of crane rail 27m
5	Working floor for the furnace	1 Set	= 4,000m^2, height 6m
6	Control room in front of furnace	2 Bldgs.	10m x 20m
7	Transformer room	4 Bldgs.	15m x 15m – 2-storied bldg.
8	Electrical room	1 Bldg.	35m x 40m – 2-storied bldg.
9	Analysis room	1 Bldg.	
10	Office room	1 Bldg.	
10.	Civil engineering work	1 Set	Building foundation, foundation for equipment

(10) Operation Data of EAF

The basic units and the annual consumption for main and sub-materials are given in Table 15.3.11, while those for the utilities are given in Table 15.3.12.

Table 15.3.11 Annual Consumption of Raw Materials, Fluxes and Others

Classi-fication	Items	Unit consumption	Annual consumption 1st stage	Annual consumption 2nd stage
Main materials	DRI	935 kg/t	1,211,000 t	1,912,000 t
	(Fe content)	(850)	(1,102,000)	(1,740,000)
	Scrap	213	276,000	435,000
Sub-materials	Burnt lime	70 kg/t	90,700 t	143,100 t
	Fuorite	2.5	3,200	5,100
	Fe-Mn	5.6	7,250	11,400
	Fe-Si	0.7	900	1,400
	Aℓ	2	2,600	4,100
	Carburizing material	3.6	4,700	7,400
Others	Electrode	7 kg/t	9,100 t	14,300 t
	Furnace shell brick	9.8	12,700	20,000
	Gun-mix	8	10,400	16,300
	Dolomite clinker	10	13,000	20,400

Table 15.3.12 Annual Consumption of Utilities for EAF

Name	Unit consumption	Annual consumption (1st stage)	Annual consumption (2nd stage)
Electric power	756 kWh/t	979,000 x 10^3 kWh	1,545,000 x 10^3 kWh
Natural gas	12 Nm^3/t	15,500 x 10^3 Nm^3	24,500 x 10^3 Nm^3
Compressed air	8	10,400 x 10^3	16,400 x 10^3
Oxygen	5	6,500 x 10^3	10,200 x 10^3
Recirculating water	63 m^3/t	8,800 x $10^3 m^3$	12,900 x $10^3 m^3$
Make-up water	3.1	3,960 x 10^3	6,300 x 10^3
Industrial water	3.1	3,960 x 10^3	6,300 x 10^3

(11) Continuous Casting Plant in General

The continuous casting facilities have two 2-strand curved types slab continuous casting machines (CCM) for casting into slab a total of 1,295,000 tonnes per year of molten steel produced by four electric arc furnaces. And in the 2nd stage, additional one 2-strand slab CCM will be installed; so as to process 2,044,000 tonnes of molten steel produced by six electric arc furnaces.

The equipment described here includes that of down-stream of the EAF, i.e., the CCM proper and its ancillary equipment, slab treating equipment, conveying equipment and associated crane equipment, etc.

The specifications, type, capacity, capability, etc., of the equipment are based on the product mix established based on the production plan for the steel plant.

All the slab is sent to the hot strip mill for rolling and further processed at the cold strip mill.

The process outline of the CC operation is as follows: Molten steel tapped from the EAF is received by a ladle and transferred on ladle cars to the swing tower yard. Here the ladle is hoisted by a ladle crane and is set to the molten steel temperature adjustment unit. The temperature adjustment unit consists of a nitrogen gas or argon gas bubbler and cooling material charging device and a temperature measurement and sampling device. The ladle after complete temperature conditioning is mounted on the swing tower (turret). On the other hand, after the completely preheated tundish has travelled to the casting position, the swing tower is turned to set the ladle to the casting position. Casting work then proceeds with the order of ladle nozzle opening → tundish nozzle opening → and starting of the dummy bar extraction. The cast and cut slab is piled on the roller table by the electric tonged crane and spray cooled in the bay cooling area to a surface temperature of below 1,000°C. Then the slab is transferred to the cold scarfing line by means of a lifting magnet crane and the slab surface is scarfed. Slabs requiring further treatment are hand scarfed. The conditioned slab is piled by the crane and conveyed directly to the hot strip mill by the slab cars.

The arrangement of the main equipment described above is shown on the layout drawing (Fig. 15.3.3).

In designing the layout, the space for future installations of the CCM and its ancillary equipment has been considered in addition to the three CCM of the 1st and 2nd stages.

(12) Conditions for Continuous Casting Plant

i. Output

The production plans at the 1st and 2nd stages are shown in Table 15.3.13 and the product-mix for slab size determination in Table 15.3.14.

Table 15.3.13 Continuous Casting Production Plan and Standard Yield

		1st stage		2nd stage	
		Tonne/year	%	Tonne/year	(%)
Molten steel	Tapping	1,295,000		2,044,000	
Slab	As cast slab (yield to steel tapped)	1,230,000	(95)	1,942,000	(95)
	Conditioned (yield to as cast slab)	1,205,000	(98)	1,903,000	(98)

Table 15.3.14 Product-mix for Hot Strip Mill

Slab width	1st stage		2nd stage	
	Tonne/year	(%)	Tonne/year	(%)
2.5 feet	196,000	16.8	268,000	14.5
3.0	126,000	10.8	332,000	18.0
4.0	801,000	68.5	1,177,000	63.8
5.0	46,000	3.9	69,000	3.7

ii. Slab size

The slab size produced by CCM plant is planned as shown in Table 15.3.15 depending on the size of the hot rolled coil.

Table 15.3.15 Dimensions of Slab

		Size
Slab	Thickness	200 mm
	Width	800 ~ 1,600 mm
	Cut length	4,000 ~ 9,300 mm
	Weight	max. 22,900 kg

iii. Type of steel produced

The types of steel produced are low carbon steels for hot and cold strips shown earlier in the basic production plan.

iv. Number of working days/year

The continuous casting shall be 3-shift, 24-hour per day operation, the same as for the EAF, and the number of annual working days are 300. The assumption of the non-working hours is as per Table 15.3.16.

Table 15.3.16 Continuous Casting Non-working Hours

	Frequency and hours	Annual total
Periodical repair	Once/week x 12 hours	624 hours
Overhaul repair	Once/year x 7 days	168 hours
Down time (accidents, troubles)	8.78% x 8,760 hours	768 hours

v. Number of castings:

a. Number of tappings from EAF

1st stage: $\frac{4{,}317 \text{ t/day}}{150 \text{ t/heat}} = 29$ heats/day

2nd stage: $\frac{6{,}813 \text{ t/day}}{150 \text{ t/heat}} = 45$ heats/day

b. Tapping pitch from EAF

1st stage: $\frac{1{,}440 \text{ min/day}}{29 \text{ heats}} = 50$ minutes

2nd stage: $\frac{1{,}400 \text{ min/day}}{45 \text{ heats}} = 32$ minutes

c. Number of castings per CCM

$$\text{1st stage:} \quad \frac{\text{29 heats/day}}{\text{2 units}} = \text{14.5 heats/day}$$

$$\text{2nd stage:} \quad \frac{\text{45 heats/day}}{\text{3 units}} = \text{15 heats/day}$$

vi. Casting time and cycle time

The time required for major CC operations can be divided into preparation time for casting and casting time itself. The continuous casting operation cycle is typically as illustrated in Fig. 15.3.7.

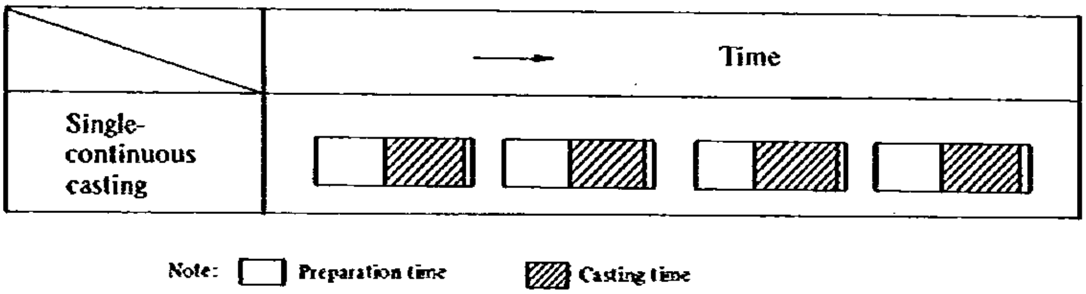


Fig. 15.3.7 Casting Schedule of Continuous Casting

The cycle time per CCM can be obtained from simple calculations.

$$\text{1st stage:} \quad \frac{\text{1,440 min.}}{\text{14.5 heats}} \fallingdotseq \text{100 minutes}$$

$$\text{2nd stage:} \quad \frac{\text{1,440 min.}}{\text{15 heats}} \fallingdotseq \text{96 minutes}$$

Therefore, at the first stage, for example, 150 tonnes of molten steel per heat is tapped from four electric arc furnaces at a 50-min. pitch and received by two CC machines, and operation is completed within 100 minutes. This means that each machine operates 14.5 heats per day.

a. Preparation time:

The preparation time for casting assumes the conditions shown in Table 15.3.17.

Table 15.3.17 Continuous Casting Preparation Time

Item	Minutes
Head cooling (cooling of preceding slab head)	3
Slab extraction (extraction of preceding slab)	20
Dummy bar insertion (for next casting)	10
Mould seal (for next casting)	10
Tundish setting (for next casting)	5
Ladle setting	2
Total	50 minutes

b. Continuous-continuous casting (sequence casting)

In conventional continous casting, as shown in Fig. 15.3.7, each casting requires preparation time approximately equal to casting time, resulting in substantially lower casting rate (total casting time/cycle time x 100 (%)). The purpose of continuous-continuous casting (sequence casting) is to improve casting efficiency. The operation cycle is shown in Fig. 15.3.8.

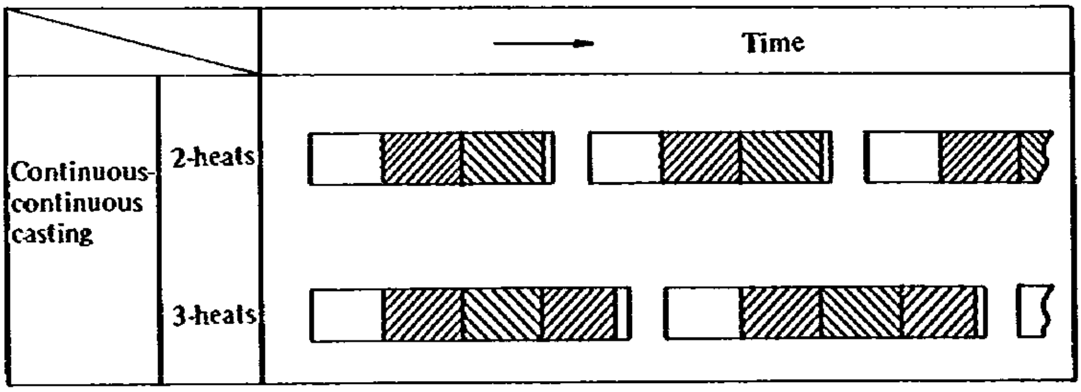


Fig. 15.3.8 Casting Schedule of Sequence Casting

c. Casting time:

When the number of heats and the preparation time in one day are considered, the allowable casting time is calculated as follows:

$$1{,}440 \text{ min/day} = (Tc + \frac{50}{n}) \times 14.5 \text{ heats/day}$$

where,

Tc = casting time (min.)

n = continuous-continuous casting ratio

Assuming a continuous-continuous casting ratio of 1.0, that is single casting only, Tc must be within 50 min. However, in the case of continuous-continuous ratio of n = 1.5, for example, two heats of continuous casting followed by one heat casting, will result in an allowable casting time of 66 minutes per heat. In other words, in the same casting time, the number of heats that can be cast increases.

d. Casting speed

Based on the above results, a continuous-continuous casting ratio of 1 ∿ 2, average 1.5, is employed in this plan. Also, casting time is assumed to be 50 ∿ 60 minutes including a safety allowance.

Assuming that a standard slab size of 200 x 1,200 mm (cross section) and a specific gravity of molten steel is 7.85 and that molten steel of 150 tonnes per heat is treated by 2-strand machines, then an average casting time of 55 minutes is obtained at 0.72 m/min from the following formula:

$$\frac{\text{Molten steel to be cast (tonnes)}}{\text{Slab weight/m} \times \text{Casting speed m/min.}} = \text{Casting time}$$

The relationship between casting speed and casting time with change in slab size is shown in Table 15.3.18.

Table 15.3.18 Casting Speed and Time

(minutes per heat)

Slab width	Speed / Unit weight	0.6 (m/min)	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
800 mm	1.25 t/m			75	67	60	54	50	46	43
850	1.33			70	63	56	51	47	43	40
900	1.40		77	67	60	54	49	45	41	
950	1.48		72	63	56	51	46	42	39	
1,000	1.56	80	69	60	53	48	44	40		
1,050	1.64	76	65	57	51	46	42	38		
1,100	1.72	73	63	54	48	44	40			
1,150	1.79	70	60	52	47	42	38			
1,200	1.87	67	57	50	45	40				
1,250	1.95	64	55	48	43	38				
1,300	2.03	62	52	46	41	37				
1,350	2.11	59	51	44	39					
1,400	2.18	57	49	43	38					
1,450	2.26	55	47	41	37					
1,500	2.34	53	45	40						
1,550	2.42	52	44	39						

The design value of the casting speed of this CCM is set at 1.5 m/min with an allowance of 20% over the average value.

(13) **Production Capacity of CC Plant**

Using the values established in preceding paragraph the operation has been simulated for this CC plant. Fig. 15.3.9 shows the case that all four electric arc furnaces are operating and Fig. 15.3.10, three are operating with one under repair. It is apparent that under normal operation conditions, planned production can be achieved even if the slab size is changed as many as 7 ~ 8 times per day.

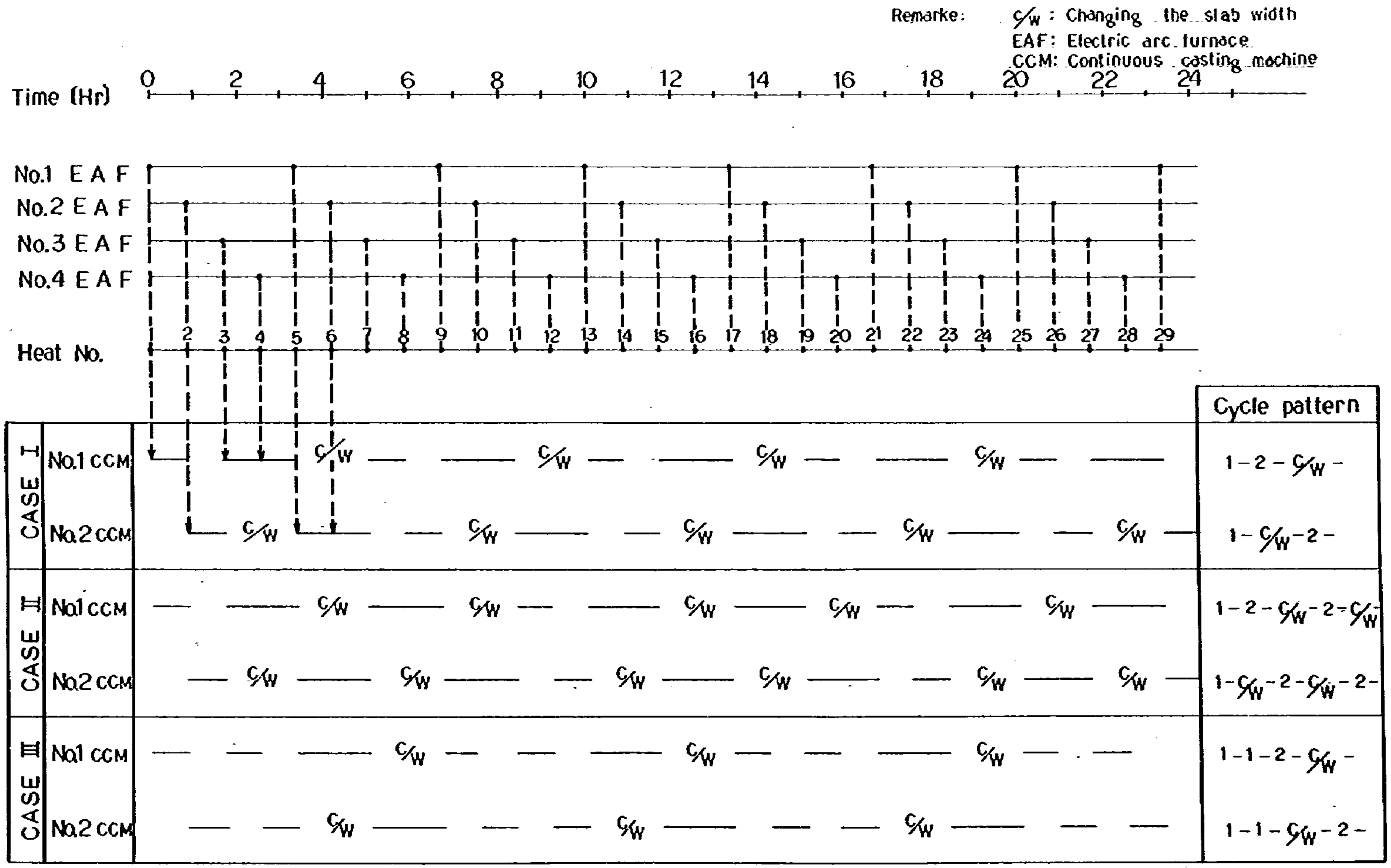


Fig. 15.3.9 Simulation – Casting Cycle – (1) (4 Furnaces are in Operation)

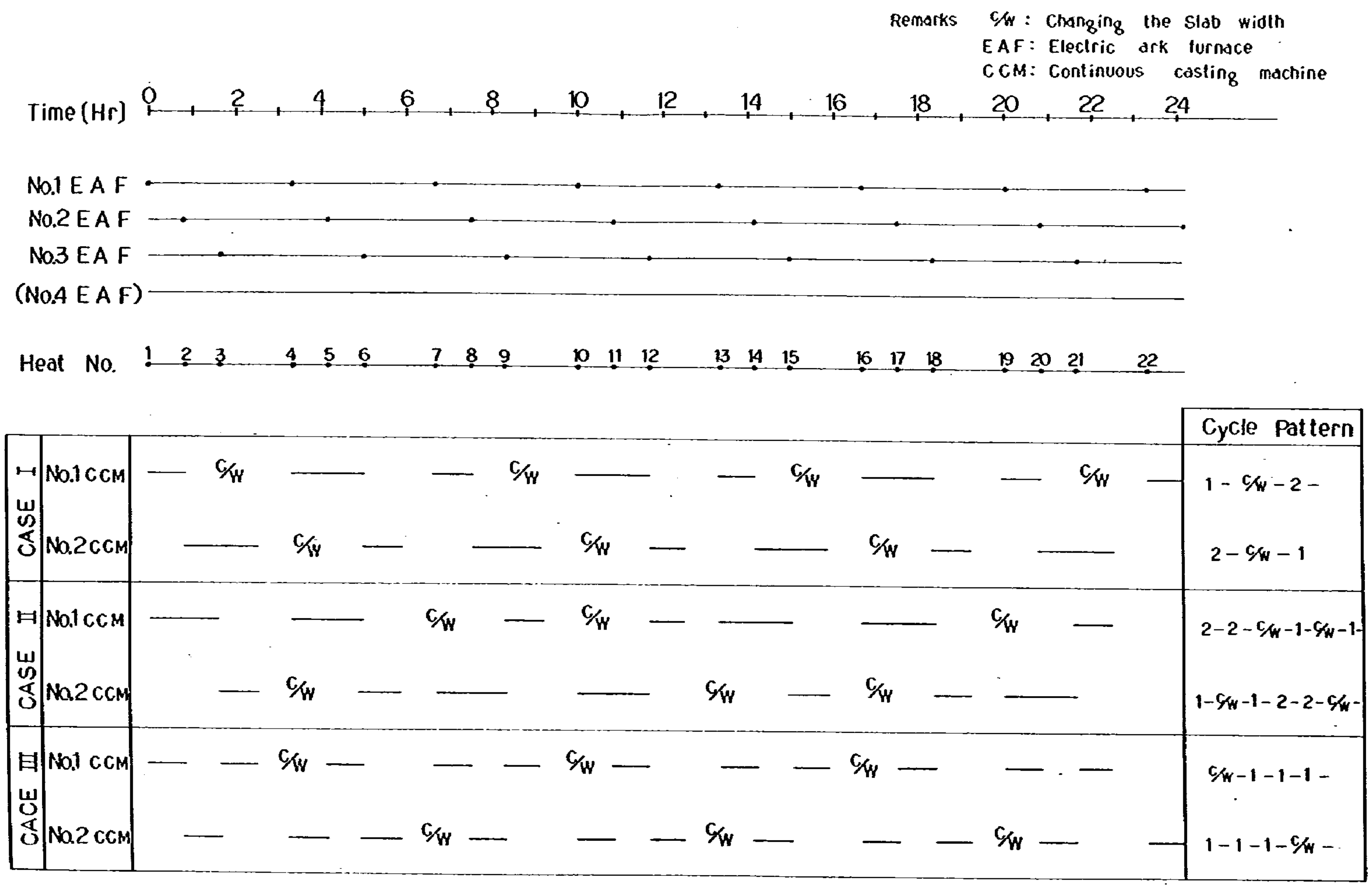


Fig. 15.3.10 Simulation – Casting Cycle – (2)

(3 Furnaces are in Operation and One is Under Repair)

(14) Description of CC Plant

i. Layout

The yard where the CC related equipment is located is divided into ladle yard, casting yard, cutting yard, slab cooling yard and slab scarfing yard according to the material flow.

The tundish repair shop is provided at the end of the casting yard and the machine maintenance shop is at the end of the cutting yard. After cooling and scarfing, slab is carried directly to the slab yard in the hot strip mill by slab cars.

In addition, the electric room which controls both CC and EAF is located outside of the plant building. The water treatment system for continuous casting plant which consists reservoir, filter, cooling tower, pump, elevated water tank, etc., is also located there.

They are shown in Figs. 15.3.2 and 15.3.3.

ii. Continuous casting machine

The length of the CC machine (slab support length including withdrawal roll) is obtained as follows:

$$L = Vc \left(\frac{S}{K}\right)^2$$

L: Machine length (m)

Vc: Casting speed (m/min)

S: Shell thickness (mm)

K: Solidification coefficient (mm $\sqrt{min}$)

Assuming a solidification coefficient of 27mm/$\sqrt{min}$, the machine length is 20.6m.

The curved mould type CCM was chosen taking into consideration the types of casting steel, construction cost, ease of operation, production efficiency, etc. The radius of curvature was set at 10.5m. Withdrawal rolls are multiple-type. Major specifications of the CCM are shown in Table 15.3.19.

Table 15.3.19 Major Specifications of Continuous Casting Machine

		Major specifications
Type		Curved mould type
Number of strands		2
Strand interval		5,000mm
Slab size	Thickness	200mm
	Width	800 ∿ 1,600
	Length	4.0 ∿ 9.3m
Max. slab weight		21.9t
Machine length		20.6m
Casting radius		10.5m
Max. casting speed		1.5m/min.
Pass line height		FL + 800mm
Casting floor height		FL + 11,300mm

Schematic drawing of these items is shown in Fig. 15.3.11.

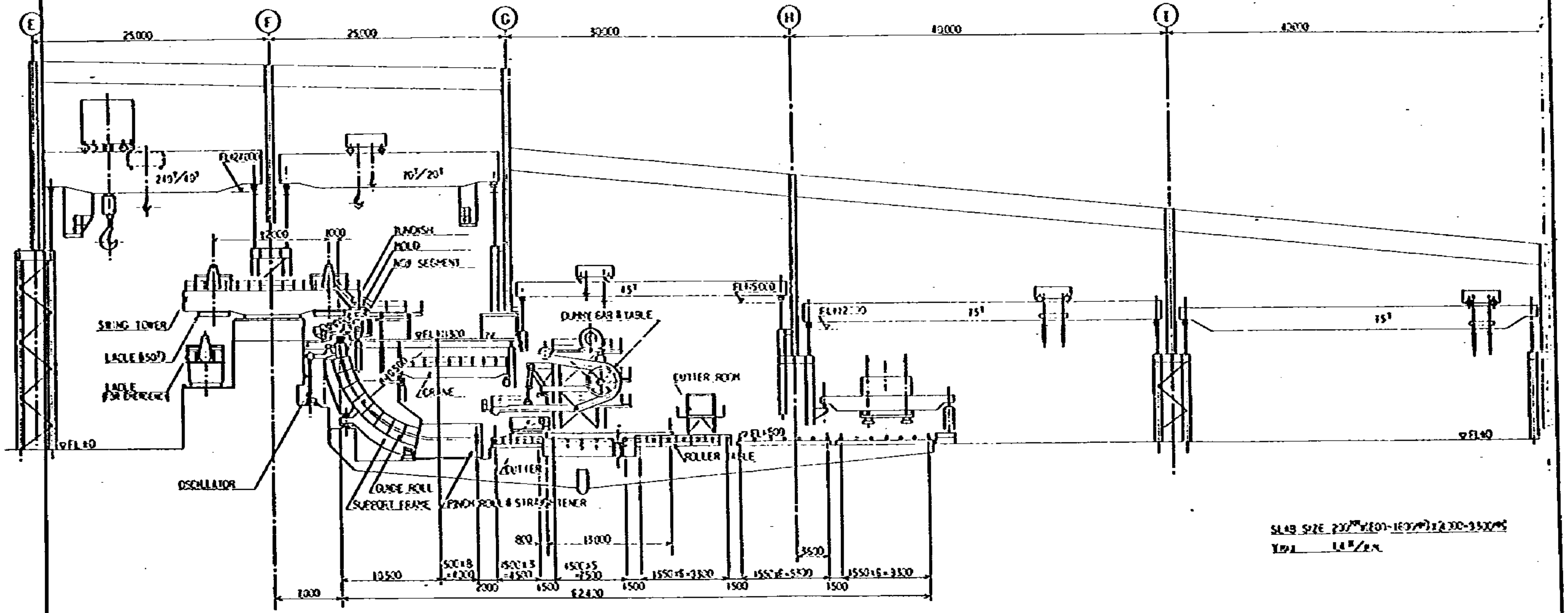


Fig. 15.3.11 Continuous Casting Machine Side View (Scale 1/200)

iii. Continuous casting ancillary facilities

To facilitate continuous-continuous casting operation, a swing tower is provided for handling the ladles during casting. A ladle elevation unit is installed to facilitate use of immersion nozzles of tundish.

The tundish is of T-shape for safety and steel quality considerations. The tundish cars are located at both sides of the CC machines and pre-heating units are provided there.

To cope with an overflow of molten steel from the tundish due to casting trouble, an emergency trough is provided with empty ladles at its end. This emergency trough also serves to handle troubles involving the ladle nozzles.

iv. Slab conditioning facilities

The slab, cut to a specified length by the synchronized cutter of the CCM, is piled in the hot condition. In this plan, a slab cooler is not provided and instead spray-cooling is executed at the pit. This is for equipment cost reduction and for achieving improved yield and energy saving by charging the hot slab directly to the heating furnace of the hot strip mill in the future; i.e., to allow for future adoption of the hot charging method.

The cooled slab is transferred to the cold scarfer and those requiring additional treatment are fed to the manual scarfing line.

Ancillaries of this facility include the dust collector for the cold scarfer and the water treatment device for the scarfer. The former is a wet electric dust collector with sufficient capacity to catch and collect dust even if two scarfers are in parallel operation. Environmental measures have been fully taken including water treatment. The water treatment device for the scarfer consists of high pressure water pump, scale sluice, scale pit, etc.

v. Slab transportation to hot strip mill

Slabs are stacked in piles by three or four as a unit and are carried to the slab yard of the hot strip mill by slab cars which travel at a speed of approx. 200m per minute on the semi-underground type rails between the steelmaking shop and hot strip mill under automatic remote control.

There will be one car at the 1st stage and another shall be added at the 2nd stage.

(15) Equipment List of CC Plant

General specifications of equipment are shown in Table 15.3.20.

Table 15.3.20 List of Specifications for Continuous Casting Facilities

	Item	Description	Q'ty	Main specifications
Molten steel transporting equipment	1	Ladle	14 ladles	Capacity: max 160t
	2	Ladle car	4 cars	Load weight: max 240t, electric, self-propelling
	3	Ladle heating equipment	4 sets	Heating capacity: for 8 hs/800°C
	4	Rotary nozzle driving equipment	15 sets	Eelctrical type
	5	Rotary nozzle cassette	21 sets	
	6	Rotary nozzle replacing equipment	2 sets	Ladle stand, nozzle attaching and removing device
	7	Rotary nozzle maintenance equipment	1 set	Cassette assembling and testing devices
	8	Ladle repair equipment	1 set	Repairing deck, brick breaker
Continuous casting pouring facilities	1	Ladle holding table	4	Steel plate welded construction
	2	Cooling and insulation materials charging device	1	
	3	Temperature measuring and sampling device	1	
	4	Bubbling device	1	N_2 or Ar gas is used
	5	Aluminium supplying device	1	9mmφ wire feeder
	6	Ladle swing tower (turret)	2	With 240t x 2 ladles
	7	Tundish	16	With stopper
	8	Tundish car	4	With elevator
	9	Tundish preheating device	4	Natural gas combustion type
	10	Tundish brick piling	16	
	11	Tundish slag pan	8	Made of cast steel, approx. $3m^3$
	12	Tundish moving car	2	30t car
	13	Cooling supply for casting personnel	2	

Table 15.3.20 (cont'd)

	Item	Description	Q'ty	Main specifications
Facilities of continuous casting machine proper	1	Continuous casting machine	2	Curved type with horizontal extraction, 2-strand, slab size 200 x 800 x 1600mm, casting radius: 10.5 m, max. casting speed: 1.5m/min.
	2	Mould	14	Copper sheet fabrication, adjustable width type.
	3	Mould oscillation device	2	Eccentric shaft lever type
	4	Support roll	2	With side roll
	5	Guide roll	2	Roll segment type
	6	Pinch roll (withdrawal roll)	2	Multiple roll system
	7	Dummy bar proper	2	Permanent type
	8	Dummy bar handling device	2	Winch lifting type
	9	Slab synchronized cutting	2	2-torch horizontal synchronized type
	10	Crop handling device	1	Pusher car system
	11	Roller table in front (rear) of cutter	4	Line shaft drive
	12	Under cutter table	2	Roll elevator
	13	Slab carrying table	2	Line shaft drive
	14	Vapour discharging device	1	Turbo fan
	15	Hydraulic unit	1	Water-glycol system
	16	Casting floor frame	1	Steel frame construction self supporting
	17	Piping	1	
Slab carrying, reparing facilities	1	Piling crane	2	60t x 2, tong hoisting
	2	Unpiling crane	2	60t x 2, with lifting magnet.
	3	Receiving roller table	1	Line shaft drive
	4	Table for scarfer	1	Line shaft drive
	5	Transfer side guide	2	Electric rack and pinion
	6	Cold scarfer	2	2 sides (L type) simultaneous
	7	Slab turner	1	Crank arm type
	8	Slab conveyor	2	Slat chain type
	9	Slab turner	1	I type electric rotation type.
	10	Carrying roller table	1	Line shaft drive
	11	Piling crane	1	60t x 2, with lifting magnet.
	12	Dust collector for scarfer	1	Wet electric dust collector
	13	Slab car	1	75t, electric, remote control

Table 15.3.20 (cont'd)

	Item	Description	Q'ty	Main specifications
Continuous casting ancillary facilities	1	Tundish repair facility	1	Tundish cooling bed
	2	Machine maintenance facility	1	Centring tables, hydrostatic pressure and hydraulic test equipment, segment bed
	3	Suspension tools and hardware	1	
	4	Piping	1	Overhead gas piping, in-pit water piping.
	5	Slab cooling pit	1	Load approx. 15 t/m^2
	6	Centralized oiling and greasing unit	1	
Cranes	1	Casting yard crane	2	70t/20t x 22m
	2	Cutter yard crane	1	45t/10t x 27m
	3	Slab cooling yard crane	2	50t + 50t x 37.5m
	4	Slab scarfing yard crane	2	50t + 50t x 37.5m
	5	Scale pit crane	1	3t x 27m (with bucket)

(16) Operation of CC Plant

The operation related to CC plant is classified broadly into three: first, preparation of ladle and tundish, preparation of nozzle and dummy bar insertion, mould preparation and clearing away; second, pouring molten steel to the CC machine and extracting and cutting the slab produced; and third, cooling and surface treatment of slab and discharging of the conditioned slab to the next process.

Among these, pouring to the CC machine, of course, accounts for the major part and takes approx. 50 ∿ 60 minutes per heat.

The operation flow is shown in Fig. 15.3.12 schematically.

(17) Operation Data of CC Plant

The quantities of the major materials and the utilities used are shown in Table 15.3.21.

Table 15.3.21 Annual Consumption of Utilities and Main Materials for Continuous Casting

		Unit consumption	1st stage	2nd stage
Utilities	Electric power	14.2 kWh/t	17,100 x 10^3kWh	27,000 x 10^3kWh
	Natural gas	4.7 Nm^3/t	5,600 x $10^3$$Nm^3$	8,900 x $10^3$$Nm^3$
	Compressed air	20	24,100 x 10^3	38,100 x 10^3
	Oxygen	18.3	22,100 x 10^3	34,800 x 10^3
	N_2/Ar.	2.8	3,400 x 10^3	5,300 x 10^3
	Circulating water	48.8 m^3/t	58,800 x 10^3 m^3	92,900 x $10^3$$m^3$
	Make-up water	2.2	2,650 x 10^3	4,200 x 10^3
	Service water	2.2	2,650 x 10^3	4,200 x 10^3
Main materials	Casting powder	1.5 kg/t	1,800 t	2,900 t
	Ladle refractory	4.7	5,700	8,900
	Tundish refractory	5	6,100	9,710
	Mould	4.7 g/t	7	9
	Roll	0.02 kg/t	24	38

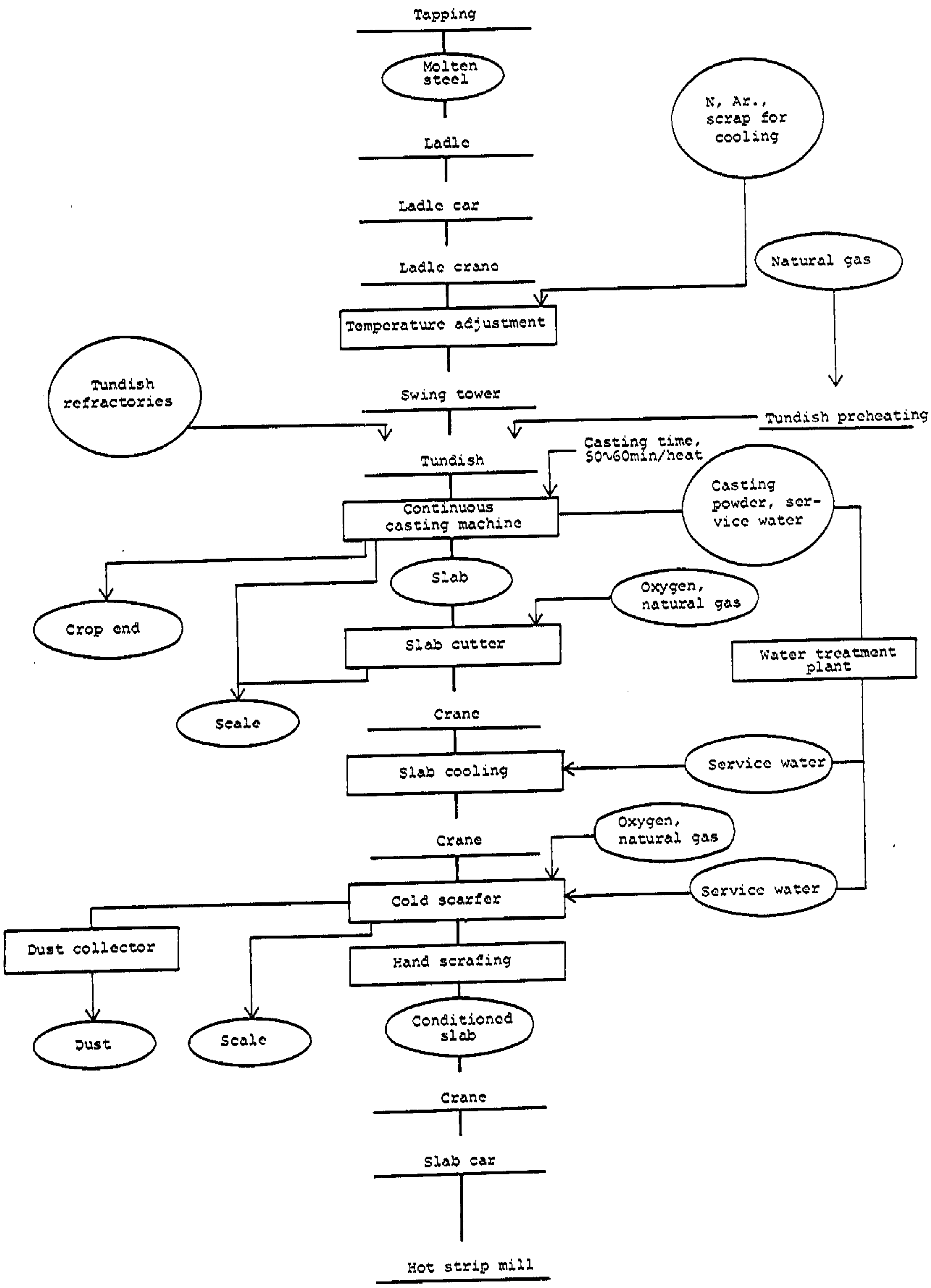


Fig. 15.3.12 Process Flow of Continuous Casting

CHAPTER 15-4

68-INCH HOT STRIP MILL PLANT

15.4 68-inch Hot Strip Mill Plant

(1) General

The hot strip mill plant produces the following hot rolled products, and hot coils for cold rolled products from the slabs supplied by the CC plant (continuous casting plant).

a. Hot rolled coil

b. Hot rolled plate and sheet

c. Hot coil for cold rolled products

The required output amount based on the as-rolled hot coils in each stage are as follows:

1st stage	1,169,000 t/y
2nd stage	1,846,000 t/y

The planned hot strip mill plant includes the rolling line and finishing line, providing the above productive capacity with effective investment in each stage. According to the plan, the following equipment will be installed in the 1st stage to meet the required output:

Rolling line :	Reheating furnace	2
	Roughing mill	1
	Finishing mill	6
	Down coiler	2
Finishing line :	Skinpass mill	1
	Shearing line	1
	Recoiling and slitting line	1

In the 2nd stage, the following equipment will be added to the rolling line to meet the planned productivity:

Reheating furnace	1
Roughing mill	1
Down coiler	1

(2) Outline of Process

Process flow sheet is shown in Fig. 15.4.1.

i. Rolling line

The slabs produced and surface conditioned in the CC plant are carried by slab transfer car to the slab yard. The slabs are removed by the overhead crane and stored waiting rolling orders.

The slabs to be rolled are piled up by the overhead crane at the side of the furnace approach table and then transferred onto the table one by one. The slabs are moved with the table to the furnace entry table and then charged into the slab reheating furnace by using the slab pusher.

The charged slabs are heated to a specified temperature, while being moved by the walking beam device through the furnace until reaching the furnace outlet. Then, slabs are extracted by the slab extractor onto the furnace delivery table.

The extracted slabs are transferred to the vertical scale breaker (VSB), where the vertical roll transversely rolls the slabs and high-pressure water is sprayed onto the slab surfaces to remove the primary scale produced on the slab surface while they are in the furnace. The slabs, 200 mm thick, are rolled into the sheet bars, 22 to 28 mm thick, by one roughing mill in the 1st stage or two roughing mills in the 2nd stage. The transverse spreading and variations caused by rolling are corrected by the edger attached to the roughing mill and finished to a specified width.

The fish tail of the sheet bars are removed by the crop shear installed in front of the finishing mill. The sheet bars then enter the finishing scale breaker (FSB), where the secondary surface scale is removed by high-pressure water jets. The treated sheet bars are then fed to the finishing mill.

The sheet bars are continuously rolled by the 6-stand finishing mill into the strip of 1.2 to 12.7 mm thick. On the hot run table, the strip is water cooled from the both sides to a specified coiling temperature. The strip is, then, wound into a coil by the down-coiler (as-rolled hot coil).

The wound coils are extracted from the down-coiler by the stripper car, up-ended and loaded on to the coil conveyor.

The coils for the finishing lines are transferred towards the coil yard by No. 1 coil conveyor and put in eye-horizontal by the down-ender. Then they are carried by the overhead crane to the coil yard and there, cooled and stored in a single layer.

The coils for the cold strip mill plant are transferred by the No. 2 coil conveyor to the coil yard. The coils are eye-horizontally positioned by the down-ender, loaded onto the trailer by the overhead crane, and transferred to the cold strip mill plant, where they are cooled.

ii. Finishing line

a. Skinpass mill

The strips are lightly cold rolled by the skinpass mill to effectuate shape corrections, mechanical property improvement, and improved surface characteristics.

The coils completely cooled at the coil yard are, according to skinpass orders, loaded by the overhead crane onto the entry conveyor to pass through the uncoiler, the mill, and the tension reel to be the skinpassed coils.

The coils to be shipped as "mill edges" are divided into a specified coil weight (max. 8 t/coil) by the dividing shear mounted between the mill stand and the tension reel, then bound and packaged.

The coils to be shorn are, by the coil transfer car, transferred to the coil yard for the shearing line without being divided.

b. Shearing line

The coils completely cooled at the coil yard and the skinpassed coils are, in accordance with shearing orders, loaded onto the entry conveyor by the overhead crane to pass through the main equipment such as the uncoiler, the side trimmer, the up-cut shear or the flying shear, the heavy gauge leveller or the light gauge leveller, and the prime piler to be formed into the plates and sheets, then bound and packaged.

c. Recoiling and slitting line

The coils completely cooled at the coil yard are, according to orders of recoiling or slitting, loaded by the overhead crane onto the entry conveyor to pass the main equipment of the uncoiler, the slitter, the dividing shear, and the tension reel to be formed into the trimmed-edge coil, then bound and packaged.

d. Delivery

The bound and packaged products are loaded by the overhead crane onto the trailer and transferred to the product warehouse.

(3) Conditions for Equipment Plan

i. Slab

a. Material: Low carbon mild steel

b. Size

Thickness : 200 mm

Width : 600 to 1,600 mm

Length : 4,000 to 9,100 mm

c. Weight : 22.9 t/slab (max.) [800 PIW]

ii. Products

a. Hot rolled coil

Thickness : 1.2 to 12.7 mm

Width : 600 to 1,600 mm

Weight : 8 t/coil (max.)

b. Hot rolled plate and sheet

Thickness : 1.2 to 12.7 mm

Width : 762 to 1,524 mm

Length : 10,000 mm (max.)

c. Hot coil for cold rolled products

Thickness : 1.6 to 6.0 mm

Width : 600 to 1,300 mm

Weight : 18 t/coil (max.)

iii. Respective production and typical size by use

a. Annual production

Annual production in each stage is shown in Table 15.4.1.

b. Typical size of products

Typical size and coil weight of products are shown in Table 15.4.2.

iv. Operating conditions

The operating conditions of each equipment are shown in Table 15.4.3.

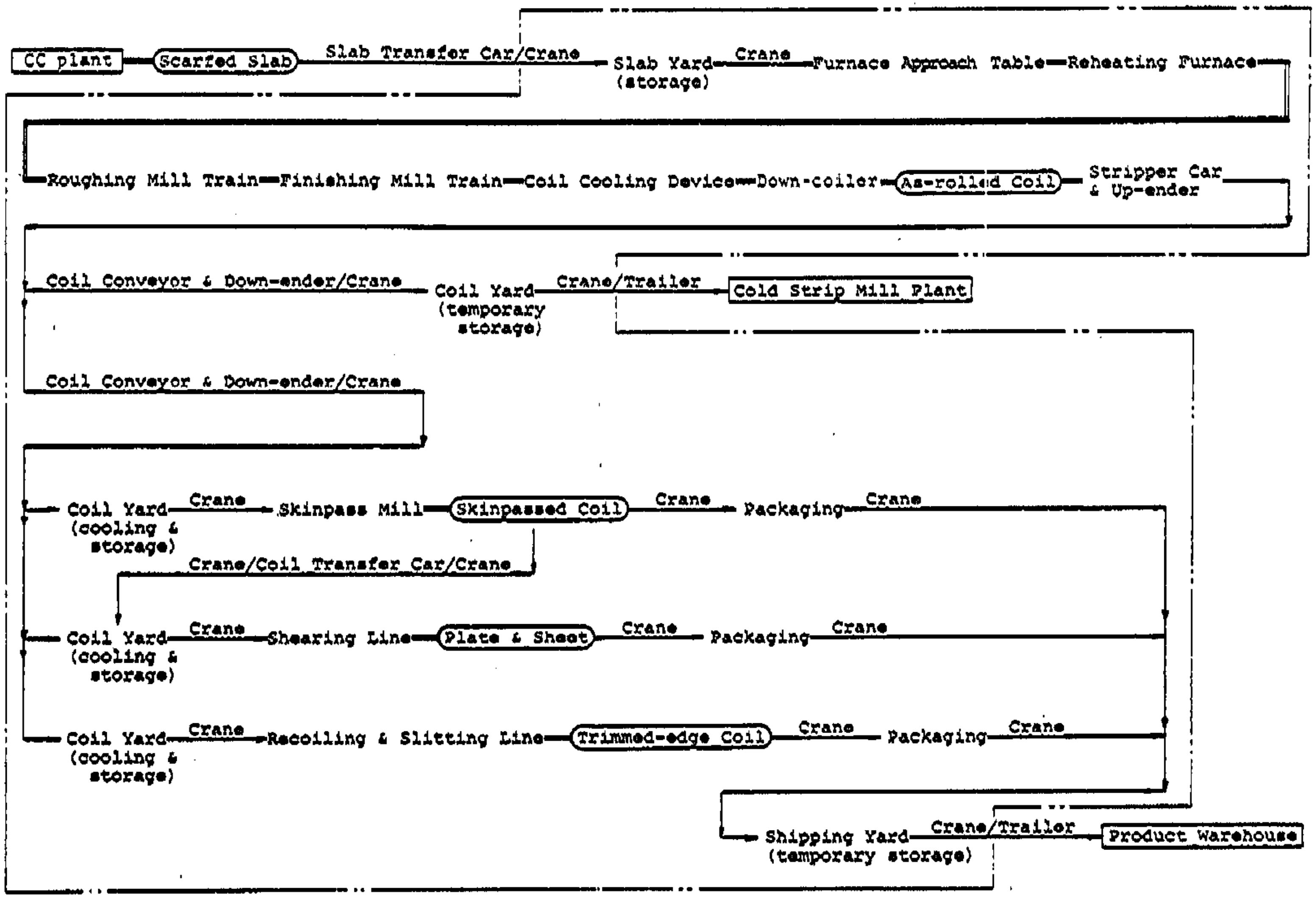


Fig. 15.4.1 Process Flow

Table 15.4.1 Annual Production (As-rolled Hot Coil)

Use	1st stage		2nd stage	
	1,000 t/y	%	1,000 t/y	%
Hot rolled coil	436	37.3	679	36.8
Hot rolled plate & sheet	212	18.1	291	15.7
Sub-total	(648)	(55.4)	(970)	(52.5)
Cold rolled coil	56	4.8	77	4.2
Cold rolled sheet	130	11.1	183	9.9
Galvanized sheet	246	21.1	334	18.1
Tinplate	89	7.6	282	15.3
Sub-total	(521)	(44.6)	(876)	(47.5)
Grand total	1,169	100	1,846	100

Table 15.4.2 Typical Size of Products (As-rolled Hot Coil)

Use	Thickness (mm)	Width (mm)	Coil weight (t)
Hot rolled coil	3.2	1,240	17.2
Hot rolled plate & sheet	6.0	1,240	17.2
Cold rolled coil	3.8	1,240	17.2
Cold rolled sheet	2.8	1,240	17.2
Galvanized sheet	1.8	785	10.9
Tinplate	2.0	835	11.6

Table 15.4.3 Operating Conditions

Item	Unit	Rolling line	Skinpass mill		Shearing Line		Recoiling & slitting line	
Stage		1st & 2nd	1st	2nd	1st	2nd	1st	2nd
(1) Calender time *1	(h/y)	8,760	8,760		8,760		8,760	
(2) Annual maintenance time	(h/y)	144 *2	120 *3		72 *4		72 *4	
(3) Weekly maintenance time *5	(h/y)	816	816		816		816	
(4) Lunch time	(h/y)	0	618 *6	978 *7	622 *8	984 *9	622 *8	984 *9
(5) Non shift working time	(h/y)	0	2,472 *10	0	2,488 *11	0	2,488 *11	0
(6) Total scheduled suspension time =(2)+(3)+(4)+(5)	(h/y)	960	4,026	1,914	3,998	1,872	3,998	1,872
(7) Time to operate =(1)-(6)	(h/y)	7,800	4,734	6,846	4,762	6,888	4,762	6,888
(8) Rate of operation	(%)	75	85	85	75	75	70	70
(9) Operating time = (7) x (8)	(h/y)	5,850	4,024	5,819	3,572	5,166	3,333	4,821
(10) Number of shift *12	(S/d)	3	2	3	2	3	2	3

Notes:

*1) 24h/d x 365d/y = 8,760h/y
*2) 24h/d x 6d/y = 144h/y
*3) 24h/d x 5d/y = 120h/y
*4) 24h/d x 3d/y = 72h/y
*5) 16h/w x 51w/y = 816h/y
*6) 1h/S x [2S/d x (365-5-51)d/y] = 618h/y
*7) 1h/S x [3S/d x (365-5-51)d/y + 1S/d x 51d/y] = 978h/y
*8) 1h/S x [2S/d x (365-3-51)d/y] = 622h/y
*9) 1h/S x [3S/d x (365-3-51)d/y + 1S/d x 51d/y] = 984h/y
*10) 8h/S x 1S/d x (365-5-51)d/y = 2,472h/y
*11) 8h/S x 1S/d x (365-3-51)d/y = 2,488h/y
*12) 3S/d = 24h/d, 2S/d = 16h/d
(w: week)
(S: shift)

(4) Description of Equipment

i. Rolling line

The rolling line layout is designed so that the total requirement of productive capacity including the 2nd stage will be covered by one line. That is, one rolling line will produce 1,846,000 t/y based on as-rolled hot coil, when the 2nd stage is completed, while each equipment will be installed to meet the product amount required for each stage.

The 5 feet maximum product width is planned, together with the use of 68-inch mill, based on the consideration that, first, this plan does not include a plate mill installation, and second, this plan's product width should meet future possibility of rolling hot rolled flat products which will be wider.

The planned rolling line is capable of meeting 85% of heavy plate demand and 97% of total demand of hot rolled flat products in Thailand.

a. Slab yard

In this plant, the slab yard will be provided next to the CC plant, so that this slab yard will receive and store the slabs produced and conditioned in the CC plant.

The slabs transferred from the CC plant by the slab transfer cars are picked up by the overhead crane and transported to be stored at desired places in the slab yard. The stored slabs wait rolling order to be delivered to the furnace approach table. The slab yard will have two buildings in the 1st stage and one more building in the 2nd stage; three buildings in total. In each stage, the planned slab yard will have enough space to store about 10 days production.

b. Reheating furnace

The number of reheating furnaces will be, based on the ease of operation and investment efficiency, two in the 1st stage and one in the 2nd stage; three in total. The type of reheating furnace is specified as the walking beam type to reduce skid marks and damages on the slab back surfaces. The fuel for the reheating furnaces will be natural gas only.

c. Roughing mill train

The semi-continuous type roughing mill train is selected from full continuous, semi-continuous and three quarter types, from the viewpoint of the capacity and investment efficiency.

The planned reversible roughing mills will be installed one by one in each stage, two in total.

d. Finishing mill train

In the 1st stage, 6 stand finishing mill will be installed to secure high quality strip (rolling temperature, shapes, gauge accuracy, etc.). The 1st stage facility can cover the total productivity, so the 2nd stage needs no additional mill stand or mill motor power.

Work roll autochanging device for facilitation of roll changing operation and automatic gauge control (AGC) device for accuracy of strip gauge will be installed respectively.

e. Downcoiler

As the down-coiler is used under extremely severe conditions, such as high temperature, high humidity, high speed, and strong impact, it is generaly vulnerable to equipment troubles requiring frequent maintenance. Therefore, it is planned to install a total of three down-coilers, two in the 1st stage and one in the 2nd stage in order to secure designated level of mill operation.

f. Coil yard

The coils are cooled and stored in eye-horizontal state at the coil yard of each finishing line. The transfer is made by the overhead crane with coil tong. The coils for cold strip mill plant are cooled and stored in the cold plant.

ii. Finishing lines

a. Skinpass mill

2-Hi type is selected from 4-Hi type and 2-Hi type, on the basis of product quality and investment efficiency. The dividing shear will be installed between the mill stand and the tension reel to meet the need that the skinpassed coils products should be divided. (The maximum weight is 22.2 tonnes/coil at the entry, 8 tonnes/coil at the exit.)

b. Shearing line

The shearing line uses only one line for shearing a wide range of thickness, 1.2 to 12.7 mm.

The planned line layout is as follows.

Uncoiler —— Side trimmer —┬— Up-cut shear — Heavy leveller (Thick gauge) —┬— Piler
                                                  └— Flying shear — Light leveller (Thin gauge) —┘

This shearing line is planned by considering the up-cut shear's cutting ability for thick material and the flying shear's productivity for thin material.

c. Recoiling and slitting line

The recoiling and slitting line uses only one line to make recoiling and slitting. To enable this, the planned line layout essentially comprises uncoiler, crop shear, slitter, dividing shear, tension reel and belt wrapper. The maximum weight of coil is 8 tonnes at the exit.

d. Binding

The products from the above a. b. and c. finishing lines are temporarily stored at each line exit. The products to be bound with bare bands are manually bound on the chain conveyors located at each line exit. If the products need to be packed with paper or metal, the packing will be performed off-line.

e. Delivery

The hot coils for the cold products are carried to the cold plant and the finished hot products are carried to the product warehouse by trailers. A sidetrack to the hot strip mill plant is recommended to facilitate directly loading finished products to freight car.

iii. Main equipment

Table 15.4.4 shows the number of main equipment.

Table 15.4.4 Number of Main Equipment

Main equipment		1st stage	2nd stage
Rolling line	Reheating furnace	2	3
	Roughing mill	1	2
	Finishing mill	6	6
	Down-coiler	2	3
Finishing line	Skinpass mill	1	1
	Shearing line	1	1
	Recoiling & slitting line	1	1

iv. Specification of main equipment

Specification of main equipment is shown in Table 15.4.5.

Table 15.4.5 Specifications of Main Equipment

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
1. Rolling line		Capacity: Refer to Table 15.4.6		Capacity: Refer to Table 15.4.6
(1) Reheating furnace facilities				
(a) Reheating furnace	2	Capacity: 150 t/h/each Type : Walking beam type	1	Same as left
(b) Slab pusher	2	Type: Motor driven rack & pinion type	1	Same as left
(c) Slab extractor	2	No. of rams : Four(4)/each Up-down motion: Hyd. cylinder Running : Motor driven	1	Same as left
(2) Roughing mill train				
(a) Vertical scale breaker (VSB)	1	Main motor : AC 1,000 kW Rolling speed : 70 m/min Roll size : $1,140^{\phi} \times 430^{L}$ mm	-	
(b) No.1 edger (E-1)	-		1	"R-1" Front edger Main motor: DC 740 kW Roll size : $860^{\phi} \times 380^{L}$ mm
(c) No.1 roughing mill (R-1)	-		1	Mill type : 4Hi, Reversible Main motor : DC 4,000 kW Rolling speed: 75/150 m/min Roll size: WR: $1,070^{\phi} \times 1,727^{L}$ mm BUR: $1,570^{\phi} \times 1,727^{L}$ mm

Note: The quantities of 2nd stage mean an additional equipment.

Table 15.4.5 (cont'd)

	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
(d) No.2A edger (E-2A)	1	"R-2" Front edger Main motor: DC 740 kW Roll size : $860^{\phi} \times 380^{L}$ mm	-	
(e) No.2 roughing mill (R-2)	1	Mill type : 4Hi, Reversible Main motor : DC 7,000 kW Rolling speed: 135/270 m/min Roll size: WR: $1,070^{\phi} \times 1,727^{L}$ mm BUR: $1,570^{\phi} \times 1,727^{L}$ mm	-	
(f) No.2B edger (E-2B)	1	"R-2" Back edger Same as "E-2A"	-	
(g) Roll changing device	1	For "R-2" WR : Changing car with side shift type BUR: Hyd. operated sled type	1	For "R-1" WR : Same as left BUR: Same as left
(3) Finishing mill train				
(a) Crop shear	1	Capacity: Thickness: 35 mm (max) Width : 1,600 mm (max) at 900°C (min) Type : Rotary drum type		

Table 15.4.5 (cont'd)

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
(b) Finishing mill	1	Mill type : 4Hi, 6stand tandem mill. Main motor : F-1～5 : DC 5,500 kW /each stand F-6 : DC 4,500 KW Rolling speed: 950 m/min (max) Roll size: WR: $740^{\phi}\times1,727^{L}$ mm BUR: $1,570^{\phi}\times1,727^{L}$ mm	-	
(c) Roll changing device	6	WR : Changing car with side shift type BUR: Hyd. operated sled type	-	
(4) Hot run table & strip cooling device	1	Strip cooling: Laminer flow type	-	
(5) Down-coiler	2	Type : 3 Wrapper roll type Main motor : DC 600 kW /each Mandrel dia. : 760^{ϕ} mm	1	Same as left
(6) Coil conveyor	1	From coiler to coil yard Total length: 370 m (approx.)	-	

Table 15.4.5 (cont'd)

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
2. Finishing lines				
(1) Skinpass mill	1	Capacity : 334,000 t/y (skinpassed coil) Type : 2Hi Strip thickness: 1.2 ~ 6.5 mm Strip width : 600 ~ 1,600 mm Coil weight : 23t/coil (max) Skinpass speed : 350 m/min (max) Roll size : $860^{\phi} \times 1{,}727^{L}$ mm Main equipment : Uncoiler Mill Dividing shear Tension reel Conveyor for packaging	-	Capacity: 488,000 t/y (skinpassed coil) Note: 1st Stage: 2 shift/d operation 2nd Stage: 3 shift/d operation

Table 15.4.5 (cont'd)

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
(2) Shearing line	1	Capacity : 206,000 t/y (plate & sheet) Type : Stop cut & flying cut Strip thickness: 1.2~12.7 mm Strip width : 600~1,600 mm Coil weight : 23 t/coil (max) (entry section) Cut-to-length : 10,000 mm (max) Line speed : 60/100 m/min Main equipment : Uncoiler Side trimmer Up-cut shear Flying shear Heavy leveller Light leveller Piler Conveyor for packaging	-	Cpacity: 301,000 t/y (plate & sheet) Note: 1st Stage: 2 shift/d operation 2nd Stage: 3 shift/d operation

Table 15.4.5 (cont'd)

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
(3) Recoiling & slitting line	1	Capacity : 192,000 t/y (trimmed-edge coil) Strip thickness: 1.2～9.0 mm Strip width : 1,600 mm (max) Coil weight Entry: 23 t/coil (max) Delivery: 8 t/coil (max) Line speed : 100 m/min (max) Slitting cap. : 4 cuts in 9mm thickness at 100 m/min Main Equipment : Uncoiler Slitter Dividing shear Tension reel Belt wrapper Conveyor for packaging	-	Capacity: 281,000 t/y (trimmed-edge coil) Note: 1st Stage: 2 shift/d operation 2nd Stage: 3 shift/d operation

Table 15.4.5 (cont'd)

Equipment	1st stage		2nd stage	
	Q'ty	Main specifications	Q'ty	Main specifications
3. Auxiliary equipment				
(1) Roll grinder	4	For back up roll (R-mill & F-mill)	1	For work roll (F-mill)
		For work roll (R-mill)		
		For work roll (F-mill)		
		For general use		
(2) Roll lathe	1	For back up roll & other use		
(3) Crane	28		3	
4. Area of main building		Approx. 79,400 m^2		Approx. 6,700 m^2
5. Capacity of Slab Yard		Approx. 41,000 tonne (for 10 days)		Approx. 61,000 tonne (for 10 days)

v. Production capacity of rolling line

Production capacity of rolling line is shown in Table 15.4.6.

Table 15.4.6 Production Capacity of Rolling Line

Item	Unit	1st stage	2nd stage
Time to operate	h/y	7,800	7,800
Rate of operation	%	75	75
Yield	%	97	97
Average t/h	slab-t/h	242	373
Line capacity *1)	coil-t/y	1,373,000	2,116,000
Required production	coil-t/y	1,169,000	1,846,000

Note: *1) Calculation of line capacity
1st stage: 242 t/h x 7,800 h/y x 0.75 x 0.97 = 1,373,000 t/y
2nd stage: 373 t/y x 7,800 h/y x 0.75 x 0.97 = 2,116,000 t/y

(5) Material Flow

The material flow is shown in Fig. 15.4.2.

(6) Plant Layout

Plant layout is shown in Fig. 15.4.3.

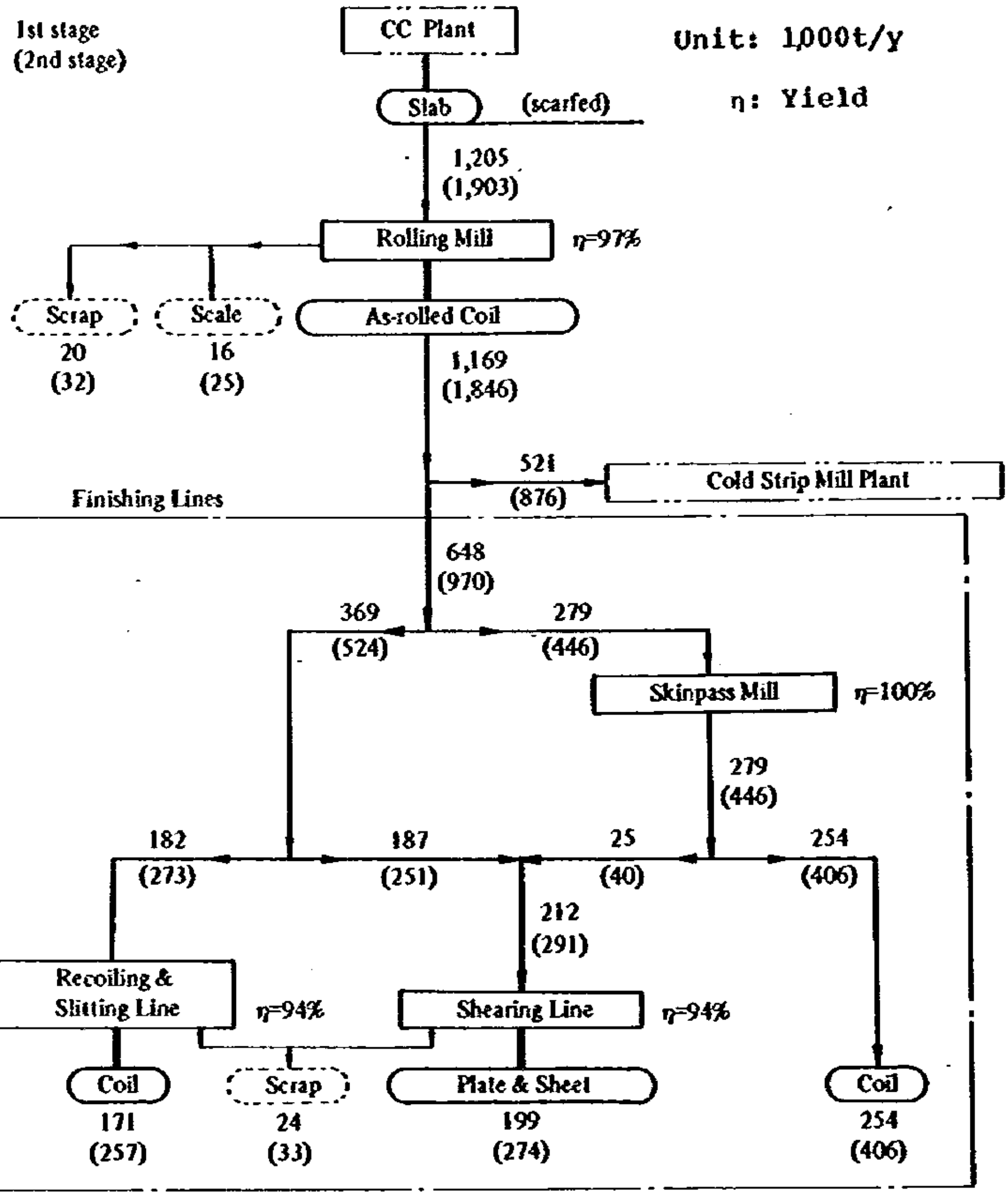
(7) Operation Data

i. Utility

Consumption of utilities is shown in Table 15.4.7.

ii. By-product

Amount of by-products is shown in Table 15.4.8.



Finished Products:	624 (937)
By-product (Scrap):	44 (65)
By-product (Scale):	16 (25)

Fig. 15.4.2 Material Flow

NO	NAME
1	SLAB TRANSFER CARS
2	SLAB REHEATING FURNACE NO.1 AND NO.2 (NO.3 F'CE: 2nd Stage)
3	VERTICAL SCALE BREAKER
4	ROUGHING MILL R-1 WITH ATACHED EDGER, E-1 (2nd Stage)
5	ROUGHING MILL R-2 WITH ATACHED EDGER, E-2a, E-2b
6	FINISHING MILL GROUP, F-1 ~ 6
7	DOWN-COILER NO.1 AND NO.2 (NO.3 D.C: 2nd Stage)

NO	NAME
8	COIL CONVEYOR
9	SKINPASS MILL
10	SHEARING LINE
11	SHEET PACKAGING LINE
12	RECOILING AND SLITTING LINE
13	COIL PACKAGING LINE
14	SCALE PIT NO.1, NO.2 AND NO.3

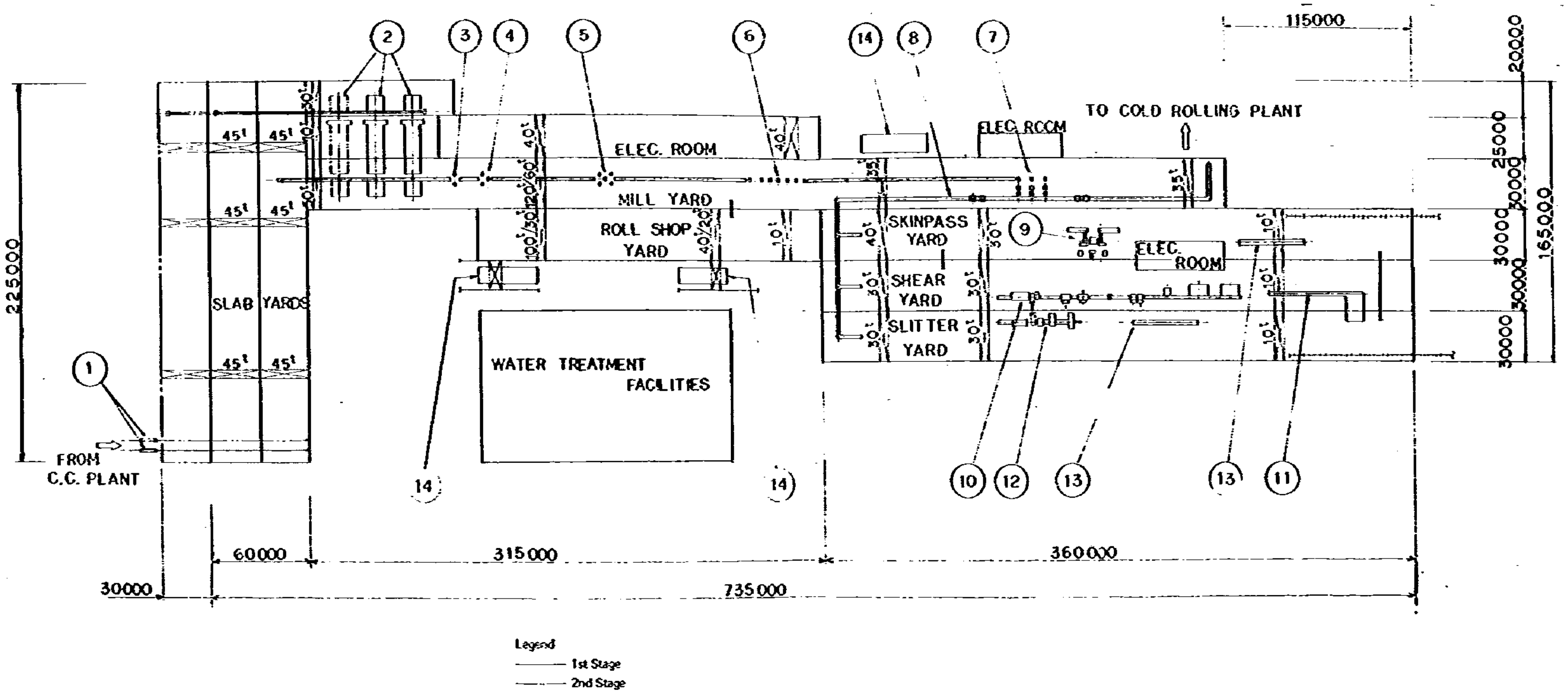


Fig. 15.4.3 Plant Layout

Table 15.4.7 Consumption of Utilities

Item	Stage	Unit consumption	Annual consumption
Natural gas	1st	56.4 Nm^3/t	65.9 x 10^6 Nm^3/y
	2nd	56.4 Nm^3/t	104 x 10^6 Nm^3/y
Electric power	1st	101 kWh/t	118 x 10^6 kWh/y
	2nd	101 kWh/t	186 x 10^6 kWh/y
Make-up water	1st	2.78 m^3/t	3.25 x 10^6 m^3/y
	2nd	2.32 m^3/t	4.28 x 10^6 m^3/y
Recirculation water	1st	61.8 m^3/t	72.3 x 10^6 m^3/y
	2nd	51.6 m^3/t	95.2 x 10^6 m^3/y
Steam	1st	12.4 kg/t	14.5 x 10^6 kg/y
	2nd	12.4 kg/t	22.8 x 10^6 kg/y
Compressed air	1st	36.7 Nm^3/t	42.9 x 10^6 Nm^3/y
	2nd	28.3 Nm^3/t	52.2 x 10^6 Nm^3/y

Note: Production (as-rolled hot coil)
1st stage: 1,169,000 t/y
2nd stage: 1,846,000 t/y

Table 15.4.8 Amount of By-products

Line	By-products	1st stage (t/y)	2nd stage (t/y)
Rolling line	Scrap	20,000	32,000
	Scale	16,000	25,000
Shearing line	Scrap	13,000	17,000
Recoiling & slitting line	Scrap	11,000	16,000
Total	Scrap	44,000	65,000
	Scale	16,000	25,000

(8) Organization and Personnel

i. Organization

The organization is as follows.

- Hot strip mill plant
  - Office work group
  - Hot rolling group
  - Hot finishing group
  - Crane group
  - Roll group

ii. Personnel

Personnel for hot strip mill plant are shown in Table 15.4.9.

Table 15.4.9 Personnel for Hot Strip Mill Plant

Sup't.	Group	Ass't. sup't.	Engineer	Clerk	Foreman	Skilled worker	Semi-skilled worker	Un-skilled worker	Sub-total of group
1 (1)	Office work	1 (1)	– (–)	4 (4)	– (–)	– (–)	– (–)	– (–)	5 (7)
	Rolling	1 (1)	3 (3)	9 (11)	7 (8)	38 (41)	77 (86)	55 (81)	190 (231)
	Finishing	1 (1)	2 (2)	2 (3)	3 (4)	16 (24)	31 (47)	50 (75)	105 (156)
	Crane	1 (1)	1 (1)	1 (1)	3 (3)	17 (24)	23 (29)	21 (27)	67 (86)
	Roll	1 (1)	1 (1)	1 (1)	3 (3)	10 (14)	7 (11)	17 (23)	40 (54)
1 (1)		5 (5)	7 (7)	17 (22)	16 (18)	82 (103)	137 (173)	143 (206)	407 (534)
Total						408 (535)			

Notes: 1) Figures in ( ) show the number of personnel required at the 2nd stage.
2) Finishing means skinpass, shearing & slitting.

CHAPTER 15-5

56-INCH COLD STRIP MILL PLANT

15.5 56-inch Cold Strip Mill Plant

(1) General

The cold strip mill plant produces the following products from hot coils supplied by the hot strip mill plant:

a. Cold rolled coils and sheets for general use

b. Cold rolled coils for galvanized sheet

c. Cold rolled coils for tinplate

Annual output in each stage is as follows:

1 st stage	479,000 t/y
2nd stage	804,000 t/y

The cold strip mill plant plan is to satisfy the above production volume as planned with the effective investment at each stage.

In each stage, the following major equipment will be installed.

1st stage

Pickling line	1
5 stand tandem cold strip mill	1
Cleaning line	2
Batch annealing furnace	1
2 stand skinpass mill	1
Shearing & slitting line	1
Coil preparation line	1

2nd stage

6 stand tandem cold strip mill	Expansion
Reversing cold strip mill	1
Batch annealing furnace	Expansion

Continuous annealing line	1
Single stand skinpass mill	1
Shearing line	1
Coil preparation line	1

(2) **Outline of Process**

Process flow is shown in Fig. 15.5.1.

i. Pickling

Hot coils rolled in the hot strip mill plant are transferred by trailer into the hot coil yard in the cold strip mill plant, relayed from the trailer to the overhead crane to be stored. In accordance with pickling order, the coils are loaded by the overhead crane into the pickling line. The pickling line handles coil surface descaling, coil build-up, side trimming, pre-coat oiling, etc. The pickled coils are transferred from the pickling yard by the coil conveyor to the rolling yard, where the overhead crane handles the coils to place them in the rolling coil yard.

ii. Cold rolling

Coils are, according to the respective rolling orders, loaded by the overhead crane into the tandem cold strip mill or the reversing cold strip mill and rolled into cold strip of a specified thickness. Coils to be cleaned are transferred by the overhead crane to the cleaning coil yard. Coils not to be cleaned are loaded by the overhead crane into the up-ender to be brought into the eye-vertical state, then transferred by the overhead crane to the coil yard for batch annealing. Coils to be continuously annealed are transferred by the overhead crane and the coil car from the rolling yard to the continuous annealing yard to be stored.

iii. Cleaning

The cold rolled strips which are rolled in the cold strip mill using palm or tallow base rolling oil have to be degreased and cleaned to remove the oil from the surface of the strips. These oils, if remained, may cause in the next annealing process carbon deposit on the surface of the strips and may affect surface appearance and plating efficiency. In the cleaning line, the coils are loaded by the overhead crane into the line to be degreased by electrolytic and brushing operation. The cleaned coils are transferred by the coil conveyor to the up-ender to be brought into the eye-vertical state, then transferred by the overhead crane to the annealing coil yard. Full hard coils for galvanized sheet are transferred by the coil conveyor to the finishing coil yard without receiving annealing.

iv. Batch annealing

Cold rolled strip has, as it is, a property too hard to be processed by bending or deep drawing. Annealing is carried out to provide the cold rolled strip with improved mechanical property and formability. Then the coils are transferred from the coil yard to the batch annealing furnace by the overhead crane and coil car. The coils are stacked in several tiers on the annealing base, mounted with inner cover and outer cover, then subjected to heating and soaking at a specified temperature, and, with the outer cover removed, the coils are cooled down.

In cooling process, cooling cover is used to reduce cooling time. In annealing process, a reducing atomospheric gas is introduced into the inner cover to prevent the strip oxidation. The annealed coils are transferred by the overhead crane and the coil car to the down-ender. The coils are brought into the eye-horizontal state by the down-ender, and transferred by the coil conveyor to the coil cooling yard. In the coil cooling yard, the coils are transferred by the overhead crane to the coil yard to be stored, where the coils are cooled down to near room temperature, while receiving dry air blow to prevent rust development.

v. Continuous annealing

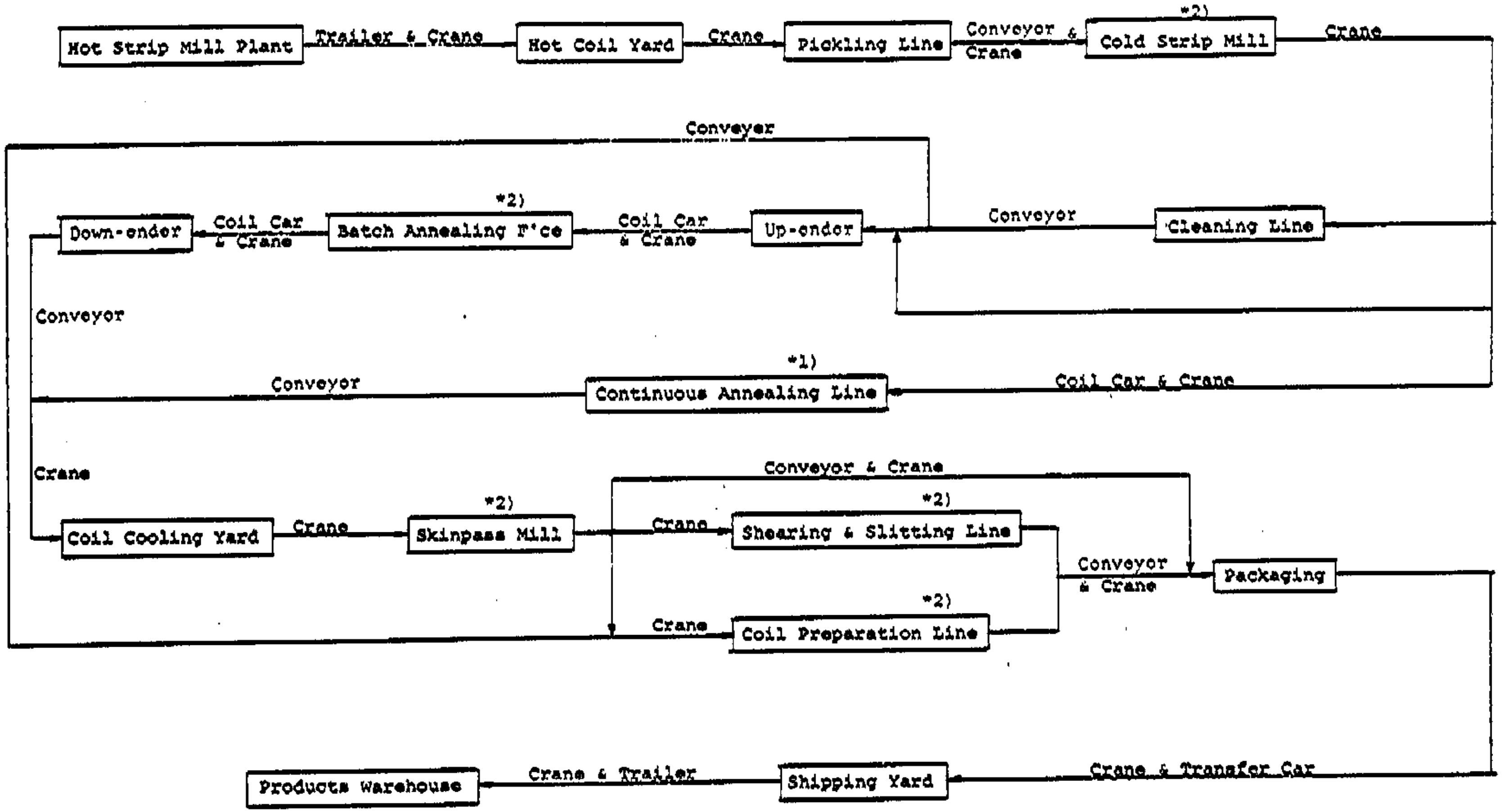
The coils for continuous annealing are loaded by the overhead crane from the coil yard into the continuous annealing line and continuously degreased and annealed. The entire length of the strip is uniformly annealed and subjected to rapid heating and cooling. Therefore, the continuous annealing line is used to anneal high temper grade coils for tinplate where hardness is required. The annealed coils are transferred by the coil conveyor to the coil cooling yard.

vi. Temper rolling

The annealed coils are temper rolled by skinpass mill so that the coils are prevented from stretcher strain at processing and provided with required mechanical property, corrected strip shape, and surface finish having adequate roughness for respective applications. The coils in the coil yard are loaded by the overhead crane into the skinpass mill and temper rolled. Either the single stand skinpass mill or the 2-stand skinpass mill is used according to the thickness of the strip and the temper grade. The temper rolled coils are transferred by the overhead crane to the required finishing equipment. The cold coils for general use to be shipped as "mill edges" are divided into a specified unit weight of coils by using the dividing shear mounted on the skinpass mill, and are transferred by the coil conveyor to the packaging yard.

vii. Finishing

The temper rolled coils are, in accordance with the customer's specifications, processed into side trimming, recoiling, shearing, slitting, etc., in respective coil preparation line, shearing and slitting line, shearing line, and finished into coils or sheets with specified unit weights and dimensions. At the same time, the products undergo final delivery inspection for dimensional accuracy, surface defects, flatness, etc., and applied with rust preventive oil and packaged. The coil preparation line handles cold coils for tinplate and cold coils for galvanized sheet, which are then packaged in sequence on the following coil packaging line to be transferred by the overhead crane to the shipping yard. Cold coils for general use are shorn or slitted into sheets or coils in the shearing and slitting line or the shearing line. The cut sheets are packaged in sequence on the following packaging line and transferred by the overhead crane to the shipping yard. Meanwhile, the slitted coils are packaged, similarly to the skinpass mill divided coils, on the off-line package yard and transferred to the shipping yard by the overhead crane and transfer cars. The finished and packaged products are loaded on the trailers by the overhead crane and transferred to the products warehouse.



Note
*1) Installed at 2nd Stage
*2) Expanded at 2nd Stage
Refer to Table 15.5.4

Fig. 15.5.1 Process Flow