Table 3.1.15 COALFIELDS-WISE, MODE-WISE COAL MOVEMENT

(Unit : million tons)

COALFIELD	RAIL	ROAD	MGR	OTHER	TOTAL
MAKUM	0.73	0.22			0.95
RANIGANJ	17.72	3.72			21.44
MUGMA-SALANPUR	4.00	0.92			4.92
RAJMAHAL			2.85		2.85
JHARIA	16.37	5.53			21.90
(MIDDLINGS)	1.40			0.50	1.90
GIRIDIH	0.68	0.08			0.76
EAST BOKARO	3.44	0.63	0.16	0.93	5.16
(MIDDLINGS)	0.60	0.20		0.15	0.95
WEST BOKARO	0.70	0.69			1.39
RAMGARH	1.03				1.03
(MIDDLINGS)	0.41	0.03			0.44
SOUTH KARANPURA	5.33	2.15			7.48
(MIDDLINGS)	0.60				0.60
NORTH KARANPURA	8.77	0.65			9.42
SINGRAULI	7.69	0.30	15.28	2.29	25.56
CENTRAL INDIA	12.50	2.49		0.50	15.49
KORBA	3.51	0.84	10.00	4.84	19.19
TALCHER	4.60	0.62	2.40	1.72	9.34
IB VALLEY	9.07	0.12			9.19
WARDHA VALLEY	8.26	2.93		1.78	12.97
PATHARKHERA		1.21		1.48	2.69
UMRER	1.48				1.48
KAMPTEE-SILEWARA		0.70	0.87	1.23	2.80
PENCH-KANHAN	2.42	0.60			3.02
(MIDDLINGS)	0.14				0.14
					0.00
TOTAL CIL	108.30	24.40	31.56	14.77	179.03
(MIDDLINGS)	3.15	0.23	0.00	0.65	4.03
DOUBLE MOVEMENT	3.04				3.04
TOTAL MOVEMENT REQUIRED	114.49	24.63	31.56	15.42	186.10

SOURCE : ANNUAL PLAN 1990-91, DEPARTMENT OF COAL

Table 3.1.16 COAL PRICE INCLUSIVE OF ALL ELEMENTS

Unit : Rs/t
Index : Basic Price 100

			ECL			ECL		BCCL		BCCL		CCL	WCL	WCL	SECL	SECL	NCL	NCL
			Sales within West Bengal			Sales within Bihar		Sales within West Bengal		Sales within Bihar		Sales within Bihar	Collieries in M.Pradesh	Collieries in Maharashtra	Collieries in M.Pradesh	Collieries in Orissa	Sales within M.Pradesh	Sales within U.Pradesh
	GRADE	BASIC	1% TAX	6% TAX	12% TAX	8% TAX	16% TAX	7% TAX	8% TAX	7% TAX	8% TAX	12% TAX	4% TAX	4% TAX	4% TAX	4% TAX	12% TAX	12% TAX
Price																		
LONGFLAME NON-COKING COAL	A	427.00	611.76	642.04	678.38	653.35	701.75					680.74	468.13	455.16	468.81	474.76		
	B	392.00	562.27	590.10	623.50	600.43	644.91					625.86	431.73	418.76	432.41	438.36		
	C	346.00	496.21	520.78	550.26	530.88	570.20					552.61	381.55	369.77	382.12	386.36	416.61	403.20
	D	280.00	401.68	421.56	445.42	431.09	463.02					447.78	310.10	299.76	310.55	312.73	339.67	327.94
OTHER THAN LONGFLAME NON-COKING COAL	A	402.00	576.41	604.94	639.18	615.55	661.15	610.65	616.36	616.99	622.76	641.54	442.13	429.16	442.81	448.76	481.85	
	B	367.00	526.92	553.00	584.30	562.63	604.31	558.22	563.44	564.56	569.84	586.66	405.73	392.76	406.41	412.36	442.65	
	C	321.00	460.86	483.68	511.06	491.96	528.39	488.24	492.80	494.53	499.15	513.41	355.55	343.77	356.12	360.36	388.61	
	D	255.00	366.33	384.46	406.22	390.79	419.74	388.09	391.72	394.32	398.00	408.58	284.10	273.76	284.55	286.73	311.57	299.94
	E	203.00	290.98	305.39	322.67	310.13	333.10	310.19	313.09	316.42	319.38	327.04	230.02	219.68	230.47	232.65	253.43	241.70
	F	163.00	234.42	246.03	259.95	249.65	268.14	248.35	250.67	254.48	256.86	262.30	184.21	176.02	184.47	183.56	204.09	
	G	117.00	169.38	177.76	187.82	180.10	193.44	179.44	181.12	185.57	187.30	190.18	136.37	128.18	136.63	135.72	152.57	
COKING COAL	SG I	654.00						988.68	997.92	995.85	1005.16	1038.07						
	SG II	546.00						826.90	834.62	834.07	841.86	868.73						
	WG I	473.00						717.54	724.25	724.71	731.48	754.26						
	WG II	393.00						597.17	602.75	604.34	609.98	628.26						
	WG III	303.00						462.35	466.67	469.52	473.90	487.14						
	WG IV	283.00						431.32	435.35	438.41	442.51	454.66						
	SC I	473.00											516.75		517.43	523.38		
	SC II	393.00											433.55		434.23	440.18		
Index																		
LONGFLAME	A		143.3	150.4	158.9	153.0	164.3					159.4	109.6	106.6	109.8	111.2		
	B		143.4	150.5	159.1	153.2	164.5					159.7	110.1	106.8	110.3	111.8		
	C		143.4	150.5	159.0	153.4	164.8					159.7	110.3	106.9	110.4	111.7	120.4	116.5
	D		143.5	150.6	159.1	154.0	165.4					159.9	110.8	107.1	110.9	111.7	121.3	117.1
	A		143.4	150.5	159.0	153.1	164.5	151.9	153.3	153.5	154.9	159.6	110.0	106.8	110.2	111.6	119.9	
	B		143.6	150.7	159.2	153.3	164.7	152.1	153.5	153.8	155.3	159.9	110.6	107.0	110.7	112.4	120.6	
	C		143.6	150.7	159.2	153.3	164.6	152.1	153.5	154.1	155.5	159.9	110.8	107.1	110.9	112.3	121.1	
	D		143.7	150.8	159.3	153.3	164.6	152.2	153.6	154.6	156.1	160.2	111.4	107.4	111.6	112.4	122.2	117.6
	E		143.3	150.4	159.0	152.8	164.1	152.8	154.2	155.9	157.3	161.1	113.3	108.2	113.5	114.6	124.8	119.1
	F		143.8	150.9	159.5	153.2	164.5	152.4	153.8	156.1	157.6	160.9	113.0	108.0	113.2	112.6	125.2	
	G		144.8	151.9	160.5	153.9	165.3	153.4	154.8	158.6	160.1	162.5	116.5	109.6	116.8	116.0	130.4	
	SG I							151.2	152.6	152.3	153.7	158.7						
	SG II							151.4	152.9	152.8	154.2	159.1						
	WG I							151.7	153.1	153.2	154.6	159.5						
	WG II							152.0	153.4	153.8	155.2	159.9						
	WG III							152.6	154.0	155.0	156.4	160.8						
	WG IV							152.4	153.8	154.9	156.4	160.7						
	SC I												109.2		109.4	110.7		
	SC II												110.3		110.5	112.0		

Table 3.1.17 COAL PRICE AND COST OF PRODUCTION IN CIL

(Unit : Rs/t)

	Cost of Production	Average Pit-head Price
1974-75	58.82	44.73
1978-79	95.09	62.23
1979-80	110.04	101.18
1980-81	123.12	128.02
1984-85	190.63	183.00
1985-86	213.63	210.00
1986-87	221.54	210.00
1987-88	236.07	219.00
1988-89	248.15	219.00

NOTE : Average pit-head price has been revised to 249 Rs/t with effect from 1.1.1989.

SOURCE : REPORT 1988-89, DEPARTMENT OF COAL

Table 3.1.18 FOB PRICE OF METALLURGICAL COAL

(Unit : US$/t)

EXPORTER	AUSTRALIA			U.S.A.		
IMPORTER	JAPAN	EEC	AVERAGE	JAPAN	EEC	AVERAGE
1980	48.81	45.48	48.40	63.32	56.70	60.12
1981	54.47	52.44	54.25	64.44	62.13	63.27
1982	57.05	54.82	57.65	66.58	67.17	67.31
1983	55.76	46.64	54.34	62.89	59.79	61.17
1984	50.25	43.76	49.09	59.01	56.96	57.78
1985	45.96	41.30	44.78	56.52	55.36	55.63
1986	44.82	40.89	44.38	54.59	51.75	52.70
1987	40.18	37.96	40.00	51.31	48.27	48.98
1988	40.04	37.65	40.31	47.76	48.53	48.69
1989	44.10	43.72	44.77	48.31	50.01	49.91

SOURCE : COAL INFORMATION 1990, IEA/OECD

Table 3.1.19 CIF PRICE OF METALLURGICAL COAL

(Unit : US$/t)

IMPORTER	JAPAN						
EXPORTER	AUSTRALIA	CANADA	U.S.A.	S.AFRICA	U.S.S.R.	CHINA	AVERAGE
1980	59.59	62.16	81.27	53.14	58.10	55.81	66.40
1981	65.54	64.59	83.06	63.70	64.32	64.95	71.06
1982	68.22	70.77	83.96	67.17	71.02	68.64	74.42
1983	63.36	70.16	78.82	57.88	59.98	56.10	67.76
1984	59.04	69.53	70.94	50.98	52.25	52.16	63.09
1985	54.36	67.51	68.67	49.62	54.69	51.17	59.77
1986	52.82	66.65	64.71	46.99	52.73	47.22	57.42
1987	48.27	65.43	64.05	43.35	48.63	43.31	53.97
1988	48.30	67.36	60.34	42.55	50.13	46.05	55.05
1989	52.58	69.73	63.34	47.68	54.65	52.08	58.39
IMPORTER	EEC						
EXPORTER	AUSTRALIA	U.S.A.	S.AFRICA	POLAND	CANADA	U.S.S.R.	AVERAGE
1980	62.01	68.80	67.53	63.90	75.57	59.03	66.82
1981	73.83	77.32	72.09	72.95	76.26	64.54	75.94
1982	72.05	75.99	73.28	75.13	80.48	73.41	75.32
1983	60.70	67.13	56.04	61.63	69.12	62.97	64.53
1984	57.57	62.29	46.00	70.00	60.80	47.09	61.05
1985	58.84	62.64	43.08	60.81	62.43	42.28	60.64
1986	56.24	59.46	38.51	60.54	56.44	50.37	57.99
1987	52.90	56.85	35.54	54.74	54.24	54.39	55.25
1988	53.14	57.28	44.17	54.77	52.84	50.69	55.63
1989	54.17	58.44	37.38	56.76	57.21	53.64	57.20

SOURCE : COAL INFORMATION 1990, IEA/OECD

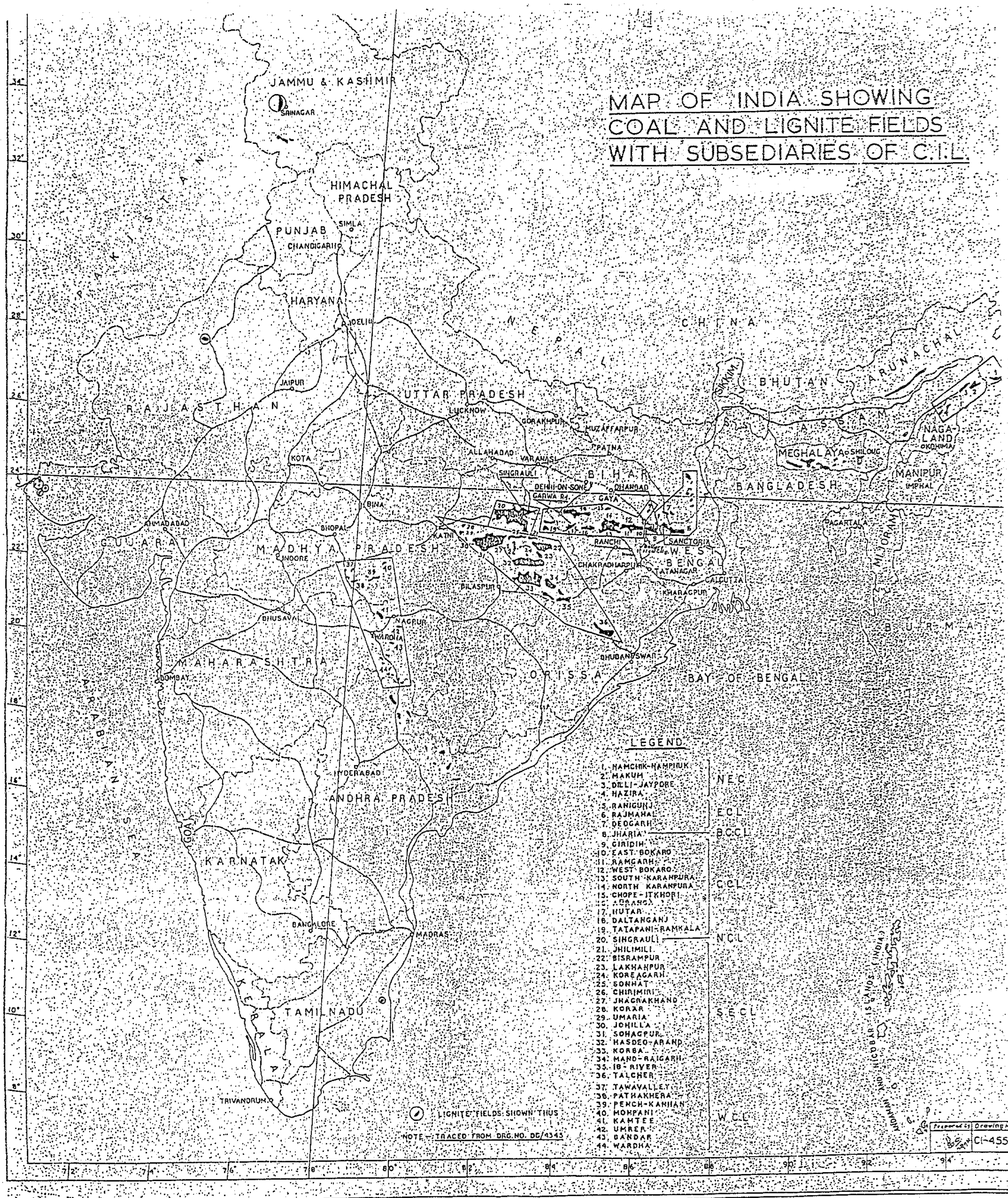

Figure 3.1.1 MAP OF INDIA SHOWING COAL AND LIGNITE FIELDS WITH SUBSIDIARIES OF C.I.L.

Table 3.2.1 CHARACTERISTICS AND RESERVES OF CANDIDATE COALS FOR TRIAL SRC PRODUCTION

No.	Items	*SAMLA Coal (Raniganj) West Bengal	ASSAM Coal High sulphur Assam	*ASSAM Coal Low sulphur Assam	*ARGADA-SIRKA Coal (South Karanpura) Bihar	*Lignite (South Arcot. Neyveli, T.Nadu)	TALCHER Coal (Bottom) Orissa	*Oil Agglomerated Middlings from LODNA
1	Proximate Analysis							
	Ash content, %	12 - 15	5 - 7	8.2	15 - 22	4 - 6	10 - 15	35 - 40(note 2)
	Moisture, % (air dry basis)	7 - 10	1.5 - 2	2.8	3 - 5	15 - 20	7 - 8	1.0
	Volatile matter, %	31 - 33	44 - 45	38.7	28 - 32	40 - 42	35 - 37	19 - 22
	Fixed carbon, %	By diff.	By diff.	50.3	By diff.	By diff.	44 - 47	By diff.
	Fuel ratio (fixed carbon/volatile matter)	1.5	1.1	1.3	1.6	0.9	1.3	2.3
2	Ultimate Analysis (dry mineral matter free basis)							
	Carbon, %	79 - 82	79 - 80	81.82	82 - 84	70 - 72	N.A.	85.5 - 86.0
	Hydrogen, %	5.2 - 5.4	5.5 - 5.8	5.84	4.9 - 5.2	4.7 - 4.8	N.A.	5 - 5.2
	Nitrogen, %	2.2 - 2.4	1.3 - 1.5	1.01	1.7 - 1.8	0.6 - 0.7	N.A.	1.8 - 2.0
	Sulphur, %	0.4 - 0.5	6 - 7	2.4	0.5 - 0.7	0.9 - 1.2	N.A.	0.6 - 0.8
	Oxygen, %	11 - 12	6 - 7	10.07	9 - 10	22 - 23	N.A.	6 - 7
3	Petrographic Composition (mineral matter free basis)							
	Vitrinite, %	80 - 85	85 - 90	87.9	44 - 50	80 - 90 (note 3)	35 - 40	40 - 50
	Exinite, %	3 - 4	5 - 10	2.8	19 - 21	5	8 - 10	2 - 3
	Inertinite, %	10 - 12	3 - 5	4.5	28 - 32	1 - 5	45 - 50	40 - 48
	Average reflectance of vitrinite	0.63	N.A.	0.63	0.63	< 0.4	< 0.5	1.0
4	Tentative Reserves (million tonnes)	500	100	(note 1)	600	3300		(note 4)

Notes: 1. This coals are being supplied to steel plants as a blendable coal for coke making. Present supply to steel plants is around 225 Mt/y.
2. The ash can be initially reduced to around 22 - 24% from these middlings by oil agglomeration using anthracene oil as bridge.
3. Huminite
4. Huge quantities of middlings are generated from various coal washeries in India. Steady supply can be ensured.
5. * marked coals were selected as candidate coals for SRC production test.

Table 3.2.2 COAL PRICE FOR SRC PLANT AT ROURKELA STEEL PLANT (ESTIMATE) (1/2)

(Rs /t)

NAME OF COAL GRADE/LOCATION	PRODUCT	BASIC PRICE (A)	ROYALTY, CESSES (B)						SUB TOTAL (C)=(A)+(B)	SALES TAX (D)	TOTAL (E)=(C)+(D)	RAILWAY FREIGHT (F)	OVERALL PRICE (E)+(F)	REMARKS
SAMLA COAL			ROYALTY*5	RURAL EMP CESS 35% *5	PRIMARY EDU CESS 5% *5	PWD CESS *5	AMBH CESS *5	STOWING CESS *5		SALES TAX 4% *5		from ASANSOL 298 km		* 1 see Note 1
LONG FLAME GRADE "B" *1	STEAM	438.90 399 x 1.1 *4	6.50	153.615 438.9X35%	21.945 438.9X5%	1.00	0.40	3.50	625.86	25.03 625.86x4%	650.89		787.89	* 2 see Note 2 * 3 see Note 3
	SLACK *2	431.20 392 x 1.1 *4	6.50	150.92 431.2X35%	21.56 431.2X5%	1.00	0.40	3.50	615.08	24.60 615.08x4%	639.68	137.00*14	776.68	* 4 see Note 4
W.BENGAL STATE	ROM (-250mm)	433.40*3 (389+5)x1.1 *4	6.50	151.69 433.4X35%	21.67 433.4X5%	1.00	0.40	3.50	618.16	24.72 618.16x4%	642.88		779.88	* 5 see Note 5 * 6 see Note 6
	WASHED COAL												950.00*11	* 7 see Note 7
ARGADA -SIRKA COAL			ROYALTY*7	CESSES*7						SALES TAX 8% C.S.T. 4% *8		from BARKAKANA		* 8 see Note 8
	STEAM	374.00	70.00						444.00	53.28 444.00x12%	497.28	282 km	630.28	* 9 see Note 9 *10 see Note 10
GRADE "B"*6	SLACK	367.00	70.00						437.00	52.44 437.00x12%	489.44	133.00*14	622.44	*11 see Note 11
BIHAR STATE	ROM (-250mm)	364.00	70.00						434.00	52.08 434.00x12%	486.08		619.08	*12 see Note 12 *13 see Note 13
ASSAM COAL *9			ROYALTY*12	CESS*12	LAND CESS*12					SALES TAX 4%*12		from MARGHERITA		*14 see Note 14
	RAW COAL	647.00 460+(22-5)x11*10	6.50	3.50	100.00				757.00	30.28 757.00x4%	787.28	643.00*14 +10.00*15	1440.28	*15 see Note 15
ASSAM STATE	WASHED COAL												1550.00*11	
NEYVELI LIGNITE TAMIL NADU STATE		275.00*13										from NEYVELI 1701 km 612.00*14	887.00	

Table 3.2.2 COAL PRICE FOR SRC PLANT AT ROURKELA STEEL PLANT (2/2)

Note 1. Refer to Annex 3.1.2 (8/22) Note 1 and (11/22) Ash + Moisture = 23.3% UHV = 5680 kcal/kg

Note 2. Slack coal shall be applied to non-coking coal for coke production with SRC.

Note 3. Refer to Annex 3.1.2 (8/22), Notes 6-(ii)

Note 4. Refer to Annex 3.1.2 (10/22) Notes 20

Note 5. Fiqures of royalty. cesses and sales tax were given by ECL.

Note 6. Refer to Annex 3.1.2 (15/22)
Ash + Moisture = 21.3 UHV = 5960 kcal/kg

Note 7. Royalty was to be increased and cesses were to be eliminated in Bihar and Orissa States from August, 1991. Rate of royalty is not decided yet, but is proposed to be increased at 70.00 Rs/t.

Note 8. Refer to Annex 3.1.2 (16/22)

Note 9. It was decided at the meeting during 2nd on site survey that ash content of Assam coal should be 4-6% (average 5%) for the feed material of SRC plant because sample coal having 2.1% ash is not considered to be representative coal.

Note 10. Refer to Annex 3.1.2 (5/22) No.4 and Annex 3.1.2 (9/22) Note 9-(ii)

Note 11. Washed coal price for Samla and Assam coal was set up by CFRI at the meeting held on February 20-22, 1992 at Ranchi. This price shall be considered for techno-economics evaluation.

	Ash	Washed Coal Yield	Rs/t(at RSP)
Washed Samla coal	9%	70%	950.00
Washed Assam coal	2-3%	90%	1550.00

Note 12. The figures of Royalty, Cess, Land Cess and Sales Tax in case of Assam coal were given by CMPDIL during 2nd on site survey, 1991.

Note 13. Price of Neyveli Lignite were given by NLC during 1st on site survey in September to October, 1990.

Note 14. Revised railway freights were given by MECON during 2nd on site survey in 1991 due to 10% increase of 1990's tariff.

Note 15. Refer to Annex 3.1.2 (9/22) 10-(ii). It is assumed in Assam case, that a distance is not more than 10 kms and loading charge is 10.00 Rs/t.

Table 3.3.1 ANALYTICAL DATA FOR COAL (1/2)

Analytical Item		SAMLA Coal	ASSAM Coal	ARGADA-SIRKA Coal	NEYVELI Lignite	OA Middlings	Deoiled OA Coal	Analysis Method
Moisture (As received)	Total moisture (wt%)	20.4	16.6	11.5	56.4	1.7	--	JIS M 8811
	Adherent moisture(wt%)	10.9	14.5	8.4	46.3	0.0	--	
Proximate Analysis (Equilibrium Moisture Basis)	Moisture (wt%)	10.7	2.4	3.4	18.8	1.7	1.0	JIS M 8812
	Ash content (wt%)	12.6	2.1	17.9	3.5	21.0	26.4	
	Volatile matter (wt%)	33.6	41.9	33.6	41.6	32.2	20.8	
	Fixed carbon (wt%)	43.1	53.6	45.1	36.1	45.1	51.8	
Calorific Value (daf basis)	(kcal/kg)	7870	8380	7940	6610	8930	8400	JIS M 8814
Ultimate Analysis (daf basis)	Carbon (wt%)	80.6	83.5	82.8	71.1	86.5	86.2	JIS M 8813
	Hydrogen (wt%)	5.1	5.8	5.4	5.0	6.5	4.9	
	Oxygen (wt%)	11.4	7.9	9.4	22.3	4.2	6.2	
	Nitrogen (wt%)	2.4	1.2	1.5	0.7	1.4	1.9	
	Sulphur (wt%)	0.5	1.6	0.9	0.9	1.4	0.8	
Grindability (HGI)		48	47	44	141	--	--	JIS M 8801
Petrographic Analysis	Vitrinite (%)	72.8	91.4	50.1	92.5	--	41.2	JIS M 8816
	Exinite (%)	5.5	3.7	8.3	1.9	--	0.9	
	Inertinite(%)	13.6	3.3	30.6	2.9	--	41.3	
	Minerals (%)	8.1	1.6	11.0	2.7	--	16.6	
Mean Maximum Reflectance (Ro) (%)		0.63	0.72	0.78	0.42	--	1.18	JIS M 8816

Table 3.3.1 ANALYTICAL DATA FOR COAL (2/2)

Analytical Item		SAMLA Coal	ASSAM Coal	ARGADA-SIRKA Coal	NEYVELI Lignite	OA Middlings	Analysis Method
Size Analysis (wt%)	+50(mm)	10.1	1.7	3.1			JIS M 8801
(As received)	50-40	10.8	5.5	12.9			
	40-30	6.1	2.9	10.0	32.3		
	30-25	11.2	5.3	15.4			
	25-20	6.7	3.6	5.0		0.6	
	20-15	4.6	3.2	7.2			
	15-10	11.8	6.8	10.9			
	10- 5	10.0	7.7	13.1			
	5- 3	9.6	10.3	5.6	67.7		
	3- 2	4.8	14.2	3.1			
	2- 1	5.6	13.5	4.3		47.3	
	1- 0.5	3.6	10.3	3.3		47.7	
	-0.5	5.1	15.0	6.1		4.4	
	Total	100.0	100.0	100.0	100.0	100.0	
Coal Ash Analysis	SiO_2	61.4	40.6	51.0	24.0	58.3	JIS M 8815
(moisture free basis)	Al_2O_3	23.77	21.93	33.66	19.33	28.07	
	Fe_2O_3	4.63	20.34	7.54	11.28	6.55	
	CaO	2.34	3.66	1.64	17.01	0.97	
	Mgo	1.36	2.16	0.83	4.36	0.74	
	Na_2O	0.37	2.95	0.12	0.67	0.12	
	K_2O	1.87	0.78	1.19	0.19	1.34	
	SO_3	0.79	4.15	0.42	20.20	0.26	
	P_2O_5	0.87	0.16	1.23	0.05	0.76	
	TiO_2	1.27	0.87	1.90	1.20	2.08	

Table 3.3.2 RESULT OF SINK-AND-FLOAT TEST (1/4)

Name of Sample : SAMLA Coal
Particle Size : -25mm   S.G.Liquid used Tetrachloroethylene + Gasoline

k	a	b	c	d	e	f	g	h	i	j
Specific Gravity	Weight (%)	Ash (%)	ΣWn-1 +Wn/2	W・A	ΣW・A	ΣW	ΣWA/ΣW	Total W・A -ΣW・A	100 -ΣW	h/i
−1.30	29.8	2.5	14.9	75.1	75.1	29.8	2.5	1032.8	70.2	14.7
1.30～1.35	34.3	9.0	47.0	308.0	383.1	64.1	6.0	724.8	35.9	20.2
1.35～1.40	12.0	13.8	70.1	166.0	549.1	76.1	7.2	558.8	23.9	23.4
1.40～1.50	19.3	18.9	85.8	364.2	913.3	95.4	9.6	194.6	4.6	42.3
1.50～1.60	1.5	27.3	96.2	40.9	954.2	96.9	9.8	153.7	3.1	49.6
+1.60	3.1	49.6	98.4	153.7	1107.9	100.0	11.1	0.0	0.0	0.0
+297μm	98.1									
−297μm	1.9	16.9								

※ f,g Float Curve ※ b,c Characteristic Curve
※ i,j Sink Curve ※ f,k Specific Gravity Curve

Table 3.3.2 RESULT OF SINK-AND-FLOAT TEST (2/4)

Name of Sample: ASSAM Coal
Particle Size: -25mm S.G.Liquid used Tetrachloroethylene + Gasoline

k	a	b	c	d	e	f	g	h	i	j
Specific Gravity	Weight (%)	Ash (%)	ΣWn-1 +Wn/2	W・A	ΣW・A	ΣW	ΣWA/ΣW	Total W・A -ΣW・A	100 -ΣW	h/i
−1.30	96.7	1.3	48.4	122.8	122.8	96.7	1.3	97.4	3.3	29.6
1.30～1.35	0.8	8.0	97.1	6.4	129.2	97.5	1.3	90.9	2.5	36.4
1.35～1.40	0.7	12.9	97.9	9.0	138.3	98.2	1.4	81.9	1.8	45.5
1.40～1.50	0.4	18.0	98.4	7.2	145.5	98.6	1.5	74.7	1.4	53.3
1.50～1.60	0.2	29.0	98.7	5.8	151.3	98.8	1.5	68.9	1.2	57.4
+1.60	1.2	57.4	99.4	68.9	220.2	100.0	2.2	0.0	0.0	0.0
+297μm	90.7									
−297μm	9.3	4.3								

※ f,g Float Curve ※ b,c Characteristic Curve
※ i,j Sink Curve ※ f,k Specific Gravity Curve

Table 3.3.2 RESULT OF SINK-AND-FLOAT TEST (3/4)

Name of Sample: ARGADA-SIRKA Coal
Particle Size: -25mm S.G.Liquid used Tetrachloroethylene + Gasoline

k	a	b	c	d	e	f	g	h	i	j
Specific Gravity	Weight (%)	Ash (%)	ΣWn-1 +Wn/2	W・A	ΣW・A	ΣW	ΣWA/ΣW	Total W・A -ΣW・A	100 -ΣW	h/i
−1.30	12.2	2.3	6.1	27.8	27.8	12.2	2.3	1836.3	87.8	20.9
1.30～1.35	23.4	7.6	23.9	178.8	206.6	35.6	5.8	1657.5	64.4	25.7
1.35～1.40	12.5	12.7	41.9	158.9	365.5	48.1	7.6	1948.6	51.9	28.9
1.40～1.50	25.6	18.9	60.9	483.8	849.3	73.7	11.5	1014.8	26.3	38.6
1.50～1.60	12.4	29.0	79.9	359.0	1208.3	86.1	14.0	655.8	13.9	47.2
+1.60	13.9	47.2	93.1	655.8	1864.1	100.0	18.5	0.0	0.0	0.0
+297μm	94.6									
−297μm	5.4	21.9								

※ f,g Float Curve ※ b,c Characteristic Curve
※ i,j Sink Curve ※ f,k Specific Gravity Curve

Table 3.3.2 RESULT OF SINK-AND-FLOAT TEST (4/4)

Name of Sample: NEYVEL-LIGNITE
Particle Size: -25mm S.G.Liquid used Tetrachloroethylene + Gasoline

k	a	b	c	d	e	f	g	h	i	j
Specific Gravity	Weight (%)	Ash (%)	ΣWn-1 +Wn/2	W・A	ΣW・A	ΣW	ΣWA/ΣW	Total W・A -ΣW・A	100 -ΣW	h/i
−1.30	44.0	2.7	22.0	120.1	120.1	44.0	2.7	261.9	56.0	4.7
1.30～1.35	22.3	3.0	55.2	66.0	186.1	66.3	2.8	195.9	33.7	5.8
1.35～1.40	11.1	3.1	71.8	34.1	220.2	77.4	2.8	161.8	22.6	7.2
1.40～1.50	21.1	3.6	88.0	77.0	297.2	98.5	3.0	84.8	1.5	56.5
1.50～1.60	0.2	17.7	98.6	3.5	300.8	98.7	3.0	81.2	1.3	62.5
+1.60	1.3	62.5	99.4	81.2	382.0	100.0	3.8	0.0	0.0	0.0
+297μm	86.0									
−297μm	14.0	5.1								

※ f,g Float Curve ※ b,c Characteristic Curve
※ i,j Sink Curve ※ f,k Specific Gravity Curve

Table 3.3.3 ANALYTICAL DATA FOR ANTHRACENE OIL

Analytical Item		Value	Method
Moisture (%)		0.0	JIS K 2425
Ultimate Analysis (%)	Carbon	91.0	JIS M 8813
	Hydrogen	6.5	
	Oxygen	1.1	
	Nitrogen	0.7	
	Sulphur	0.4	
Specific Gravity (20/20°C)		1.068	JIS K 2425
Caking index(at 35°C)		6.1	Brookfield Viscometer
fa (NMR)		0.90	Brown-Ladner method[1)]
fa (IR)		0.89	Brown method[2)]
Molecular weight		180	Vapor pressure Osmometer
Gross calorific value(kcal/kg)		9400	JIS M 8814
Distillation characteristics (recovered temperature)	IBP	198.0°C	ASTM D 1160
	5vol%	226.0°C	
	10vol%	233.0°C	
	20vol%	243.0°C	
	30vol%	250.0°C	
	50vol%	274.0°C	
	70vol%	308.0°C	
	90vol%	333.0°C	
	EP	356.0°C	

1)J.K. Brown, W.R. Ladner, Fuel, Vol. 39.87 (1960)

2)J.K. Brown, J. Chem. Soc., 744 (1955)

Table 3.3.4 ANALYTICAL DATA FOR CATALYST

Analytical Item		Value	Analytical Method
Moisture (%)		0	JIS M 8811
Ultimate Analysis (%)	C	< 0.05	JIS M 8813
	H	< 0.01	
	N	< 0.01	
	Si	0.03	JIS M 8815
	Al	0.03	
	Fe	68.33	
	Ca	< 0.01	
	Mg	0.09	
	Na	< 0.01	
	K	< 0.01	
	S	26.53	
	P	0.01	
	Ti	< 0.01	
Ignition loss (%)		2.36	JIS M 8812

Table 3.3.5 ANALYTICAL METHODS

Analytical Item	Samples						Method
	Oil	SRC	Residue	SRC* Sample	Coal Solu.	Filtrate	
1.Ultimate Analysis	○	○	○	○			JIS M 8813
2.Proximate Analysis		○	○	○			JIS K 2425
(Moisture only)					○		JIS M 8812
3.Calorific Value	○	○	○	○			JIS M 8814
4.Analysis of Major Elements of Ash			○				JIS M 8815
5.fa (NMR)	○	○					Brown-Ladner method *1
6.fa (IR)	○	○					Brown method *2
7.Molecular Weight	○	○					Vapor Pressure Osmometer
8.Softening Point		○		○			JIS K 2425
9.Solvent-Insoluble Content		○		○			JIS K 2425
10.Specific Gravity	○	○		○	○	○	JIS K 2425
11.Distillation Characteristic	○						ASTM D 1160
12.Viscosity	○				○	○	Brookfield Viscometer

1) J.K.Brown,W.R.Ladner,Fuel,Vol.39,87(1960)
2) J.K.Brown,J.Chem.Soc.,744(1955)
* SRC sample for coke production test

Table 3.3.6 TEST-1 CONDITIONS

(Tetralin Solvent, Initial Pressure 100Kg/cm^{2}G, Coal-Solvent Ratio=1/2)

Conditions			SAMLA	ASSAM	ARGADA-	NEYVELI	OA
Residence Time (minutes)	Reaction Temperature (℃)	Amount of Catalyst Added (wt%)	Coal	Coal	SIRKA Coal	Lignite	Middlings
60	380	0	○	○	○	○	○
60	380	3	○	○	○	○	○
60	410	0	○	○	○	○	○
60	410	3	○	○	○	○	○
60	430	0	○	○	○	○	○
60	430	3	○	○	○	○	○
90	380	0	○	○	○	○	○
90	380	3	○	○	○	○	○
90	410	0	○	○	○	○	○
90	410	3	○	○	○	○	○
90	430	0	○	○	○	○	○
90	430	3	○	○	○	○	○

Table 3.3.7 TEST-2 CONDITIONS

(Coal-Solvent Ratio=1/2)

Conditions					SAMLA Coal		ASSAM Coal	
Residence Time (minutes)	Initial Pressure (Kg/cm²G)	Reaction Temperature (℃)	Amount of Catalyst Added(wt%)	Hydrogen Partial Pressure (%)	Tetralin	Anthracene Oil	Tetralin	Anthracene Oil
30	100	430	3	100	○	○	○	○
120	100	430	3	100	○	○	○	○
60	80	430	3	100	○	○	○	○
60	120	430	3	100	○	○	○	○
60	100	360	3	100	○	○	○	○
60	100	450	3	100	○	○	○	○
60	100	430	6	100	○	○	○	○
60	100	430	3	70	○	○	○	○
60	100	430	3	80	○	○	○	○
60	100	430	3	90	○	○	○	○
60	100	380	3	100	*	○	*	○
60	100	410	3	100	*	○	*	○
60	100	430	0	100	*	○	*	○
60	100	430	3	100	*	○	*	○
90	100	430	3	100	*	○	*	○

N.B.) * Tests marked with asterick were completed in the TEST-1.

Table 3.3.8 YIELDS (AVERAGE VALUES) OF ASSAM COAL AFTER FOUR RECIRCULATIONS OF SOLVENT

Product		Yield (daf coal base,wt%)
Gas	C_1	2.7
	C_2	1.5
	C_3	1.0
	C_4	0.4
	CO	0.5
	CO_2	1.3
	H_2S	0.3
	Sub-total	7.7
Water		2.9
Oil		19.9
SRC		71.3
Unreacted Coal		0.8
Total		
Hydrogen Consumption		-2.6
Grand Total		100.0

Table 3.3.9 SAMPLES FOR ANALYSIS AND PRODUCTION CONDITIONS (1/2)

	Experimental Number	Coal	Solvent	Reaction Temperature	Residence Time	Initial Pressure	Catalyst Addition	H_2 -Partial Pressure
TEST I	A 1 1 0 6	ASSAM coal	Tetralin	430℃	60min	100Kg/㎠G	3wt%	100%
	A 1 2 0 6	SAMLA coal	Tetralin	430℃	60min	100Kg/㎠G	3wt%	100%
	A 1 3 0 6	NEYVELI lignite	Tetralin	430℃	60min	100Kg/㎠G	3wt%	100%
	A 1 4 0 6	ARGADA-SIRKA coal	Tetralin	430℃	60min	100Kg/㎠G	3wt%	100%
	A 1 5 0 6	O.A. middlings	Tetralin	430℃	60min	100Kg/㎠G	3wt%	100%
TEST II	A 2 1 2 2	ASSAM coal	Anthracene Oil	410℃	60min	100Kg/㎠G	3wt%	100%
	A 2 1 2 4	ASSAM coal	Anthracene Oil	430℃	60min	100Kg/㎠G	3wt%	100%
	A 2 1 1 6	ASSAM coal	Anthracene Oil	450℃	60min	100Kg/㎠G	3wt%	100%
	A 2 2 2 2	SAMLA coal	Anthracene Oil	410℃	60min	100Kg/㎠G	3wt%	100%
	A 2 2 2 4	SAMLA coal	Anthracene Oil	430℃	60min	100Kg/㎠G	3wt%	100%
	A 2 2 1 6	SAMLA coal	Anthracene Oil	450℃	60min	100Kg/㎠G	3wt%	100%
TEST III	A 3 1 0 1	ASSAM coal	Anthracene Oil	430℃	60min	100Kg/㎠G	3wt%	100%
	A 3 1 0 7	ASSAM coal	Recycle Oil I	430℃	60min	100Kg/㎠G	3wt%	100%
	A 3 1 2 3	ASSAM coal	Recycle Oil II	430℃	60min	100Kg/㎠G	3wt%	100%
	A 3 1 3 1	ASSAM coal	Recycle Oil III	430℃	60min	100Kg/㎠G	3wt%	100%

Table 3.3.9 SAMPLES FOR ANALYSIS AND PRODUCTION CONDITIONS (2/2)

	Experimental Number	Coal	Solvent	Reaction Temperature	Residence Time	Initial Pressure	Catalyst Addition	H_2 -Partial Pressure
SRC SAMPLE	S 2 1 2 2	ASSAM coal	Anthracene Oil	410℃	60min	100Kg/cm²G	3wt%	100%
	S 2 1 2 4	ASSAM coal	Anthracene Oil	430℃	60min	100Kg/cm²G	3wt%	100%
	S 2 1 1 6	ASSAM coal	Anthracene Oil	450℃	60min	100Kg/cm²G	3wt%	100%
	S 2 2 2 2	SAMLA coal	Anthracene Oil	410℃	60min	100Kg/cm²G	3wt%	100%
	S 2 2 2 4	SAMLA coal	Anthracene Oil	430℃	60min	100Kg/cm²G	3wt%	100%
	S 2 2 1 6	SAMLA coal	Anthracene Oil	450℃	60min	100Kg/cm²G	3wt%	100%
	S 3 1 0 1	ASSAM coal	Anthracene Oil	430℃	60min.	100Kg/cm²G	3wt%	100%

Table 3.3.10 ANALYSIS OF PRODUCED OIL (1)

OIL	Test Condition			Ultimate Analysis (daf ;wt%)					Proximate Analysis (dry;wt%)			Calorif. Value (dry base) (kcal/kg)	Specific Gravity (at 20℃)	Viscosity (cP)
Exper. NO.	Coal	Solvent	Temp.	C	H	N	S	O	Ash	V.M.	F.C.			
A 1 1 0 6	ASSAM	Tetralin	430℃	90.2	9.0	0.1	0.1	0.6	--	--	--	9990	0.973	4.4
A 1 2 0 6	SAMLA	Tetralin	430℃	89.4	8.6	0.2	0.0	1.8	--	--	--	9970	0.975	4.3
A 1 3 0 6	LIGNITE	Tetralin	430℃	89.8	8.6	0.1	0.1	0.4	--	--	--	9900	0.981	4.6
A 1 4 0 6	ARGADA	Tetralin	430℃	88.7	8.5	0.1	0.0	2.7	--	--	--	10020	0.973	4.5
A 1 5 0 6	O.A.midd.	Tetralin	430℃	90.3	9.2	0.1	0.1	0.3	--	--	--	10100	0.961	5.0
A 2 1 2 2	ASSAM	Anth.Oil	410℃	91.3	7.2	0.7	0.4	0.4	--	--	--	9480	1.058	8.0
A 2 1 2 4	ASSAM	Anth.Oil	430℃	90.3	7.1	0.7	0.4	1.5	--	--	--	9500	1.051	7.9
A 2 1 1 6	ASSAM	Anth.Oil	450℃	90.3	6.9	0.7	0.3	1.8	--	--	--	9500	1.032	8.0
A 2 2 2 2	SAMLA	Anth.Oil	410℃	90.5	6.3	0.7	0.4	2.1	--	--	--	9450	1.060	7.5
A 2 2 2 4	SAMLA	Anth.Oil	430℃	91.0	7.1	0.7	0.3	0.9	--	--	--	9470	1.057	8.0
A 2 2 1 6	SAMLA	Anth.Oil	450℃	91.2	7.0	0.8	0.3	0.8	--	--	--	9470	1.056	8.5
A 3 1 0 1	ASSAM	Anth.Oil	430℃	91.1	7.1	0.7	0.4	0.7	--	--	--	9430	1.051	7.9
A 3 1 0 7	ASSAM	Recycle I	430℃	90.3	7.4	0.6	0.3	1.4	--	--	--	9520	1.046	7.7
A 3 1 2 3	ASSAM	Recycle II	430℃	90.0	7.6	0.6	0.3	1.5	--	--	--	9520	1.038	8.0
A 3 1 3 1	ASSAM	Recycle III	430℃	89.2	7.7	0.5	0.3	2.3	--	--	--	9530	1.038	8.0

Table 3.3.11 ANALYSIS OF PRODUCED OIL (2)

OIL	Test Condition			fa		Molecular Weight	Distillation Characteristics (recovered temperature; ℃)								
Exper. NO.	Coal	Solvent	Temp.	^{1}H-NMR	IR		IBP	5vol%	10vol%	20vol%	30vol%	50vol%	70vol%	80vol%	EP(℃ /vol%)
A1106	ASSAM	Tetralin	430℃	0.63	0.54	220	193	203	204	205	206	207	212	245	450 /86.0
A1206	SAMLA	Tetralin	430℃	0.65	0.57	220	197	204	205	205	206	207	209	215	450 /89.0
A1306	LIGNITE	Tetralin	430℃	0.67	0.59	210	190	202	202	204	205	207	211	229	451 /89.5
A1406	ARGADA	Tetralin	430℃	0.63	0.54	220	195	203	204	205	205	206	208	212	451 /89.4
A1506	O.A.midd.	Tetralin	430℃	0.59	0.53	230	188	202	203	204	204	204	206	211	450 /88.0
A2122	ASSAM	Anth.Oil	410℃	0.84	0.82	180	207	230	236	250	265	309	353	--	450 /76.0
A2124	ASSAM	Anth.Oil	430℃	0.82	0.80	180	186	225	233	247	260	299	337	437	450 /80.0
A2116	ASSAM	Anth.Oil	450℃	0.83	0.81	180	176	218	224	240	256	302	351	--	450 /76.5
A2222	SAMLA	Anth.Oil	410℃	0.86	0.84	170	193	224	231	243	257	295	332	370	450 /83.9
A2224	SAMLA	Anth.Oil	430℃	0.85	0.84	170	190	221	223	241	254	288	327	345	450 /87.2
A2216	SAMLA	Anth.Oil	450℃	0.84	0.84	170	181	221	227	239	251	290	327	352	450 /86.1
A3101	ASSAM	Anth.OIL	430℃	0.82	0.81	180	186	225	233	247	260	299	337	437	450 /80.0
A3107	ASSAM	Recycle I	430℃	0.78	0.75	180	188	222	230	245	264	304	344	429	450 /80.5
A3123	ASSAM	Recycle II	430℃	0.76	0.72	180	184	219	228	244	263	308	349	438	450 /80.5
A3131	ASSAM	Recycle III	430℃	0.73	0.69	180	186	219	228	244	264	308	348	422	450 /81.0

Table 3.3.12 ANALYSIS OF SRC (1)

SRC	Test Condition			Ultimate Analysis (daf ;wt%)					Proximate Analysis (dry;wt%)			Calorif. Value (dry base) (kcal/kg)	Specific Gravity (at 20℃)	Softening Point (℃)
Exper. NO.	Coal	Solvent	Temp.	C	H	N	S	O	Ash	V.M.	F.C.			
A 1 1 0 6	ASSAM	Tetralin	430℃	87.9	6.3	1.3	0.7	3.8	--	38.3	61.7	8930	1.217	169
A 1 2 0 6	SAMLA	Tetralin	430℃	87.4	6.3	2.6	0.2	3.5	--	37.9	62.1	8890	1.217	178
A 1 3 0 6	LIGNITE	Tetralin	430℃	86.2	6.4	1.0	0.4	6.0	--	43.8	56.2	8770	1.208	145
A 1 4 0 6	ARGADA	Tetralin	430℃	88.5	6.3	1.8	0.3	3.1	--	40.0	60.0	8820	1.220	171
A 1 5 0 6	O.A.midd.	Tetralin	430℃	89.5	6.6	1.6	1.2	1.1	--	39.2	60.8	9230	1.204	163
A 2 1 2 2	ASSAM	Anth.Oil	410℃	87.9	6.2	1.5	0.8	3.6	--	37.2	62.8	8730	1.239	231
A 2 1 2 4	ASSAM	Anth.Oil	430℃	88.5	5.6	1.6	0.7	3.6	--	31.0	69.0	8780	1.250	207
A 2 1 1 6	ASSAM	Anth.Oil	450℃	89.9	5.2	1.7	0.6	2.6	--	30.9	69.1	8820	1.267	171
A 2 2 2 2	SAMLA	Anth.Oil	410℃	87.3	5.5	2.9	0.2	4.1	--	35.9	64.1	8670	1.255	231
A 2 2 2 4	SAMLA	Anth.Oil	430℃	88.4	5.5	3.0	0.2	2.9	--	29.3	70.7	8720	1.262	225
A 2 2 1 6	SAMLA	Anth.Oil	450℃	89.4	5.1	3.0	0.2	2.3	--	28.6	71.4	8770	1.274	208
A 3 1 0 1	ASSAM	Anth.Oil	430℃	88.5	5.7	1.6	0.7	3.5	--	32.7	67.3	8810	1.250	200
A 3 1 0 7	ASSAM	Recycle I	430℃	88.0	5.9	1.6	0.7	3.8	--	27.3	72.7	8830	1.240	198
A 3 1 2 3	ASSAM	Recycle II	430℃	87.9	5.9	1.6	0.7	3.9	--	35.0	65.0	8840	1.236	191
A 3 1 3 1	ASSAM	Recycle III	430℃	88.4	6.1	1.6	0.7	3.2	--	35.2	64.8	8830	1.235	192

Table 3.3.13 ANALYSIS OF SRC (2)

SRC	Test Condition			fa		Molecular Weight	Solvent-Insoluble Content(wt%)		
Exper. NO.	Coal	Solvent	Temp.	H-NMR	IR		HI	TI	QI
A1106	ASSAM	Tetralin	430℃	0.71	0.75	560	87.5	16.1	<0.1
A1206	SAMLA	Tetralin	430℃	0.72	0.75	450	95.1	22.7	0.1
A1306	LIGNITE	Tetralin	430℃	0.70	0.71	410	86.2	11.6	0.1
A1406	ARGADA	Tetralin	430℃	0.72	0.75	440	88.9	17.9	0.1
A1506	O.A.midd.	Tetralin	430℃	0.70	0.75	520	84.3	17.5	<0.1
A2122	ASSAM	Anth. Oil	410℃	0.71	0.74	730	96.5	40.9	0.1
A2124	ASSAM	Anth. Oil	430℃	0.75	0.78	590	96.0	37.9	0.1
A2116	ASSAM	Anth. Oil	450℃	0.83	0.84	490	93.8	35.7	0.1
A2222	SAMLA	Anth. Oil	410℃	0.74	0.78	600	97.9	55.2	0.1
A2224	SAMLA	Anth. Oil	430℃	0.78	0.81	510	96.8	49.6	0.1
A2216	SAMLA	Anth. Oil	450℃	0.82	0.85	470	96.3	44.9	0.1
A3101	ASSAM	Anth. Oil	430℃	0.75	0.79	700	95.7	37.0	<0.1
A3107	ASSAM	Recycle I	430℃	0.74	0.77	640	89.5	31.8	<0.1
A3123	ASSAM	Recycle II	430℃	0.75	0.76	620	89.8	30.4	0.1
A3131	ASSAM	Recycle III	430℃	0.73	0.76	590	91.0	30.5	0.1

Table 3.3.14 ANALYSIS OF RESIDUE (1)

RESIDUE	Test Condition			Ultimate Analysis (daf ;wt%)					Proximate Analysis (dry;wt%)			Calorif. Value (dry base) (kcal/kg)
Exper. NO.	Coal	Solvent	Temp.	C	H	N	S	O	Ash	V.M.	F.C.	
A1106	ASSAM	Tetralin	430℃	64.5	4.1	1.5	17.9	12.0	74.8	10.0	15.2	2440
A1206	SAMLA	Tetralin	430℃	80.6	4.6	2.3	4.6	7.9	61.9	11.7	26.4	3020
A1306	LIGNITE	Tetralin	430℃	73.5	5.6	1.1	11.0	8.8	81.0	19.0	<0.1	1980
A1406	ARGADA	Tetralin	430℃	75.5	4.7	1.5	3.7	14.6	61.5	13.1	25.4	2820
A1506	O.A.midd.	Tetralin	430℃	85.0	4.9	1.8	2.7	5.6	51.8	13.7	34.5	3900
A2122	ASSAM	Anth.Oil	410℃	33.9	3.4	0.8	21.8	40.1	85.1	8.4	6.5	1540
A2124	ASSAM	Anth.Oil	430℃	40.2	3.6	1.2	21.2	33.8	83.8	7.7	8.5	1790
A2116	ASSAM	Anth.Oil	450℃	69.6	4.0	1.5	18.8	6.1	72.0	10.0	18.0	2860
A2222	SAMLA	Anth.Oil	410℃	84.1	4.6	2.7	3.4	5.2	50.3	14.2	35.5	3980
A2224	SAMLA	Anth.Oil	430℃	84.4	4.6	2.6	3.7	4.7	52.5	12.9	34.6	3840
A2216	SAMLA	Anth.Oil	450℃	85.4	4.4	2.6	3.7	3.9	52.3	10.6	37.1	3890
A3101	ASSAM	Anth.Oil	430℃	26.3	4.2	0.9	23.2	45.4	85.8	8.7	5.5	1580
A3107	ASSAM	Recycle I	430℃	38.2	4.4	1.0	21.7	34.7	85.6	7.5	6.9	1680
A3123	ASSAM	Recycle II	430℃	33.0	3.8	0.9	21.8	40.5	86.6	7.3	6.1	1580
A3131	ASSAM	Recycle III	430℃	35.1	4.0	0.8	21.9	38.2	86.6	7.4	6.0	1320

Table 3.3.15 ANALYSIS OF RESIDUE (2)

RESIDUE	Test Condition			Analysis of Major Elements of Ash (%)										
Exper. NO.	Coal	Solvent	Temp.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	P_2O_5	TiO_2	MnO
A1106	ASSAM	Tetralin	430℃	18.3	9.98	63.05	1.58	1.03	1.30	0.40	2.28	0.09	0.34	0.22
A1206	SAMLA	Tetralin	430℃	51.2	19.46	20.18	2.04	1.10	0.35	1.51	0.85	0.69	0.99	0.07
A1306	LIGNITE	Tetralin	430℃	13.9	12.17	46.56	9.70	2.13	0.34	0.13	12.67	0.06	0.76	0.15
A1406	ARGADA	Tetralin	430℃	44.1	28.73	17.79	1.57	0.79	0.12	1.08	0.60	1.02	1.63	0.05
A1506	O.A.midd.	Tetralin	430℃	50.6	25.01	18.03	0.91	0.71	0.14	1.18	0.24	0.67	1.86	0.08
A2122	ASSAM	Anth.Oil	410℃	17.9	9.93	64.06	1.61	0.94	1.21	0.38	1.91	0.10	0.28	0.18
A2124	ASSAM	Anth.Oil	430℃	17.9	9.91	63.29	1.65	0.93	1.22	0.37	2.14	0.09	0.32	0.21
A2116	ASSAM	Anth.Oil	450℃	17.8	9.60	64.95	1.44	0.92	1.17	0.37	2.55	0.09	0.36	0.23
A2222	SAMLA	Anth.Oil	410℃	51.8	19.48	20.24	2.05	1.08	0.30	1.53	0.72	0.69	0.94	0.07
A2224	SAMLA	Anth.Oil	430℃	51.4	19.65	20.51	2.03	1.14	0.29	1.51	0.66	0.69	0.96	0.07
A2216	SAMLA	Anth.Oil	450℃	51.5	19.70	20.52	1.96	1.17	0.29	1.52	0.70	0.69	1.01	0.05
A3101	ASSAM	Anth.Oil	430℃	18.7	10.15	62.19	1.56	0.98	1.31	0.33	3.00	0.10	0.32	0.25
A3107	ASSAM	Recycle I	430℃	18.6	9.88	61.91	1.56	1.08	1.33	0.36	2.48	0.09	0.33	0.24
A3123	ASSAM	Recycle II	430℃	17.8	10.02	64.74	1.54	1.04	1.20	0.38	2.50	0.09	0.30	0.24
A3131	ASSAM	Recycle III	430℃	17.7	9.47	64.87	1.52	0.99	1.13	0.35	2.38	0.09	0.30	0.22

Table 3.3.16 ANALYSIS OF SRC FOR COKE PRODUCTION TEST

SRC Sample	Test Condition			Ultimate Analysis (daf ;wt%)					Proximate Analysis (dry;wt%)			Calorif. Value (dry base) (kcal/kg)
Exper. NO.	Coal	Solvent	Temp.	C	H	N	S	O	Ash	V.M.	F.C.	
S 2 1 2 2	ASSAM	Anth. Oil	410℃	87.1	6.4	1.5	0.9	4.1	--	37.3	62.7	8750
S 2 1 2 4	ASSAM	Anth. Oil	430℃	87.9	5.8	1.6	0.8	3.9	--	32.9	67.1	8800
S 2 1 1 6	ASSAM	Anth. Oil	450℃	89.6	5.4	1.7	0.6	2.7	--	28.5	71.5	8800
S 2 2 2 2	SAMLA	Anth. Oil	410℃	86.8	5.9	2.9	0.3	4.1	--	32.3	67.7	8640
S 2 2 2 4	SAMLA	Anth. Oil	430℃	87.9	5.5	3.1	0.2	3.3	--	28.5	71.5	8690
S 2 2 1 6	SAMLA	Anth. Oil	450℃	89.3	5.2	3.2	0.2	2.1	--	26.7	73.3	8670
S 3 1 0 1	ASSAM	Anth. Oil	430℃	87.6	5.5	1.6	0.7	4.6	--	32.3	67.7	8740

SRC Sample	Test Condition			Specific Gravity (at 20℃)	Softening Point (℃)	Solvent-Insoluble Content(wt%)		
Exper. NO.	Coal	Solvent	Temp.			H I	T I	Q I
S 2 1 2 2	ASSAM	Anth. Oil	410℃	1.225	227	96.5	36.5	0.1
S 2 1 2 4	ASSAM	Anth. Oil	430℃	1.240	208	92.7	34.6	0.1
S 2 1 1 6	ASSAM	Anth. Oil	450℃	1.262	193	96.1	39.0	0.1
S 2 2 2 2	SAMLA	Anth. Oil	410℃	1.234	245	98.3	50.2	0.1
S 2 2 2 4	SAMLA	Anth. Oil	430℃	1.257	224	98.5	50.4	0.1
S 2 2 1 6	SAMLA	Anth. Oil	450℃	1.264	209	98.2	41.4	0.2
S 3 1 0 1	ASSAM	Anth. Oil	430℃	1.250	210	95.3	35.0	0.2

Table 3.3.17 ANALYSIS OF COAL SOLUTION AND FILTRATE

Coal Sol. Filtrate Exper. NO.	Test Condition			Coal Solution			Filtrate	
	Coal	Solvent	Temp.	Moisture(wt%)	Sp. Gr. (20℃)	Vis. (cP)	Sp. Gr. (20℃)	Vis. (cP)
A1106	ASSAM	Tetralin	430℃	1.3	1.027	11.1	1.014	8.0
A1206	SAMLA	Tetralin	430℃	2.3	1.054	14.2	1.003	6.5
A1306	LIGNITE	Tetralin	430℃	3.5	1.014	11.0	1.000	6.9
A1406	ARGADA	Tetralin	430℃	1.5	1.067	18.3	1.002	5.9
A1506	O.A.midd.	Tetralin	430℃	0.5	1.015	8.5	0.985	5.1
A2122	ASSAM	Anth.Oil	410℃	1.1	1.105	72.9	1.111	109.0
A2124	ASSAM	Anth.Oil	430℃	1.1	1.099	38.8	1.095	42.5
A2116	ASSAM	Anth.Oil	450℃	1.3	1.089	18.5	1.090	20.0
A2222	SAMLA	Anth.Oil	410℃	1.9	1.138	51.4	1.096	43.4
A2224	SAMLA	Anth.Oil	430℃	2.1	1.136	45.5	1.091	27.8
A2216	SAMLA	Anth.Oil	450℃	2.3	1.131	32.5	1.088	21.1
A3101	ASSAM	Anth.Oil	430℃	1.2	1.099	38.8	1.095	42.5
A3107	ASSAM	Recycle I	430℃	1.1	1.092	34.9	1.089	43.9
A3123	ASSAM	Recycle II	430℃	1.1	1.082	35.0	1.082	42.1
A3131	ASSAM	Recycle III	430℃	1.2	1.077	36.0	1.076	44.5

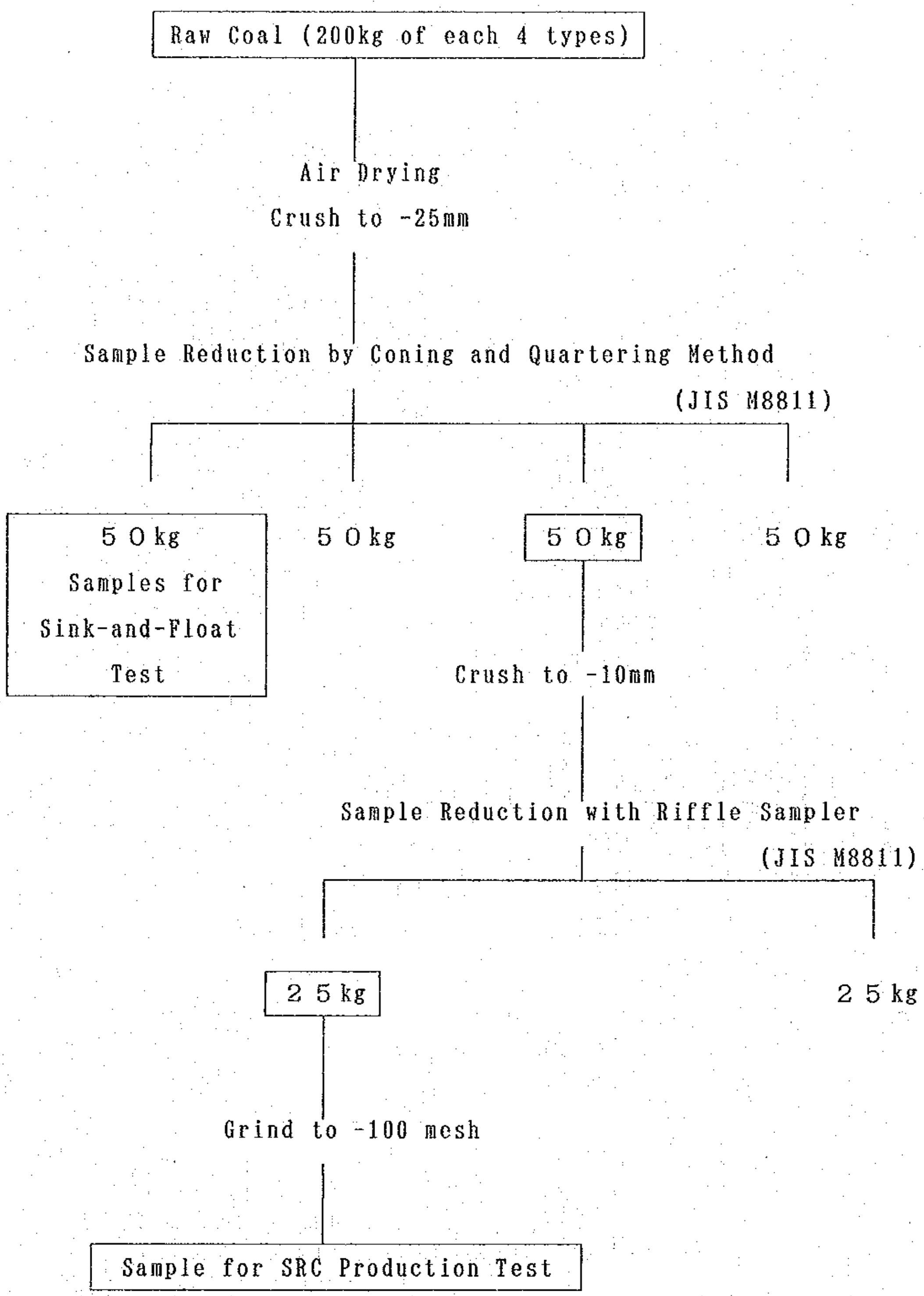

Figure 3.3.1 SAMPLE REDUCTION METHOD FOR COAL SAMPLES

1.Preparation of raw materials (coal, solvent & catalyst)
Measurement of weight
Analysis of moisture and ash contents of coal

↓

2.Charging of raw materials, Gas purging with nitrogen and then hydrogen

↓

3.Pressurizing by hydrogen → Temperature and pressure should be recorded under constant pressure.

↓

4.Heating, Maintaining, Cooling

↓

5.Venting → Measurement of gas volume and weight of trapped materials

↓

6.Recovery of products → Measurement of weight, Rinsing by solvnet

↓

7.Filtration

↓ (branches to 11 and 8)

11.Filtrate → Measurement of weight and specific gravity

↓

12.Vacuum distillation

↓ (branches to 13 and 14)

13.SRC
Measurement of weight

14.Oil
Measurement of weight

8.Residue with oils washing

↓

9.Drying

↓

10.Residue
Measurement of weight and ash content

Figure 3.3.2 FLOW DIAGRAM OF SRC PRODUCTION TEST

No.	Name
1	Agitator
2	Autoclave
3	Motor with agitator
4	Cooling Water
5	Valve (inlet)
6	Valve (outlet)
7	Pressure gauge
8	Safety valve
9	Thermo couple
10	Electric furnace

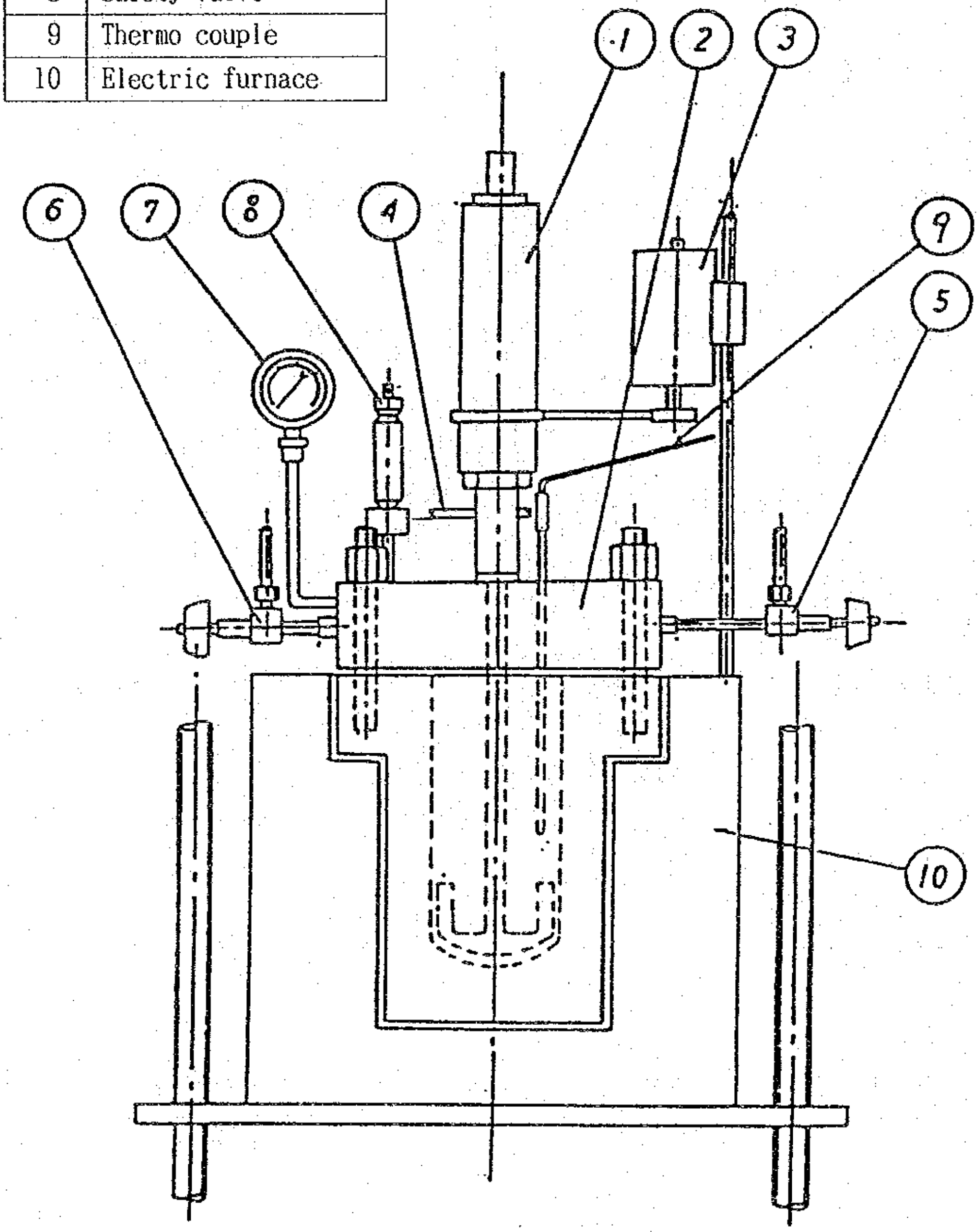

Figure 3.3.3 AUTOCLAVE APPARATUS

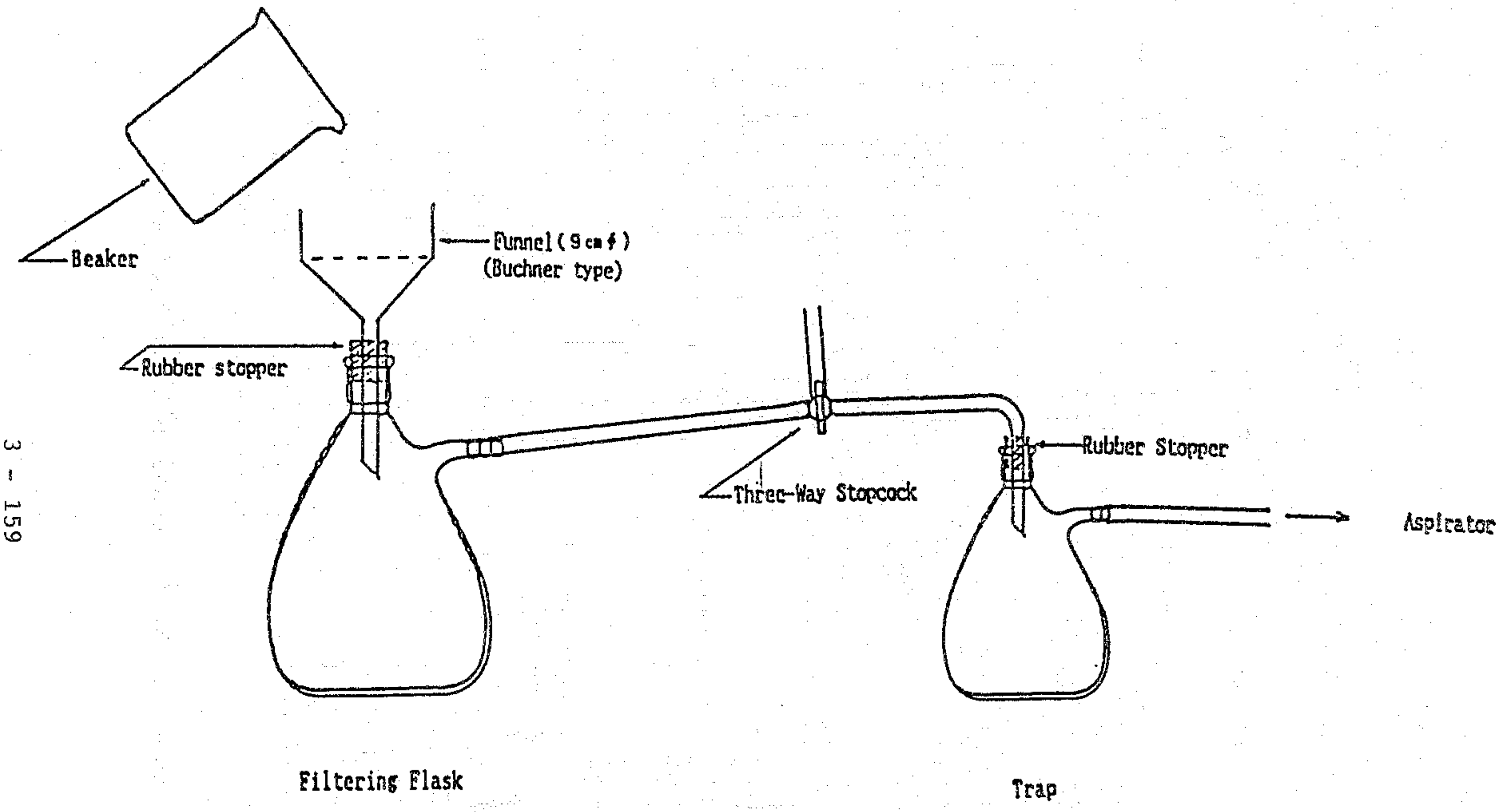

Figure 3.3.4 FILTERING APPARATUS

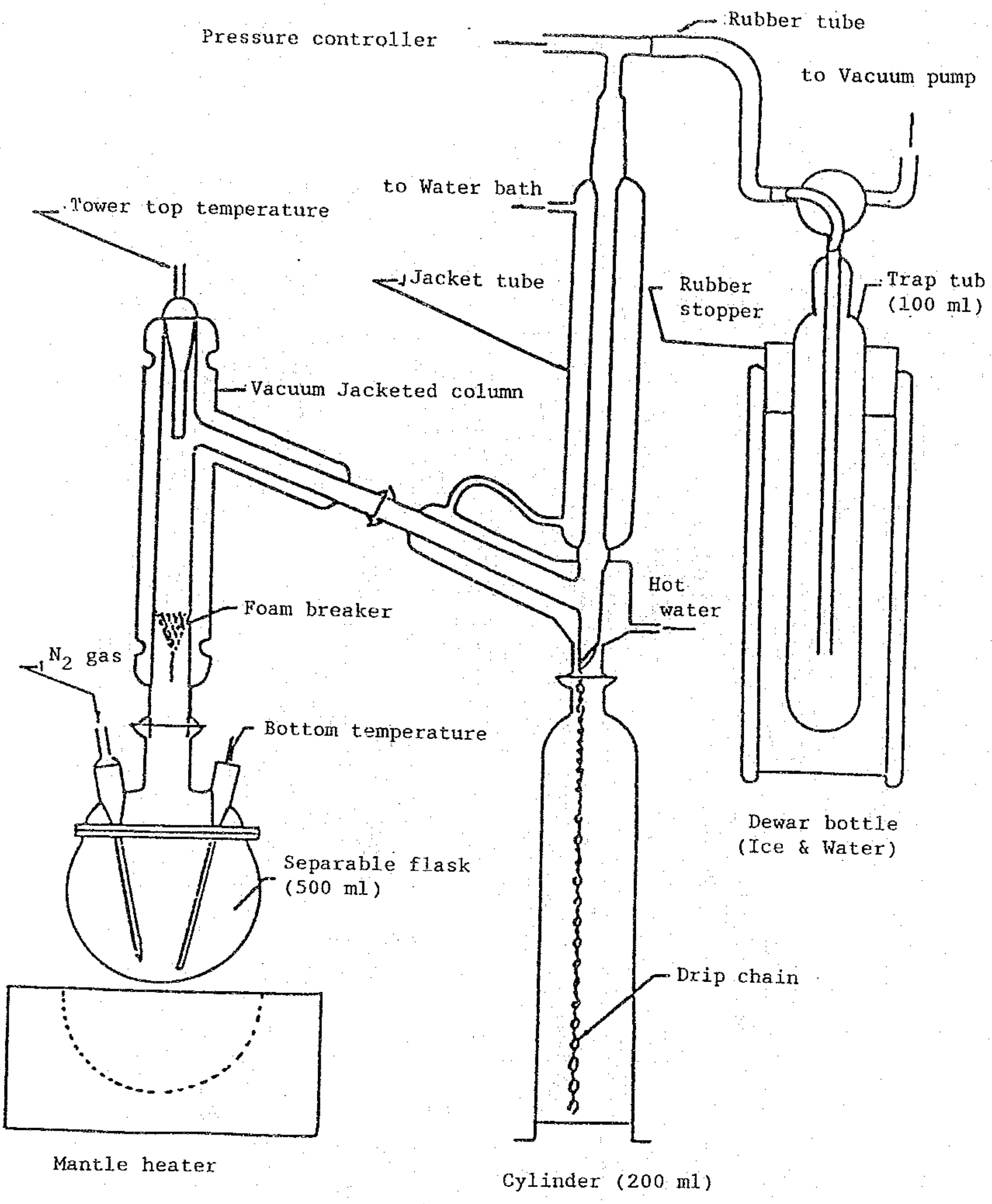

Figure 3.3.5 **FULLY AUTOMATIC VACUUM DISTILLATION APPARATUS**

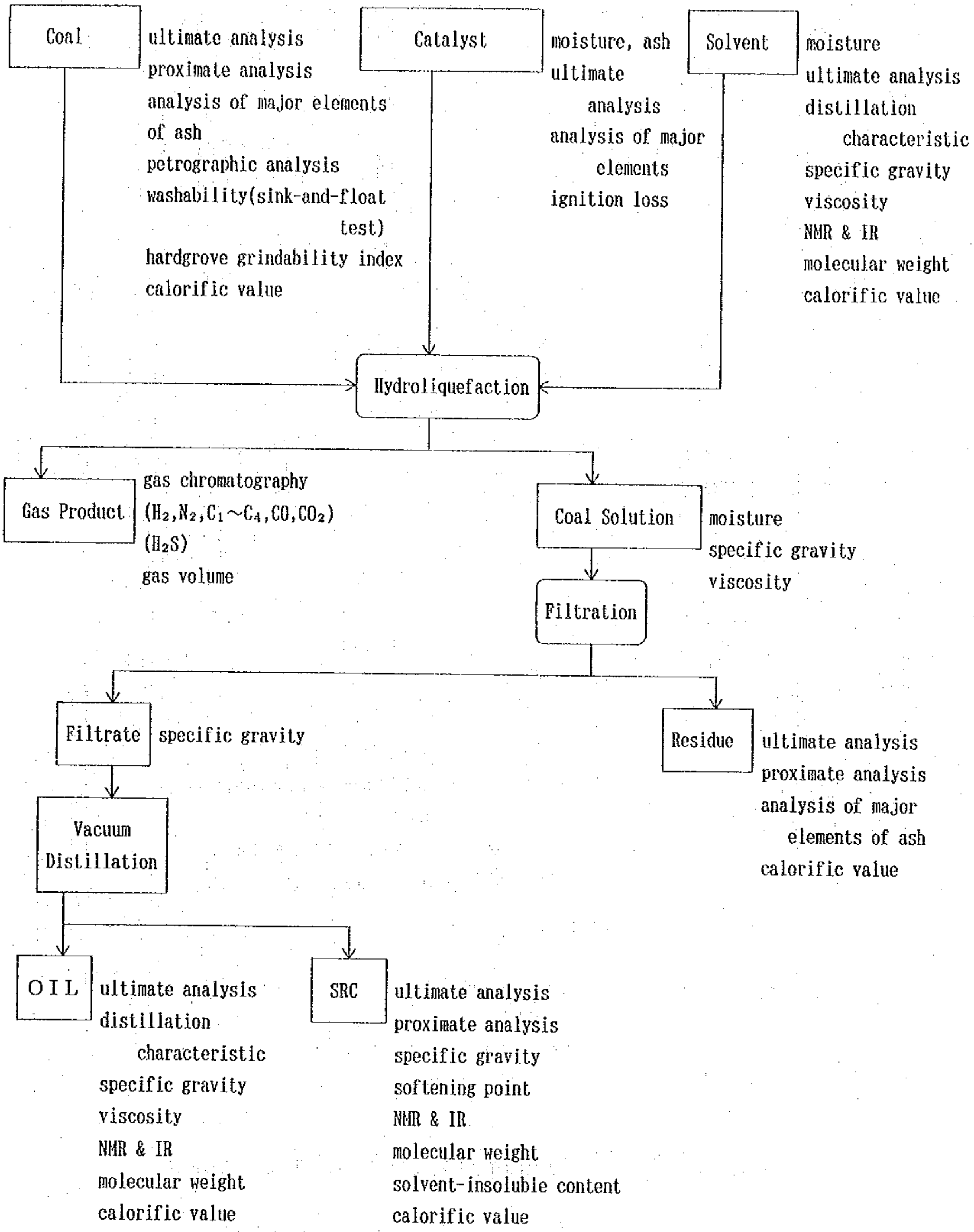

Figure 3.3.6 ITEMS OF ANALYSIS

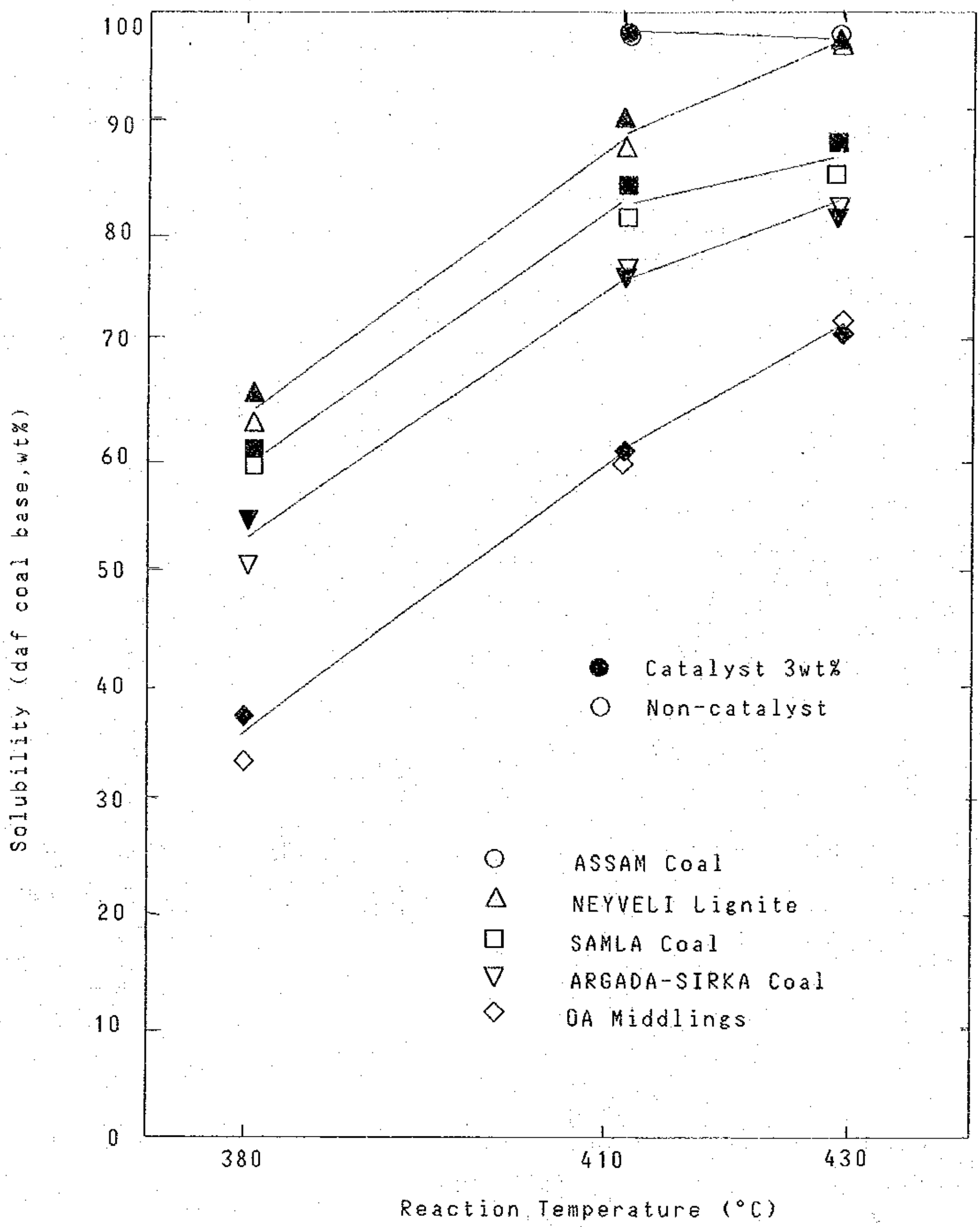

Figure 3.3.7 SOLUBILITY OF VARIOUS COALS

(Condition:Tetralin-60min-100Kg/cm^{2}G)

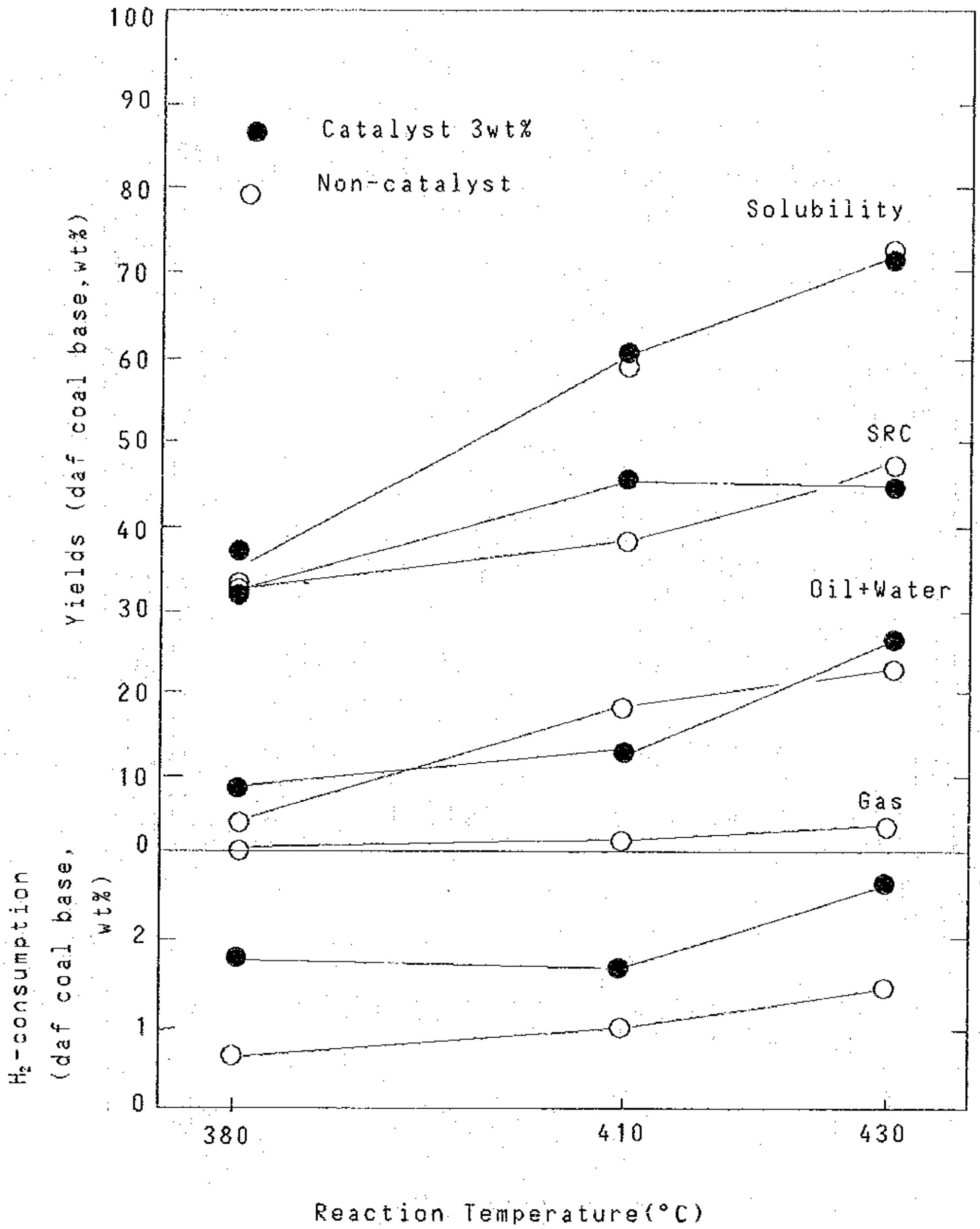

Figure 3.3.8 YIELDS OF OA MIDDLINGS

(Condition:Tetralin-60min-100Kg/cm^{2}G)

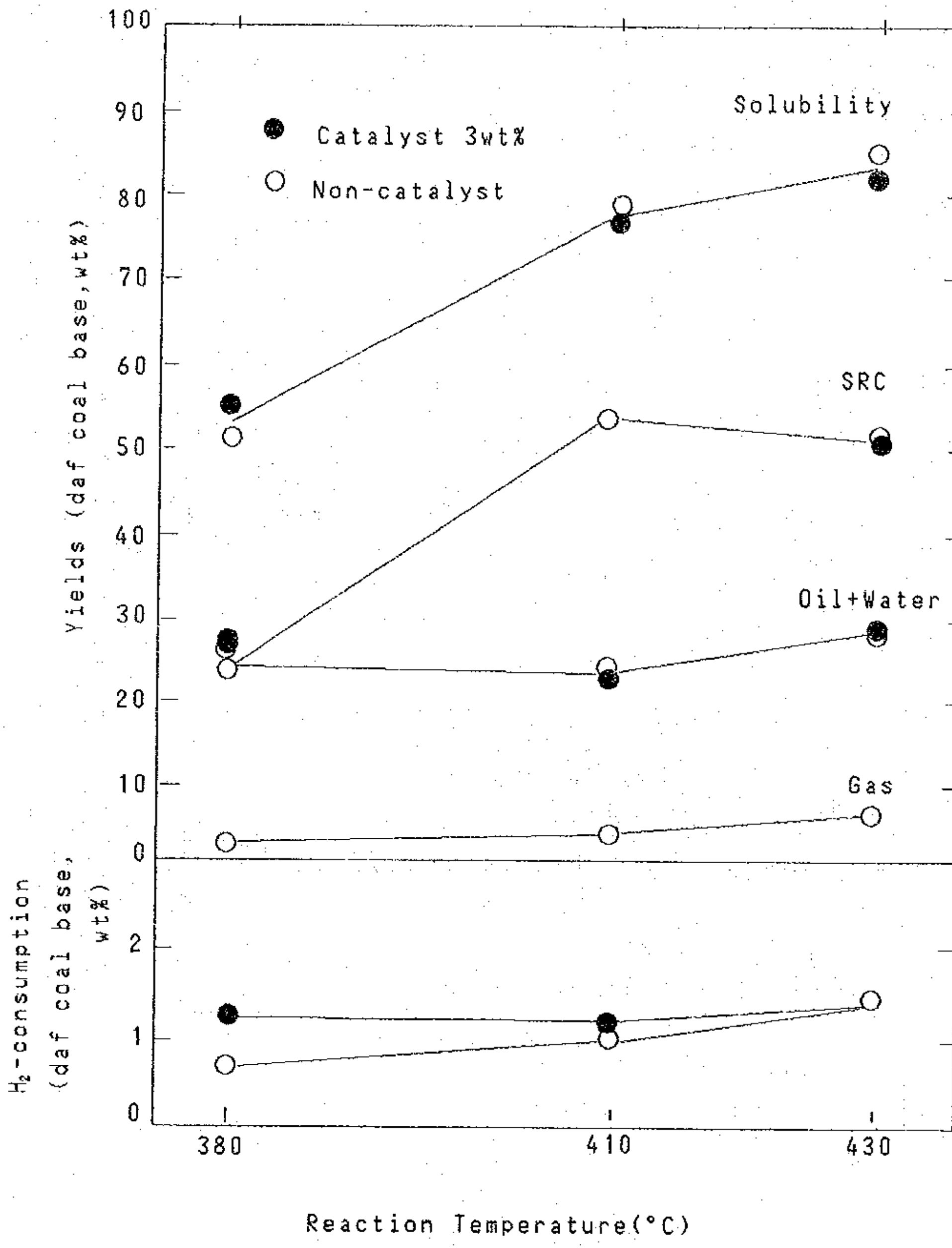

Figure 3.3.9 YIELDS OF ARGADA-SIRKA COAL

(Condition:Tetralin-60min-100Kg/cm²G)

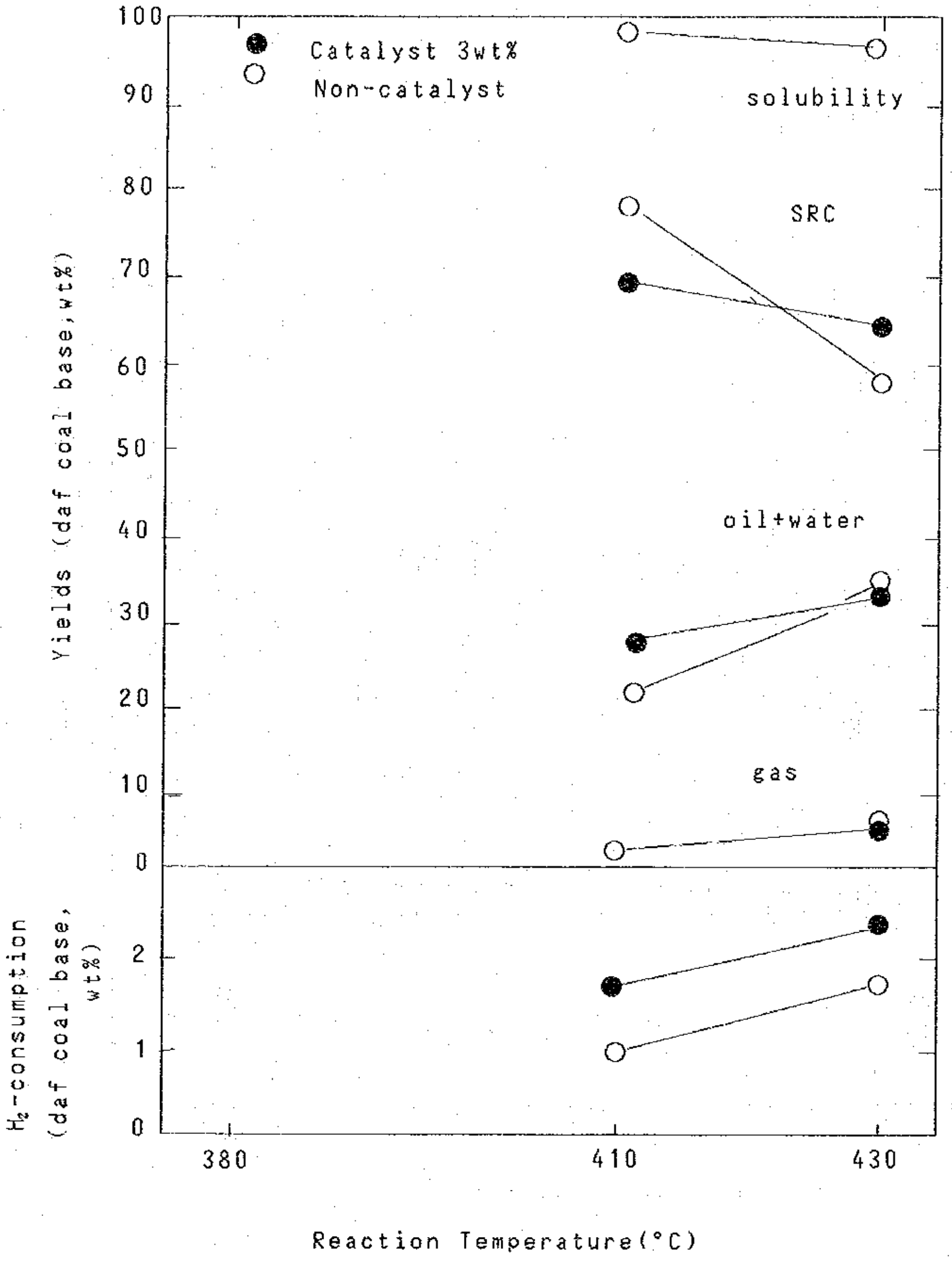

Figure 3.3.10 YIELDS OF ASSAM COAL

(Condition:Tetralin-60min-100Kg/cm^{2}G)

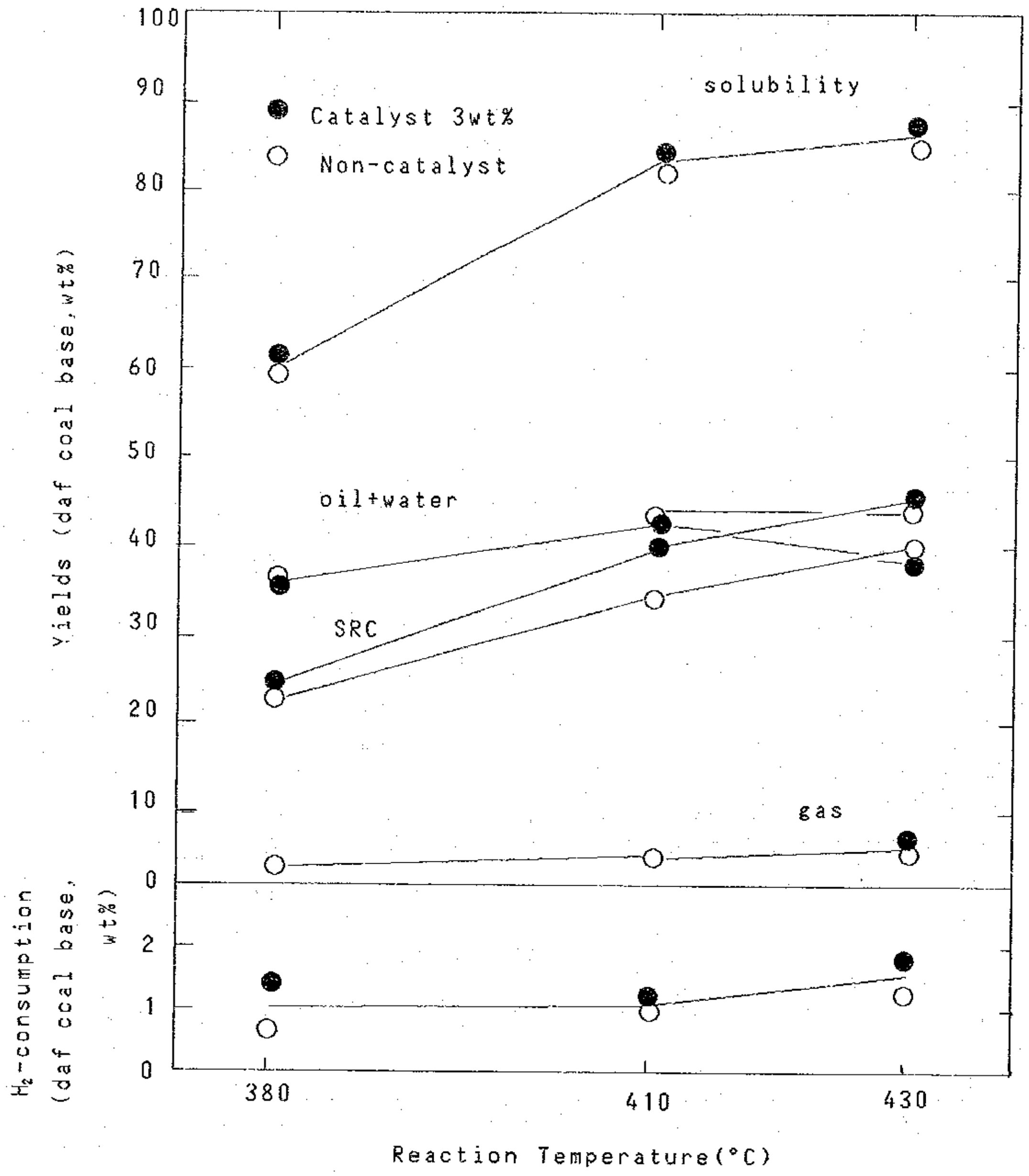

Figure 3.3.11 YIELDS OF SAMLA COAL

(Condition:Tetralin-60min-100Kg/cm²G)

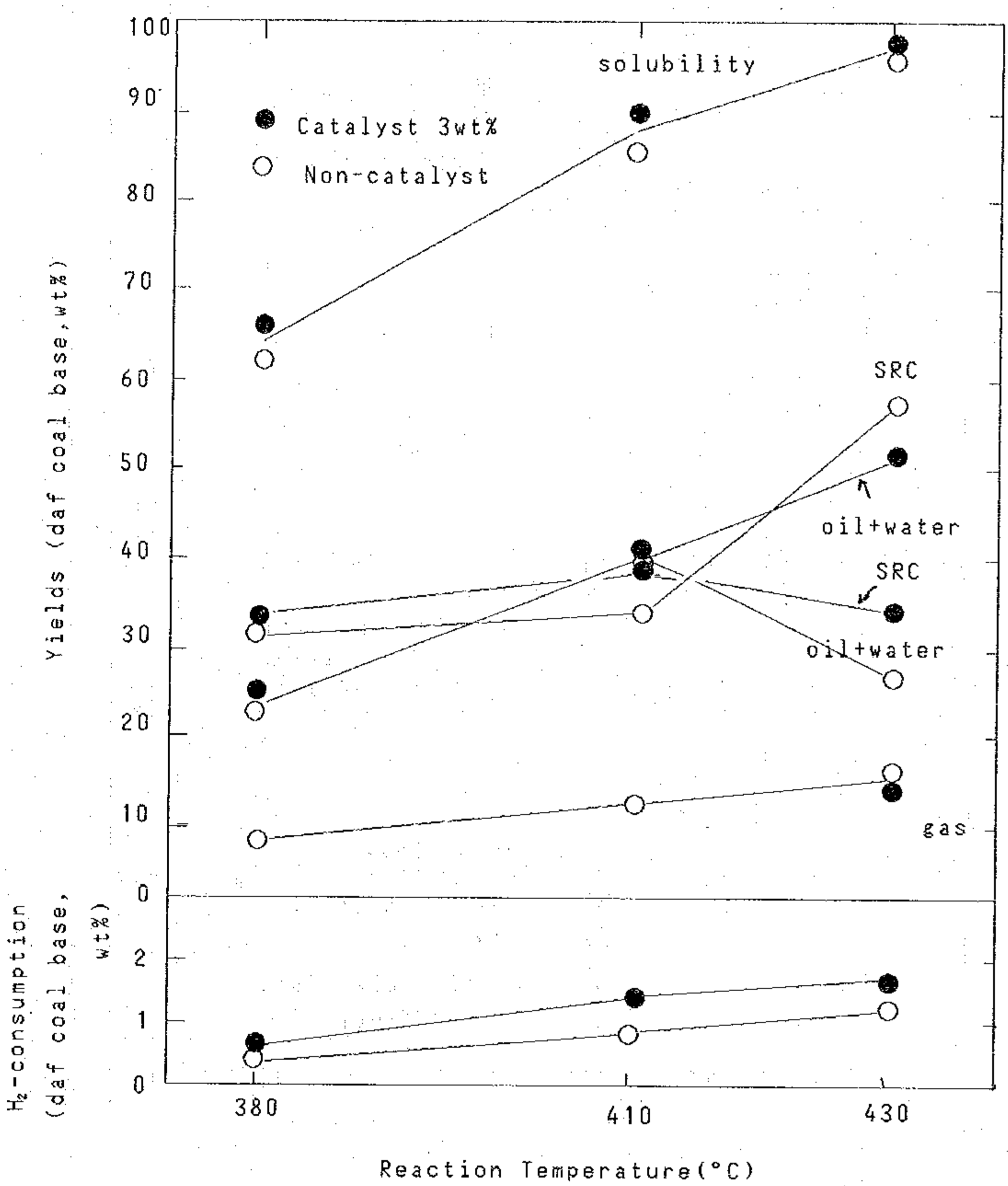

Figure 3.3.12 YIELDS OF NEYVELI LIGNITE

(Condition:Tetralin-60min-100Kg/cm²G)

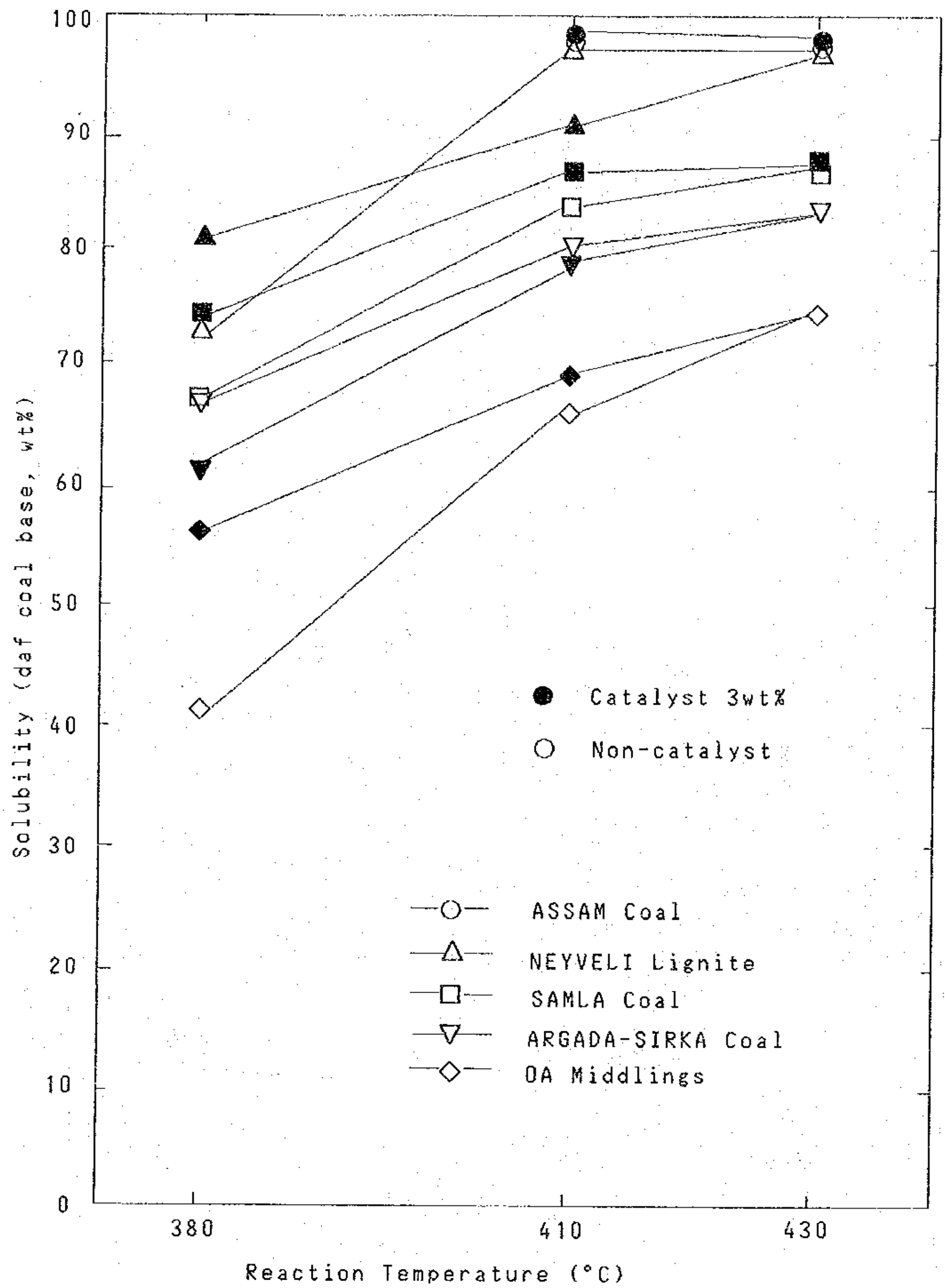

Figure 3.3.13 SOLUBILITY OF VARIOUS COALS

(Condition:Tetralin-90min-100Kg/cm²G)

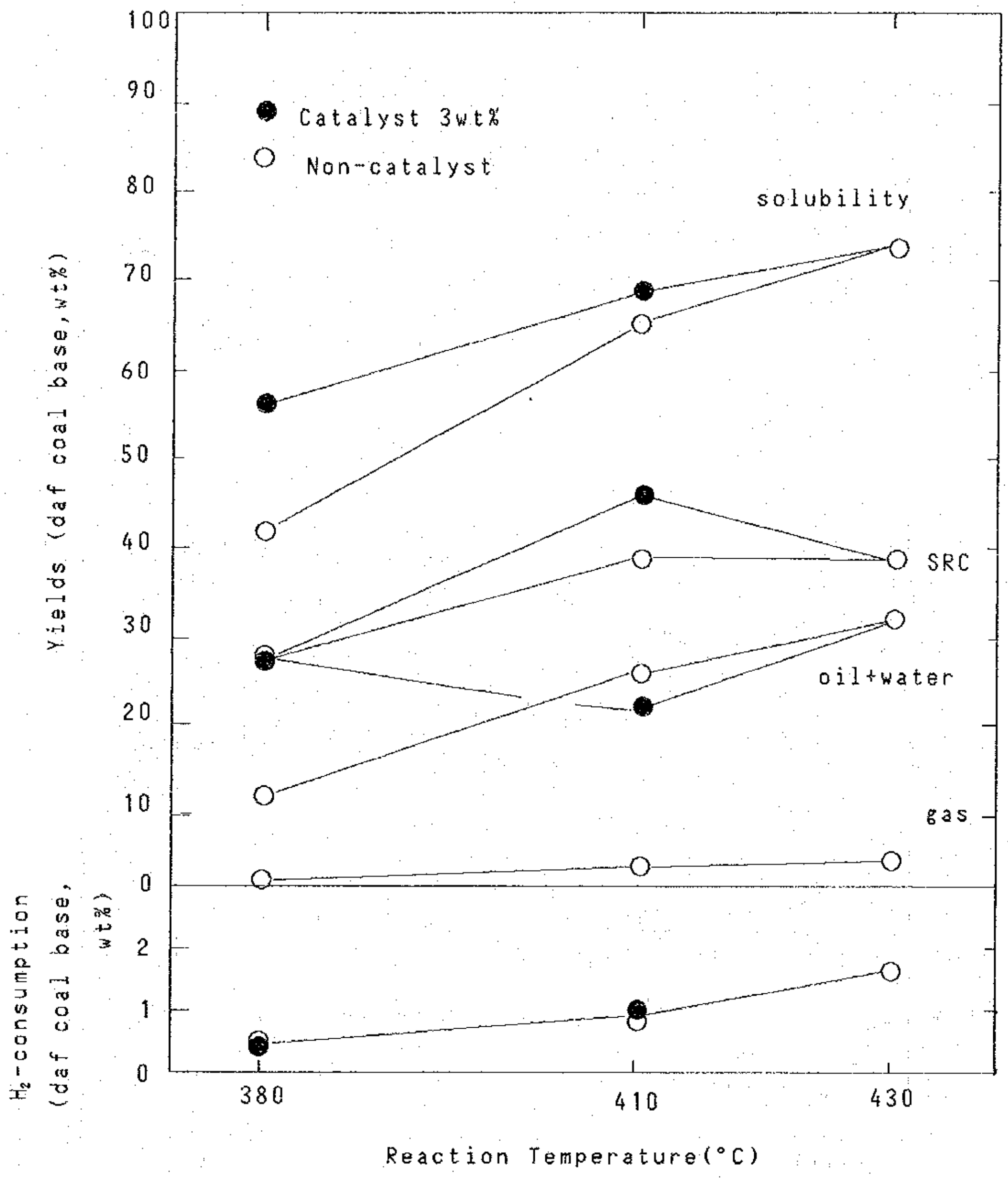

Figure 3.3.14 YIELDS OF OA MIDDLINGS

(Condition:Tetralin-90min-100Kg/cm²G)

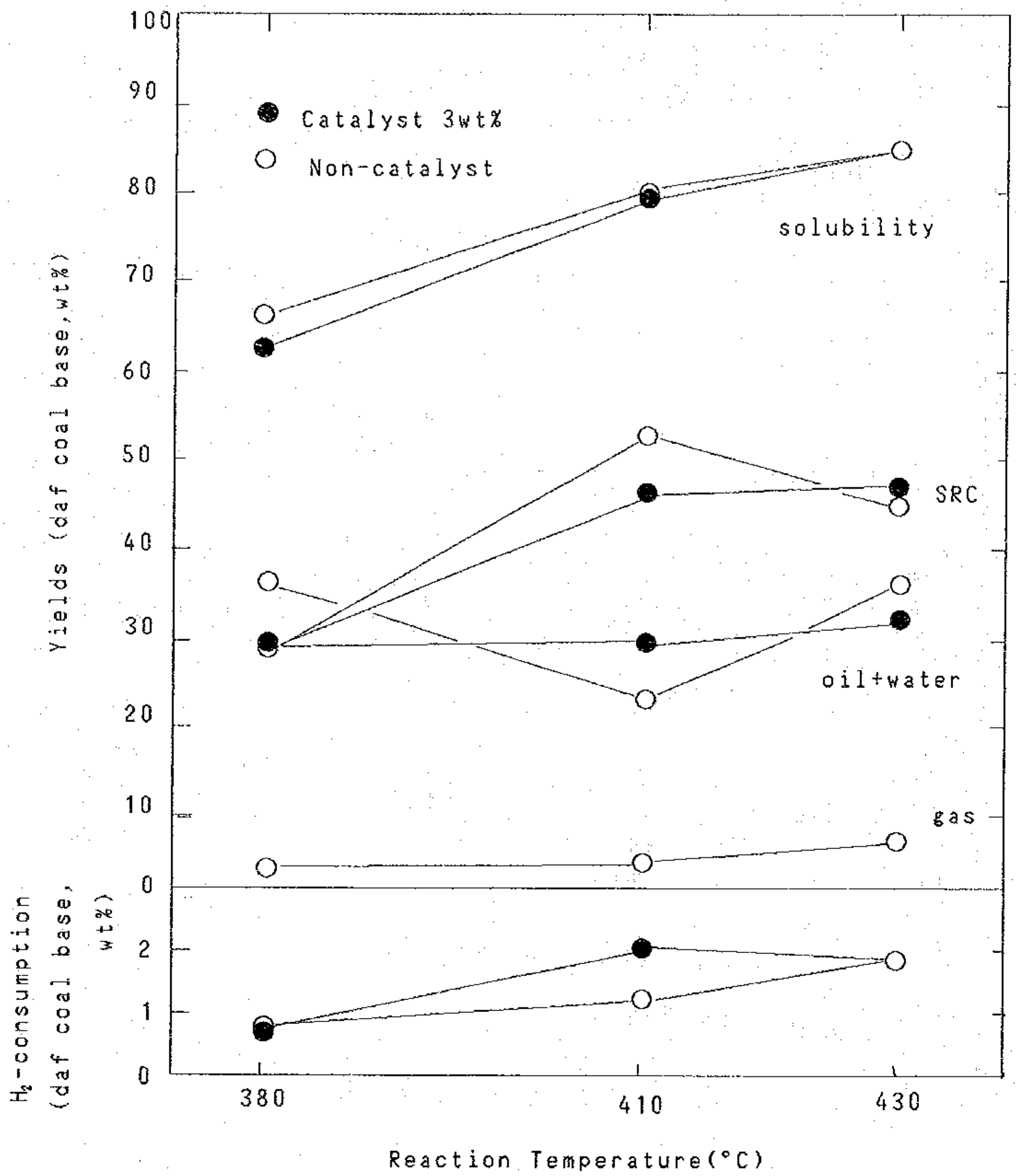

Figure 3.3.15 YIELDS OF ARGADA-SIRKA COAL

(Condition:Tetralin-90min-100Kg/cm²G)

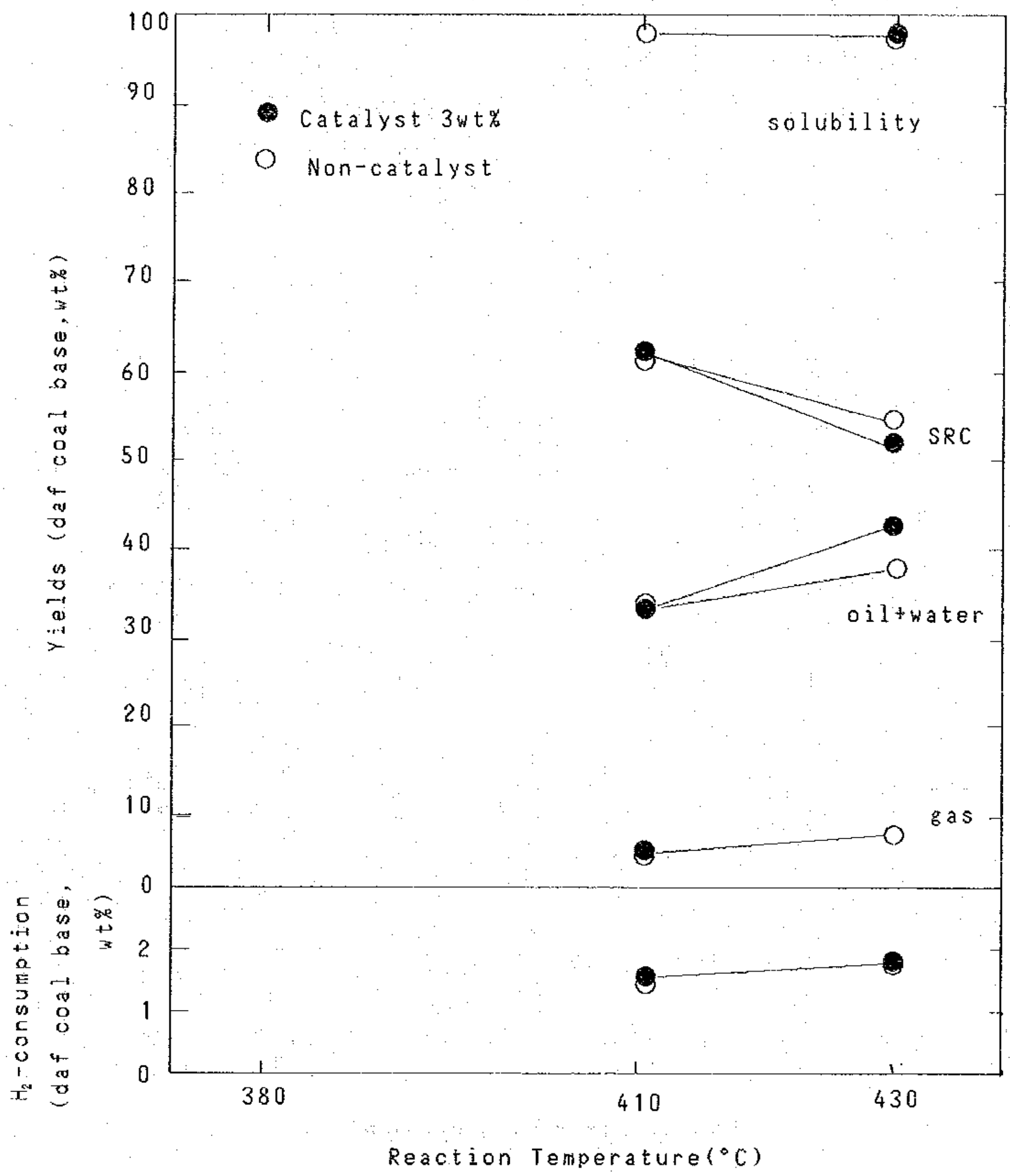

Figure 3.3.16 YIELDS OF ASSAM COAL

(Condition:Tetralin-90min-100Kg/cm^{2}G)

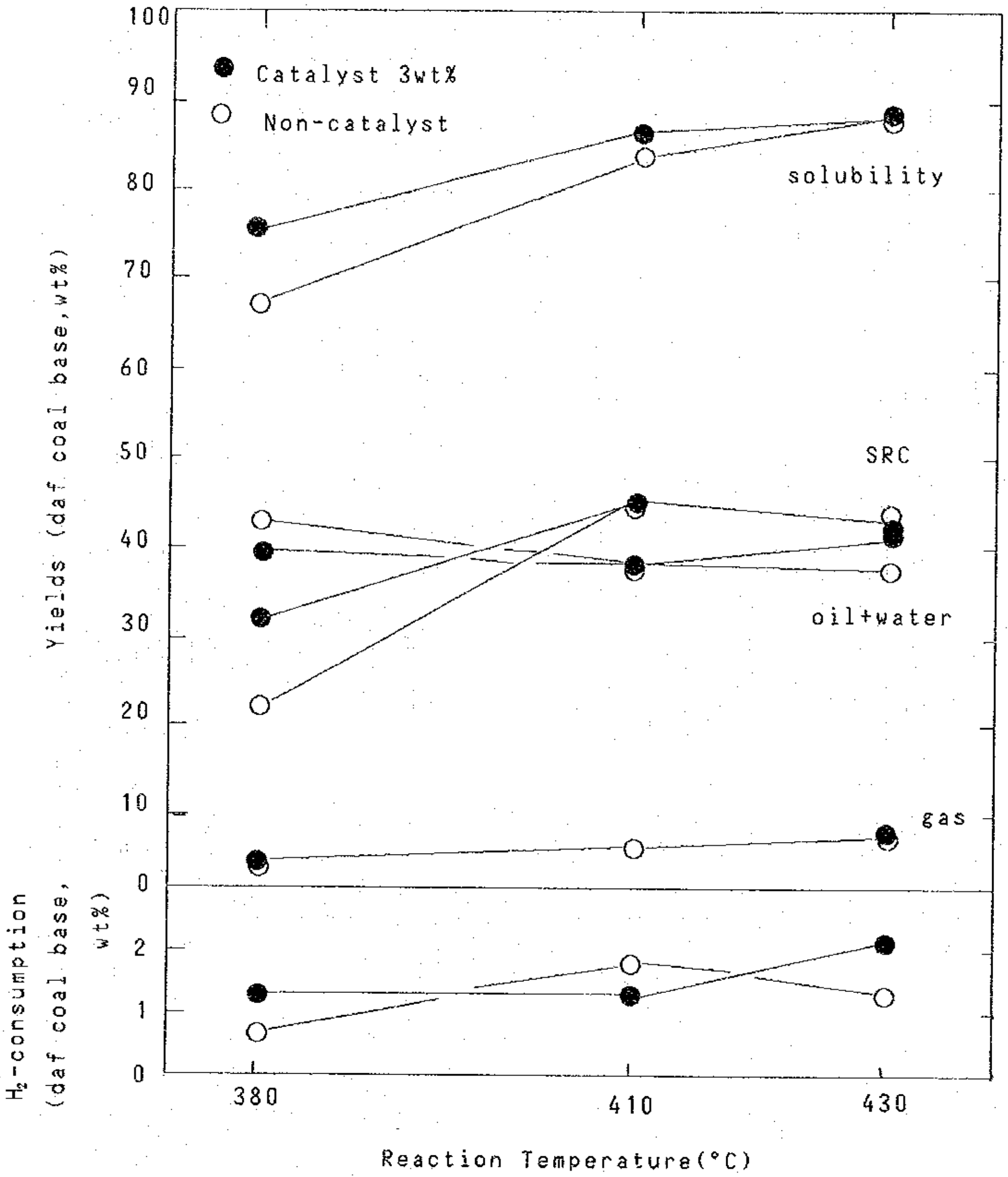

Figure 3.3.17 YIELDS OF SAMLA COAL

(Condition: Tetralin-90min-100Kg/cm²G)

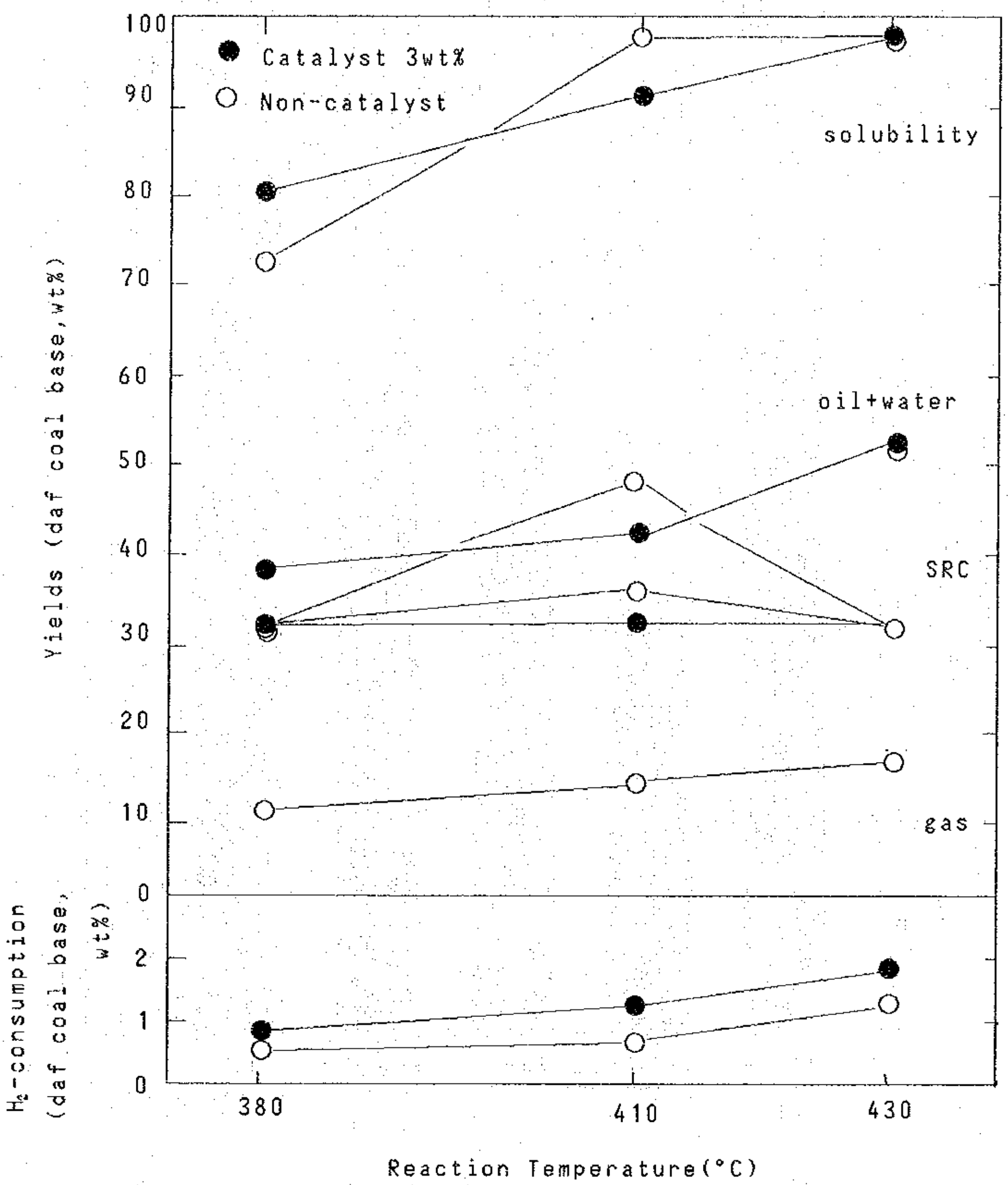

Figure 3.3.18 YIELDS OF NEYVELI LIGNITE

(Condition:Tetralin-90min-100Kg/cm²G)

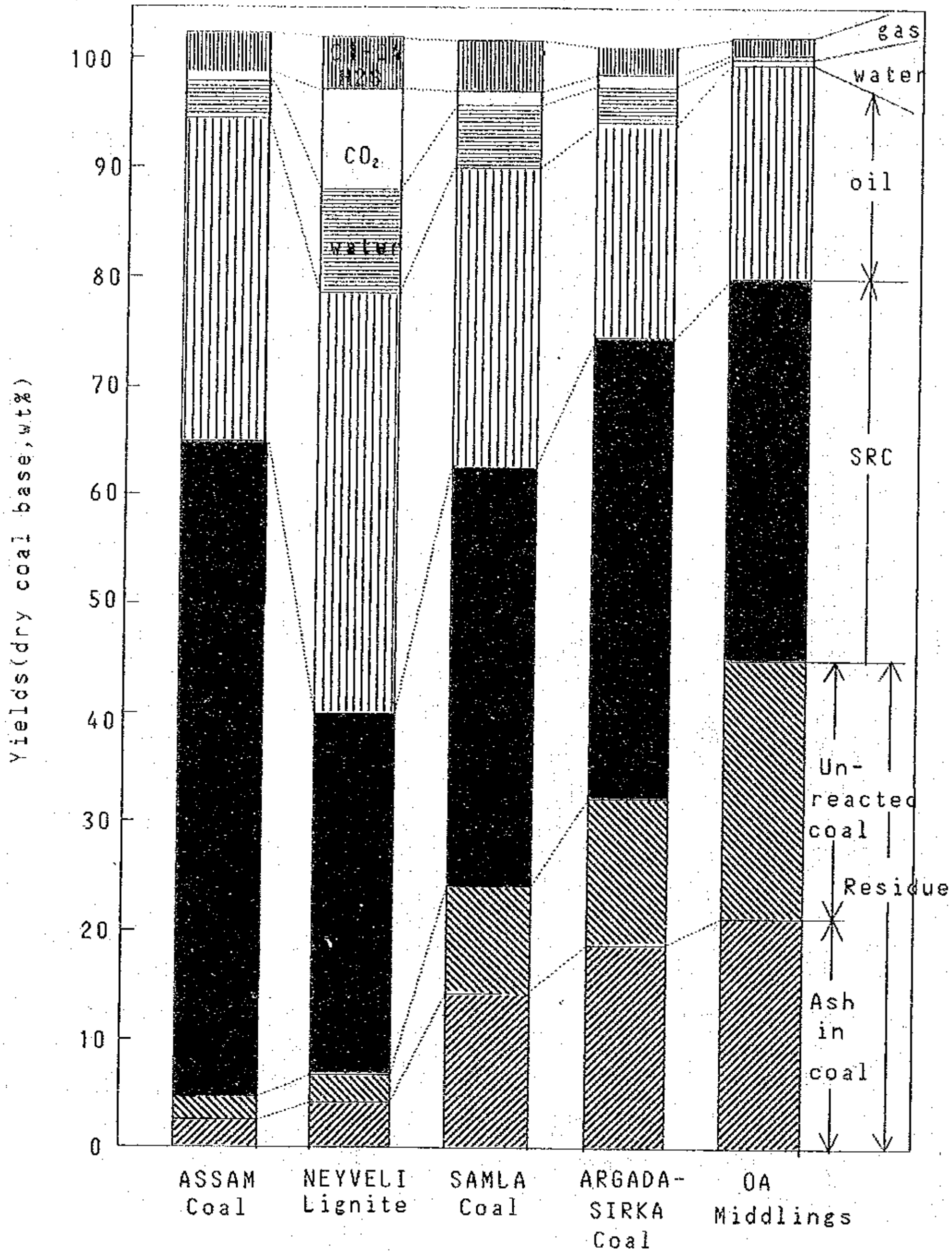

Figure 3.3.19 YIELDS OF VARIOUS COALS

(Condition:Tetralin-430°C-60min-100Kg/cm^{2}G)

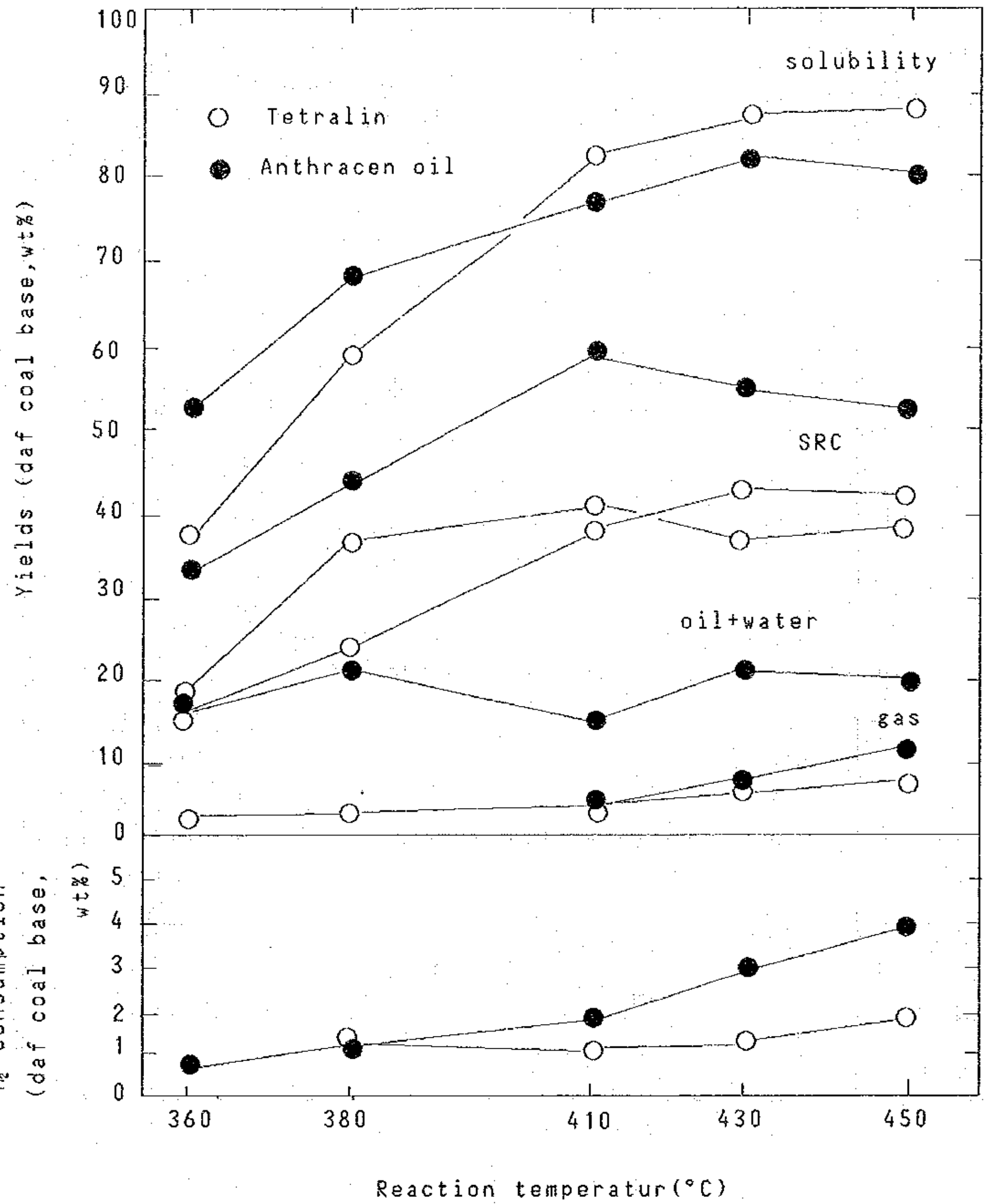

Figure 3.3.20 INFLUENCE OF REACTION TEMPERATURE (SAMLA COAL)

(Condition:60min-100Kg/cm^{2}G-3wt%-100%)

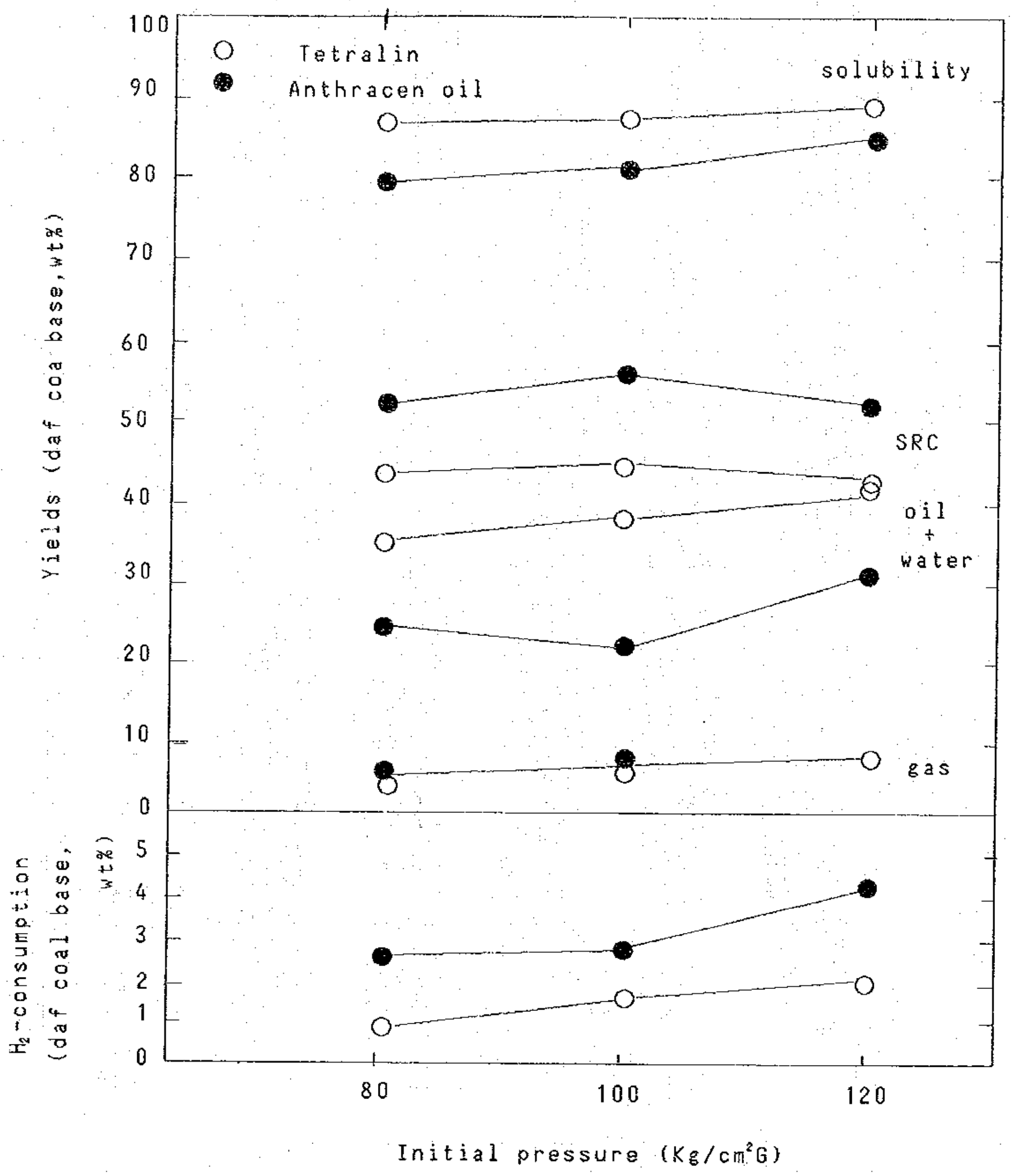

Figure 3.3.21 INFLUENCE OF INITIAL PRESSURE (SAMLA COAL)

(Condition:430°C-60min-3wt%-100%)

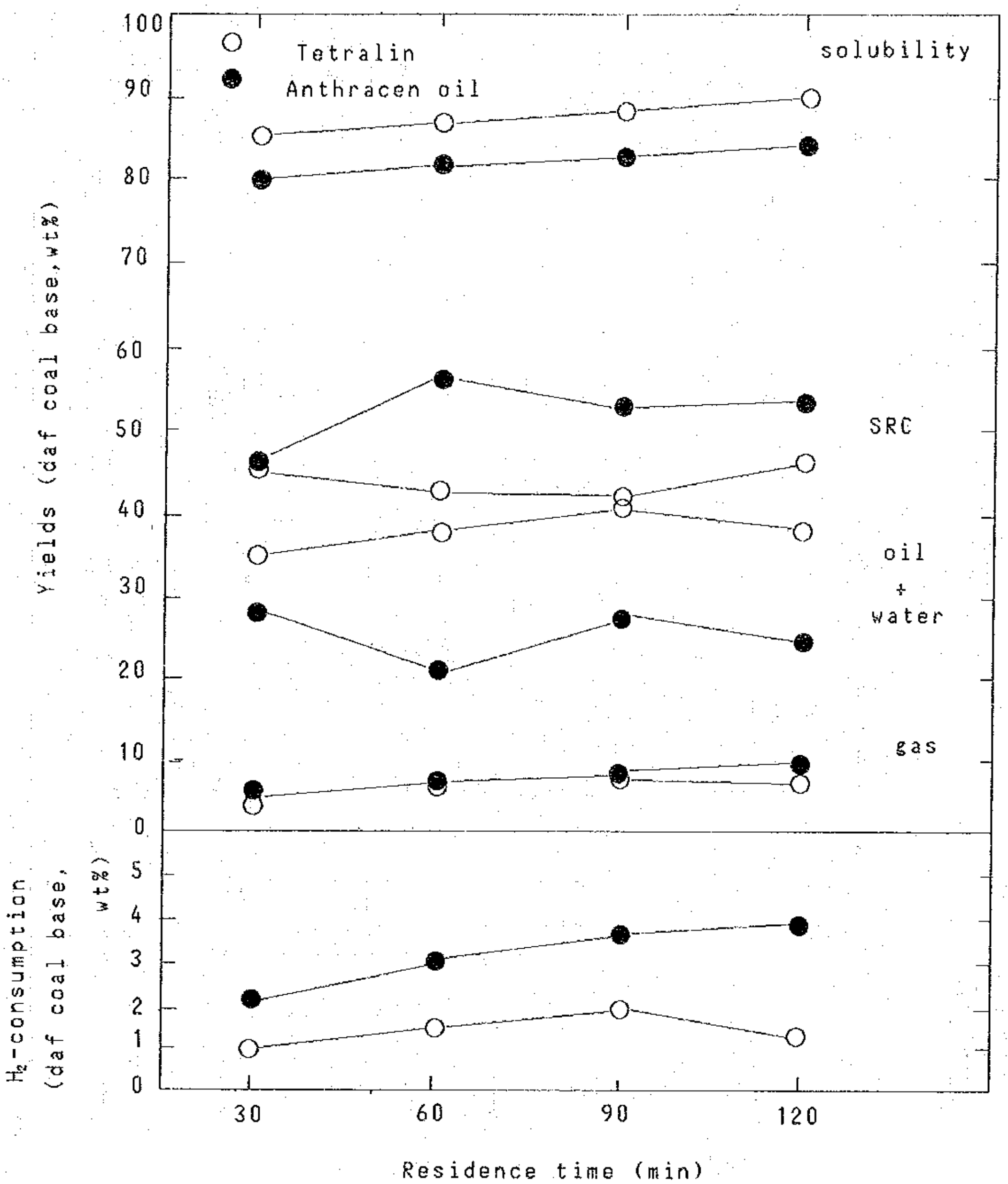

Figure 3.3.22 INFLUENCE OF RESIDENCE TIME (SAMLA COAL)

(Condition:430°C-100Kg/cm²G-3wt%-100%)

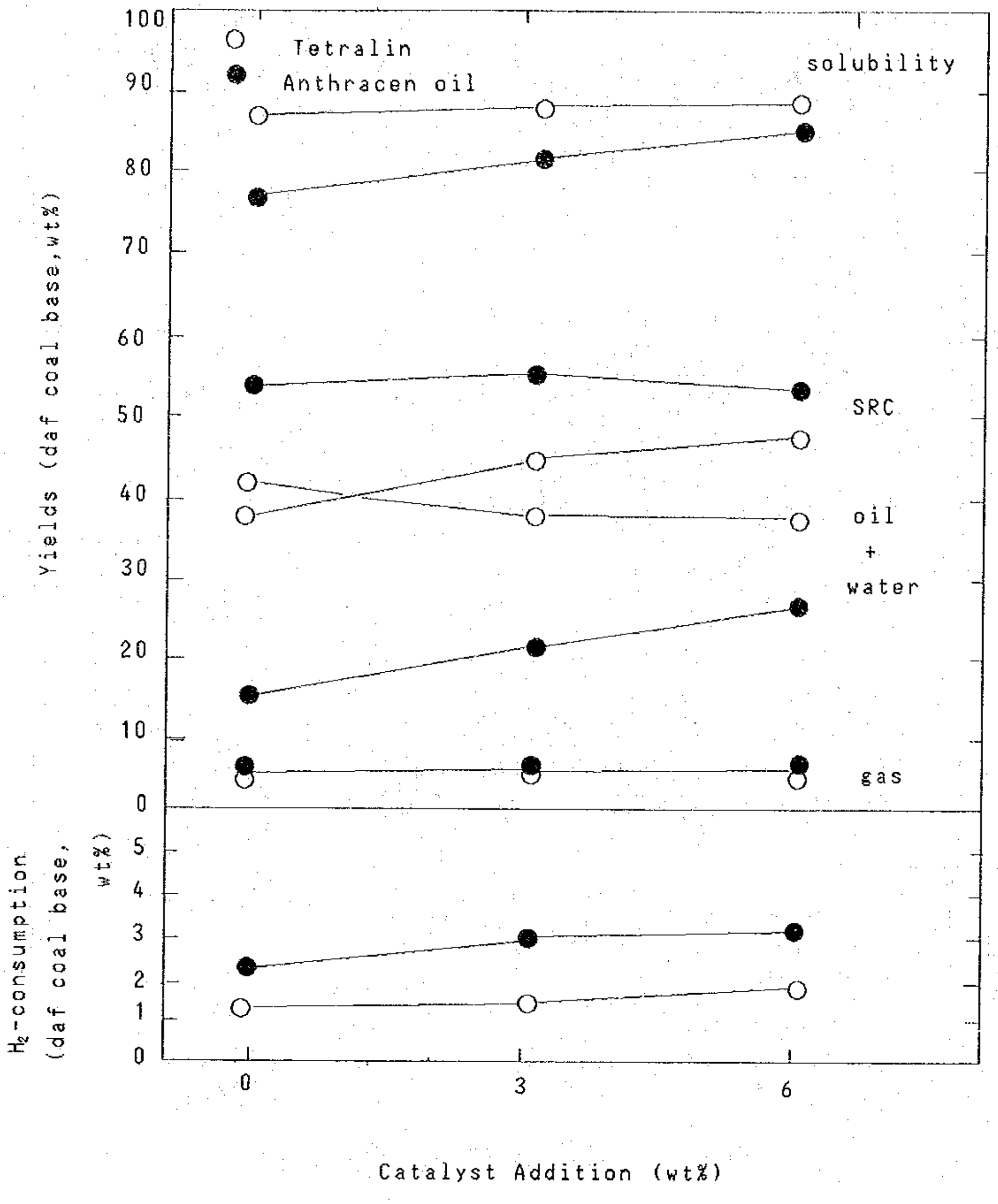

Figure 3.3.23 INFLUENCE OF CATALYST ADDITION (SAMLA COAL)

(Condition:430°C-60min-100Kg/cm²G-100%)

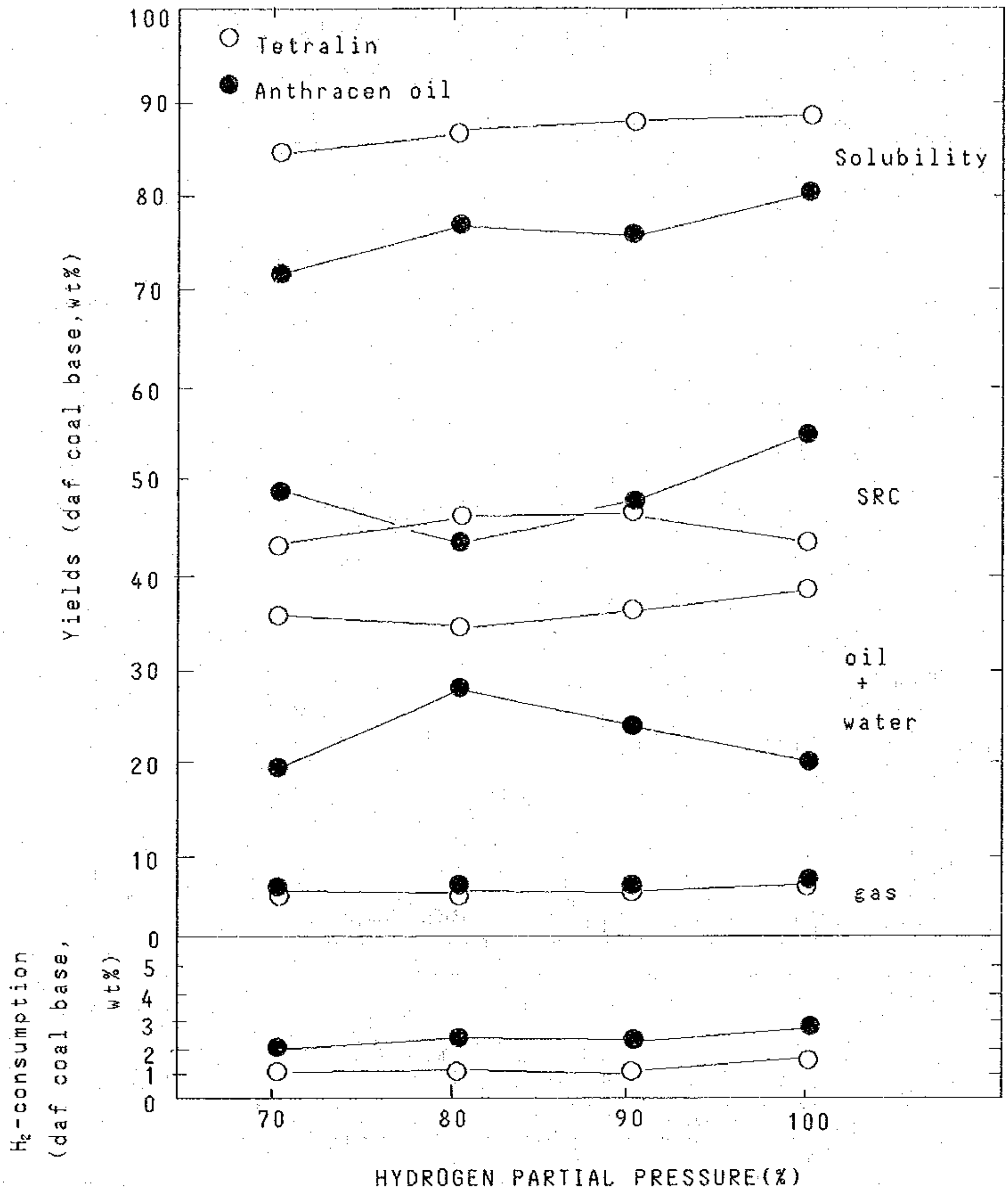

Figure 3.3.24 INFLUENCE OF HYDROGEN PARTIAL PRESSURE (SAMLA COAL)

(Condition:430°C-60min-100Kg/cm²G-3wt%)

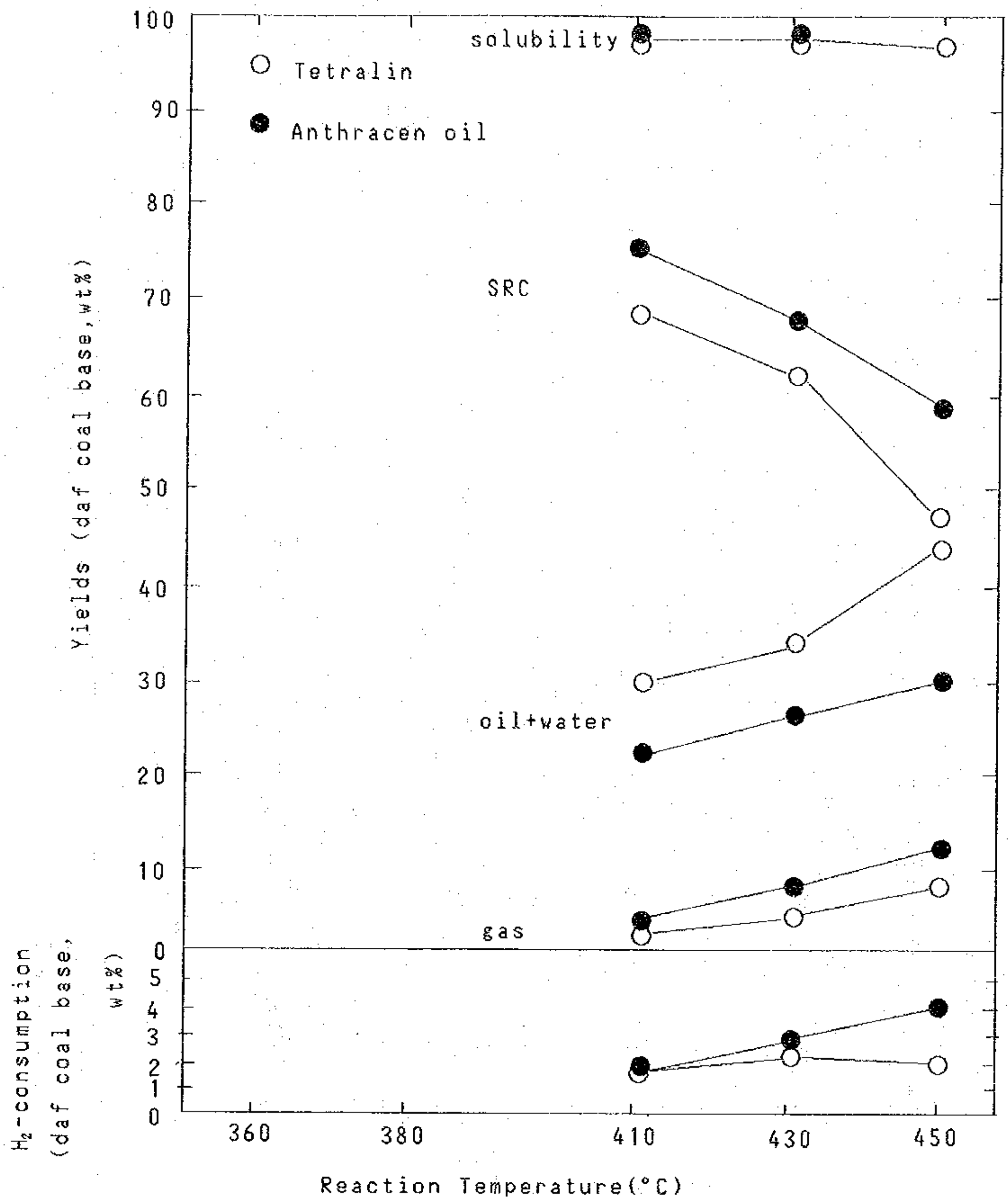

Figure 3.3.25 INFLUENCE OF REACTION TEMPERATURE (ASSAM COAL)

(Condition:60min-100Kg/cm²G-3wt%-100%)

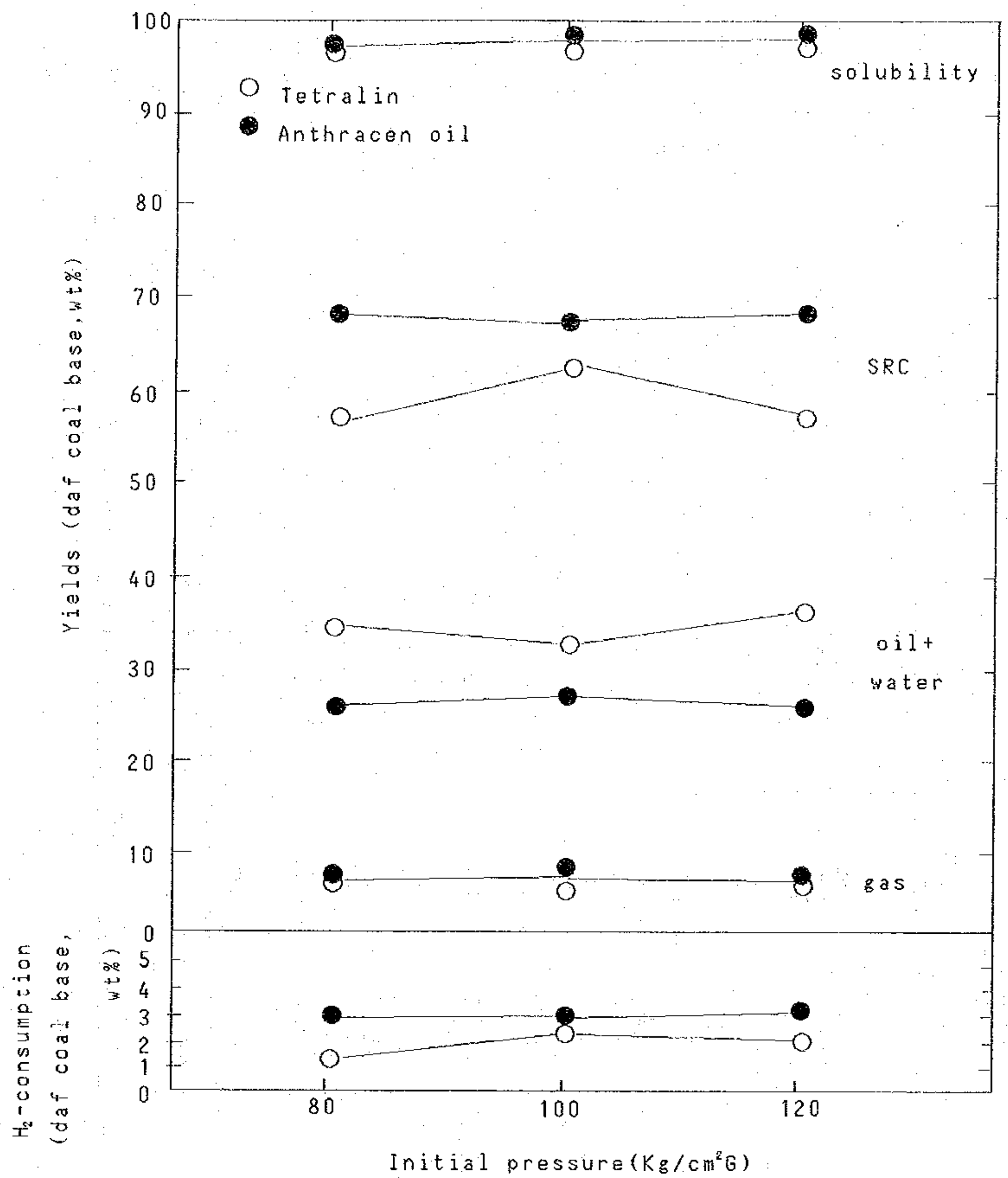

Figure 3.3.26 INFLUENCE OF INITIAL PRESSURE (ASSAM COAL)

(Condition:430°C-60min-3wt%-100%)

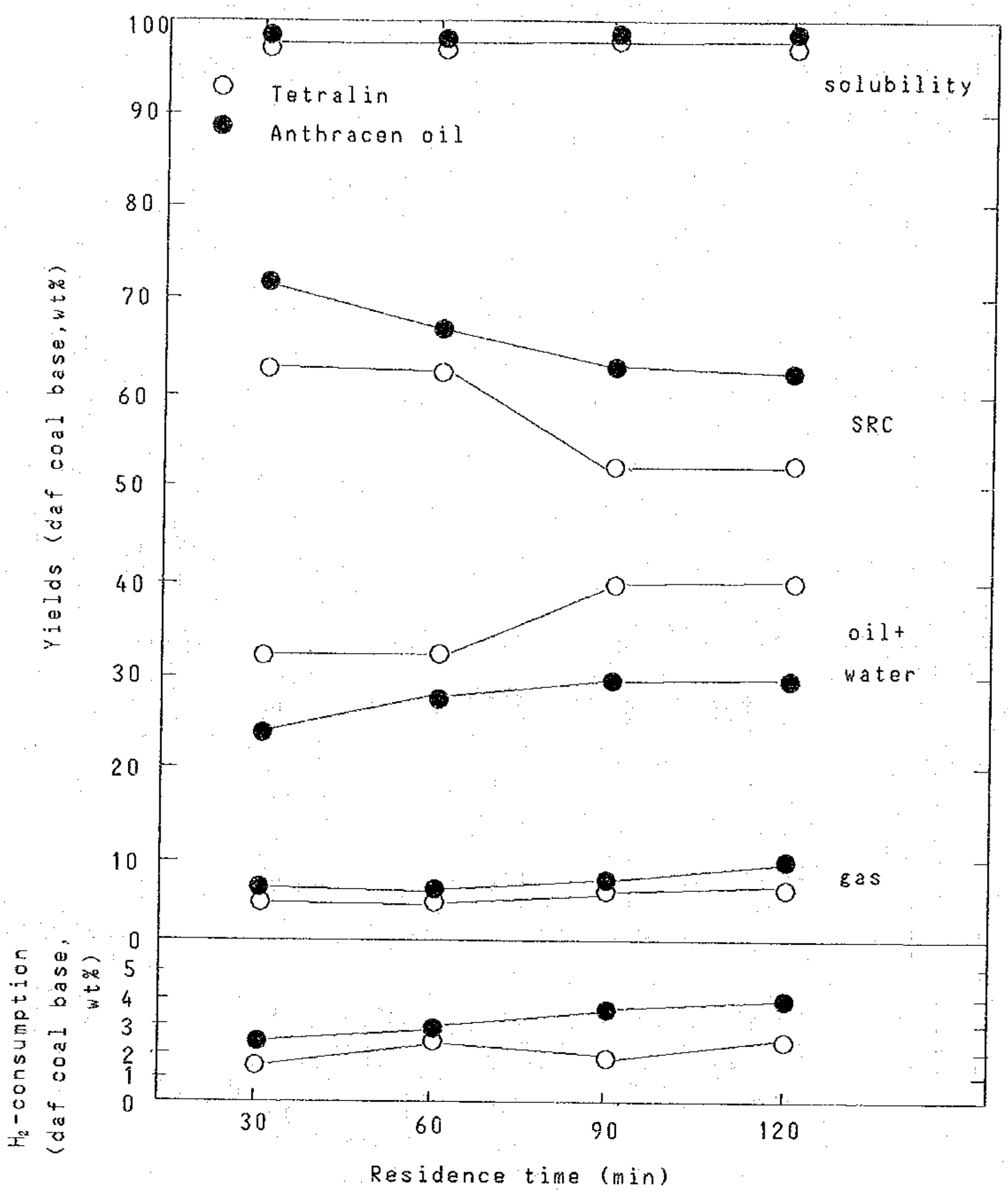

Figure 3.3.27 INFLUENCE OF RESIDENCE TIME (ASSAM COAL)

(Condition:430°C-100Kg/cm²G-3wt%-100%)

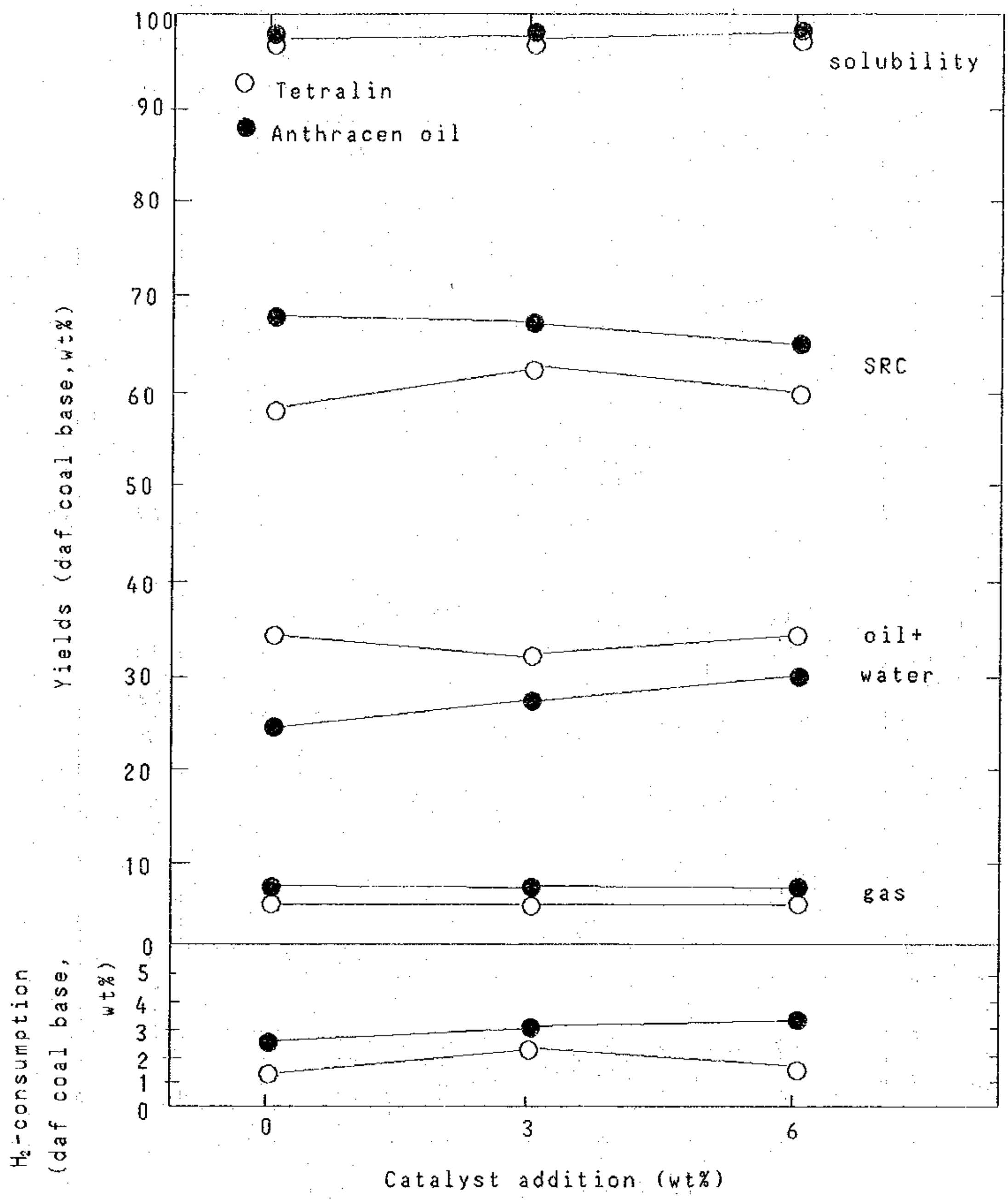

Figure 3.3.28 INFLUENCE OF CATALYST ADDITION (ASSAM COAL)

(Condition:430°C-60min-100Kg/cm²G-100%)

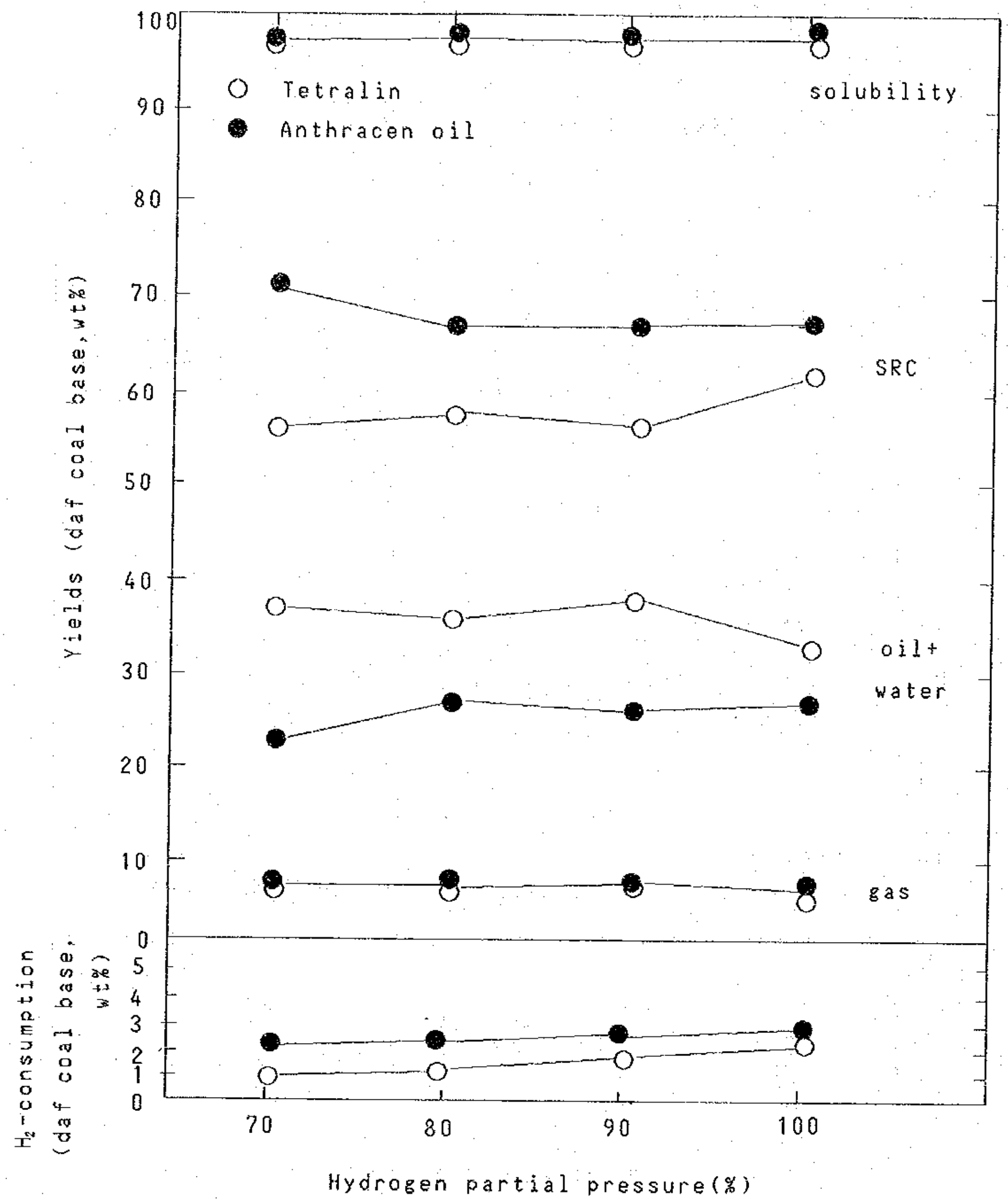

Figure 3.3.29 INFLUENCE OF HYDROGEN PARTIAL PRESSURE (ASSAM COAL)

(Condition:430°C-60min-100Kg/cm²G-3wt%)

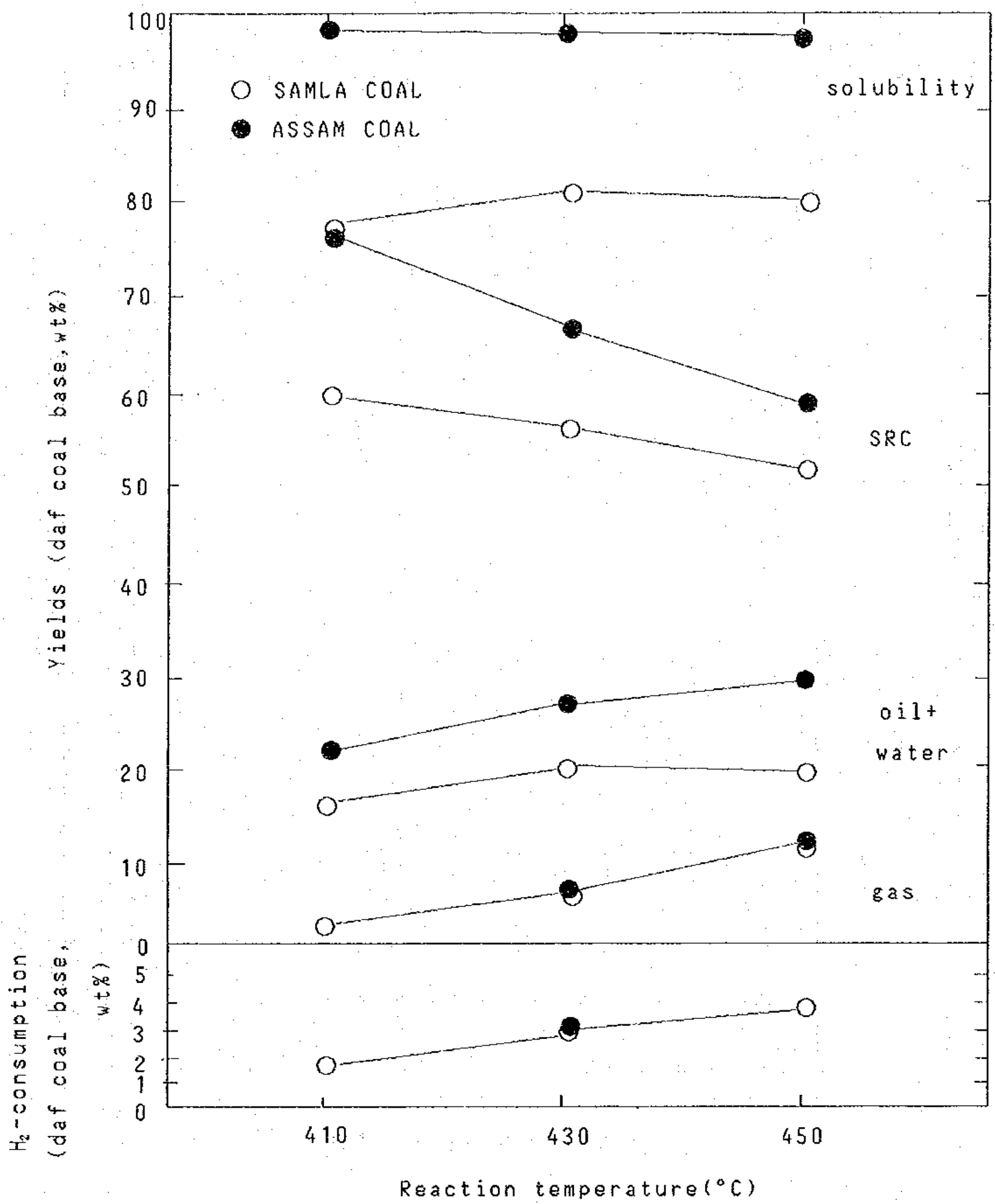

Figure 3.3.30 YIELDS OF SAMLA AND ASSAM COAL

(Condition:Anthracene oil-60min-100Kg/cm^{2}G-3wt%-100%)

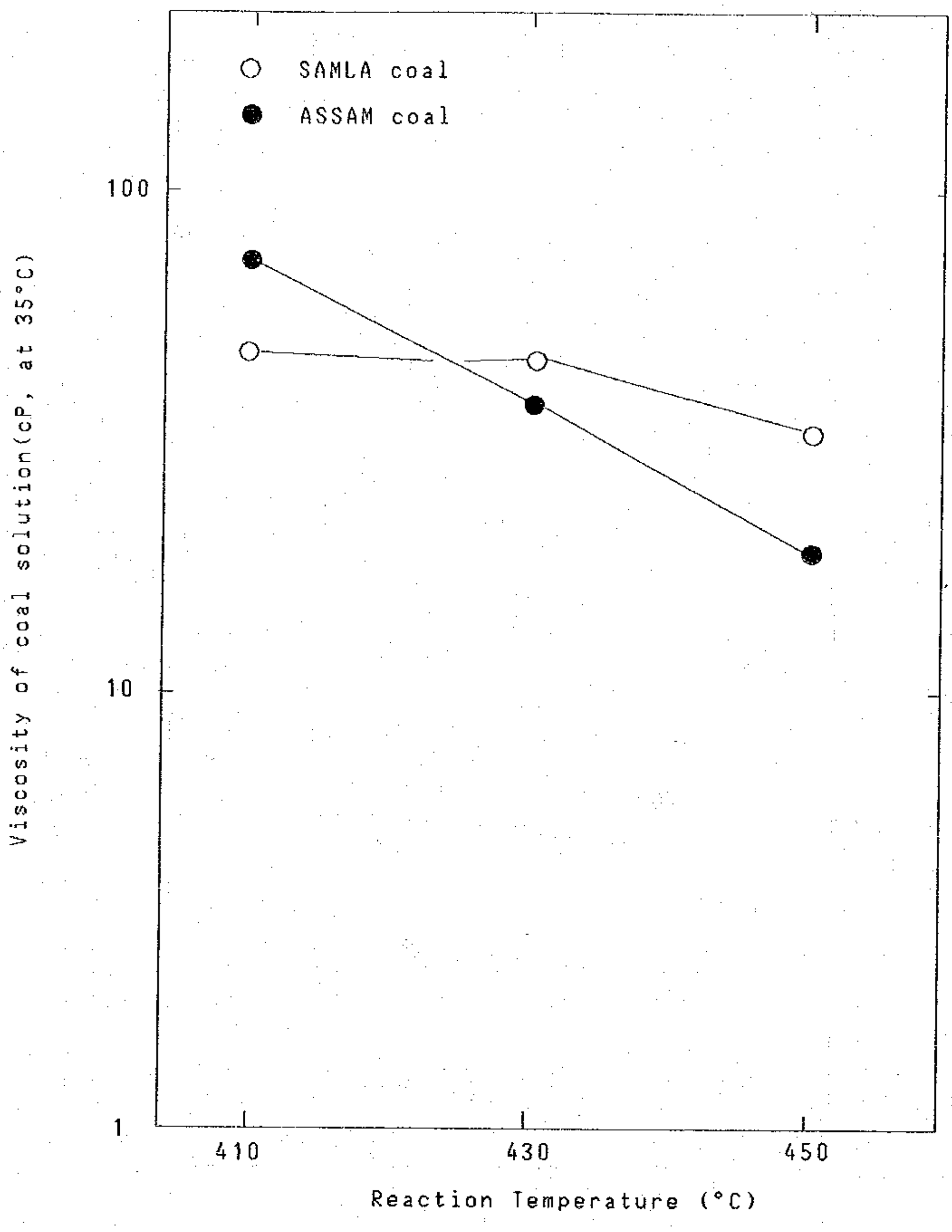

Figure 3.3.31 RELATION BETWEEN REACTION TEMPERATURE AND VISCOSITY OF COAL SOLUTION

(Condition:Anthracen oil-60min-100Kg/cm²G-3wt%-100%)

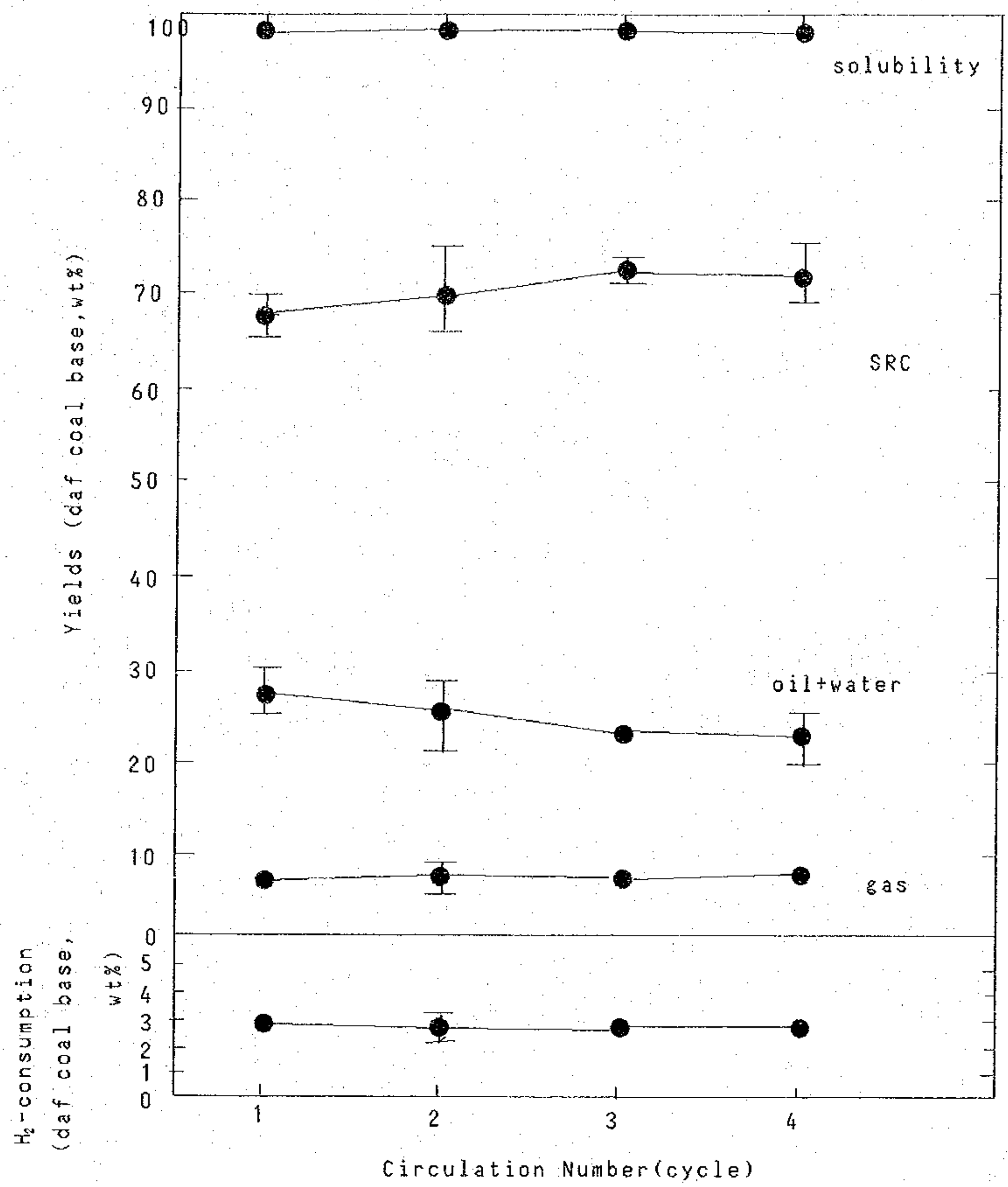

Figure 3.3.32 RELATION BETWEEN CIRCULATION NUMBER OF SOLVENT AND YIELDS OF ASSAM COAL

(Condition:430°C-60min-100Kg/cm²G-3wt%-100%)

Chapter 4 COKE PRODUCTION TEST USING SRC

Chapter 4 COKE PRODUCTION TEST USING SRC

4.1 Objectives and Scope of Study

To evaluate, through coke production tests, the effects of blending SRC with the coal used at the Indian steel plant which is scheduled to employ SRC.

(I) To determine whether SRC increases the coke strength (performative evaluation of SRC as a caking additive) and to select the SRC feed stock coal.

(II) To determine the possibility of blending non-coking coal with SRC for the substitute of coking coal (maintaining existing levels of coke strength).

This chapter describes the following:

(1) Experimental Method of Coke Production Test (evaluation method)

(2) Current Situation of Coke Production at the steel plant which is scheduled to use SRC. (present coke strength)

(3) Coke Production Test using SRC (1) to determine the effect of increase of coke strength by using SRC and to select the SRC feedstock coal.

(4) Coke Production Test using SRC (2) to determine the possibility of blending non-coking coal with SRC for the substitution of coking coal.

4.2 Experimental Method of Coke Production Test

4.2.1 Methods for Evaluating Coke Strength

(1) Policy on Evaluation of Coke Strength

As the amount of SRC for the coke production tests is very small, the production test was conducted using a 500 g Carbonization Test Oven.

It is possible to forecast the performance in an actual coke oven by an initial conversion of the coke strength by the 500 g carbonization oven tests to Simulated Coke Oven (SCO) strength. Since the relation of SCO to actual oven coke strength is already established the standard equations are then used for this stage of conversion. Conversion procedures are as follows:

Roga-drum strength (500 g carbonization test basis)
| conversion equation 1
Roga-drum strength (SCO basis)
| conversion equation 2
DI^{150}_{15} (SCO basis)
| conversion equation 3
DI^{150}_{15} (actual oven basis)
| conversion equation 4
M_{10} (actual oven basis)

(2) Examination of Conversion Method Used in Coke Production Test

In order to find the conversion equation 1 relating to the Roga-drum strength in the 500 g carbonization test oven and SCO as well as the conversion equation 2 relating to the SCO Roga-drum strength and the DI^{150}_{15} strength, coke production tests were carried out by

500 g carbonization oven and by SCO.
These tests were carried out using the same coal feed as currently used in the steel plant which is scheduled to use SRC. Also in order to cover a wide range of coke strength, supplementary carbonization tests were conducted on coal charges from three steel plants of Nippon Steel Corporation.

1) Coke Production Test

The blending ratio of the coal charges used in carbonization tests is shown in Table 4.2.1. Tests were conducted on three varieties of coal charges having a 30%, 25% and 20% content of imported coal respectively. The properties of these coal charges are shown in Table 4.2.2.

Table 4.2.3 shows the results of the coke production tests using SCO. Table 4.2.4 shows the results of the coke production tests obtained using the 500 g carbonization test oven.

2) Relations between Coke Strength Indexes (Conversion Equations)

The relations between the Roga-drum strength of 500 g carbonization oven coke and the Roga-drum strength of SCO coke are shown in Figure 4.2.1. Figure 4.2.2 shows the relations between the Roga-drum strength of SCO coke and DI^{150}_{15} (150 revolutions 15 mm index). From these results the following conversion equations 1 and 2 were obtained.

Conversion Equation 1
Roga-drum strength (SCO)
= 0.665 x Roga-drum strength (500 g oven) + 33.7

500g oven : 500g carbonization oven

Conversion Equation 2

DI_{15}^{150} (SCO)

= 0.936 x Roga-drum strength (SCO) + 0.4

The conversion equations 3 and 4 have already been established as follows:

Conversion Equation 3

DI_{15}^{150} (actual oven)

= 0.884 x DI_{15}^{150} (SCO) + 11.9

Conversion Equation 4

M_{10} (actual oven)

= -0.43 x DI_{15}^{150} (actual oven) + 42.5

4.2.2 Testing Methods

(1) Method of Carbonization Test

1) 500 g Carbonization Oven Test

Amount of coal charge:	500 g
Bulk density of coal:	0.72 g/cm^3
Heating pattern:	Temperature of external walls of coking chamber is raised at a rate of 3°C/min.
Coking time:	After temperature in the centre of the coal layer reaches 950°C it is maintained for one hour and then the content is discharged.

2) SCO Carbonization Test

Dimensions of carbonization chamber:	425W X 410H X 620L(mm)
Material of	

heating walls:	Carborundum bricks
Heating pattern:	The same control of temperature increase as that of an actual oven is used in the heating pattern.

(2) Methods of Testing Coke Strength

1) Roga-Drum Strength Test (coke strength test)

Test Apparatus:	Strength tester for measurements of Roga-index (JIS M 8801)
Coke particle size:	10-20 mm
Sample quantity:	50 g
Revolutions:	3,000 rev. (50 rpm x 60 min)
Strength index:	+ 6mm wt%

2) Drum Strength (DI) Test

Using JIS K 2151.

3) Micum Strength Test

Using ISO R556.

4) CSR (Coke Strength after Reaction with CO_2)

According to a testing method of Nippon Steel Corporation.

5) CRI (Coke Reactivity Index)

According to a testing method of Nippon Steel Corporation.

(3) Other Testing Methods of Coal and Coke

1) Proximate Analysis

Using JIS M 8812.

2) Ultimate Analysis

Using JIS M 8813.

3) Coal Property

Using JIS M 8801

4) Coke Property

Using JIS K 2151.

(4) List of Japanese Industrial Standard (JIS) Applied to This Coke Production Test

K2151-1977	Methods for Testing of Coke
K8801-1979	Methods for Testing of Coal
M8812-1984	Methods for Proximate Analysis of Coal and Coke
M8813-1988	Methods for Ultimate Analysis of Coal and Coke

4.3 Situation of Coke Production in India

4.3.1 Coke Production in the Steel Plant Scheduled to Use SRC

The Rourkela Steel Plant concerned in the present project for SRC use is one of the five steel plants controlled by SAIL (Steel Authority of India Ltd.) and is the fourth among these in terms of production scale.

(1) Outline of Coal Feedstock

The coal feedstock for the coke ovens consists of prime coking coal, medium coking coal and imported coal. Six brands of prime coking coal and six brands of medium coking coal are used.

In India imported coal is blended at a ratio of 20% to 30% to obtain the necessary coke quality.

As general reference, Table 4.3.1 shows the intake of coal over one year between April, 1988 and March 1989.

(2) Outline of Facilities

1) Coal Preparation Plant

There are two tipplers which unload coal from coal wagons at a rate of 10 wagons per hour.

Approximately 70,000 tons of coal can be stored in the coal yard. Coal preparation plants are one for a 1 million ton crude steel production unit and another for a 0.8 million ton crude steel production unit. Each coal preparation plant has a twin line pulverizer. Each line is equipped with a double roll crusher and two hammer mills.

The coal preparation plant for the 1 million ton unit is equipped with a double roll crusher and a hammer mill on standby. There are nine blending bunkers of which seven are used for blending and the remaining two are prepared to serve as service bunkers.

The coal preparation plant for the 0.8 million ton unit is equipped with two service bunkers which can operate at the same time.

2) Coke Ovens

There are at present four batteries of coke ovens operating, No. 1 Battery and No. 2 Battery having 70 ovens each while No. 4 Battery and No. 5 Battery have 80 ovens each. The oven volume is L 13,590 mm x H 4,500 mm x W 400 mm and is an underjet compound regenerative type. The dates of building and rebuilding for the coke ovens are shown in Table 4.3.2. Table 4.3.3 indicates the specifications of the coke ovens.

(3) Production

The annual production situation between April, 1989 and March 1990 is shown in Tables 4.3.4, 4.3.5, 4.3.6 and 4.3.7.

(4) Quality of Produced Coke

1) The Quality of the Coke of the Rourkela Steel Plant (daily operation data and analytical data at the Rourkela Steel Plant)

The variation of coke quality over a five day period shown in operational daily reports were examined in order to investigate the quality standards of coke at the Rourkela Steel Plant. (refer to Table 4.3.8)

2) The Quality of the Coke of the Rourkela Steel Plant (Japanese analytical data)

Coke test samples collected at the Rourkela Steel Plant in the presence of the study team during the 1st on-site survey in September to October, 1990 were tested in Japan (Nippon Steel Corporation). Results of these tests are shown in Table 4.3.9.

3) Target Quality of the Coke for Evaluating an Addition of SRC

In view of the daily report data of the Rourkela Steel Plant (Table 4.3.8) and the analysis results of the RSP sample coke (Table 4.3.9), the target values shown in Table 4.3.10 upper column of coke quality were envisaged to evaluate the performance of SRC addition. This target values were revised as shown in the down column of the same table according to the proposal of Indian counterpart.

4.3.2 Coal Feedstocks and Cokes of the Steel Plant Scheduled to Use SRC

(1) Coal Feedstock

The samples of the coal obtained during the 1st on-site survey in India were analyzed in Japan and these properties are shown in Table 4.3.11.

The ash content of Indian coal is high and it has the property of weak dilatation although the fluidity is not low.

(2) Coke

Test results of the coke of Rourkela Steel Plant are shown in Table 4.3.12. For reference, the results of tests on coke from three steel plants of Nippon Steel Corporation are also shown in Table 4.3.12.

The ash content of the coke produced by RSP is more than double that produced by Nippon Steel Corporation. The DI (30 revolutions) and M_{40} are slightly lower when compared to the coke produced by Nippon Steel Corporation but the DI (150 revolutions) and M_{10} are considerably worse. It means the strength against surface breakage is poorer than that against volume breakage. Therefore, the performance of SRC as a caking additive is expected to prove effective for improvement of coke strength.

The CSR is also low when compared to the coke produced by Nippon Steel Corporation. The CRI is not high and the reason why the CSR is low is considered that the abrasion strength is poor.

The coke size is comparatively large. However since the sampling point of the test coke is unclear it is not possible to compare this directly with the size of the coke produced by Nippon Steel Corporation.

The same characteristics of Indian coke noted above are also found in the results of the SCO carbonization test mentioned in 4.2.1 (2). The DI in this case is increased by raising the blending ratio of imported coal which increases the caking property and an improvement of coke strength can be expected as a result of using SRC.

However, the dilatation of the three blended coals is not much lower than that of the coal charges of three steel plants of Nippon Steel Corporation and the fluidity is actually higher. This is thought to be the result of the high ash content.

The size of coke from Indian coal is larger compared to that of Nippon Steel Corporation. However, this size seems to represent the size at around the wharf and before cutter of the coke oven. It is anticipated that the coke size at the time of blast furnace charging will not be such large since tests showed that Indian coke undergoes considerable size reduction by impact of handling before furnace.

4.4 Coke Production Test Using SRC (1)

4.4.1 Objective

The objective of this test is (I) of that indicated in 4.1, that is, to examine whether an addition of SRC increases coke strength, to evaluate the performance of SRC as a caking additive and to select the feed coal for production of SRC.

4.4.2 Test Method

Six samples of SRC were produced in a 0.5 l autoclave with the following coals and production conditions.

Code	Coal	Reaction Temperature of SRC production
A1	Samla	410 °C
A2	Samla	430 °C
A3	Samla	450 °C
B1	Assam	410 °C
B2	Assam	430 °C
B3	Assam	450 °C

Two alternative base blends were postulated in view of the projected use of SRC in India. In the first the imported coal was not blended at all and only Indian coals were used according to the following blend (India V):

	Bhojudih	Sudamdih	Chasnala	Kargali	Swang	Rajrappa
India V	30	20	10	20	10	10

The second base blend consisting of 90% of India III (with an imported coal of 20%) shown in Table 4.2.1 mixed with 10% non-coking coal is chosen in order to pre-examine blending non-coking coal. This is titled India IV (that is 90% India III plus 10% non-coking coal).

The coke production test is carried out using a 500 g carbonization oven and the Roga-drum strength of the coke is evaluated. Further, the changes in caking property resulting from the blending of SRC are examined.

4.4.3 Test Results

Figures 4.4.1 and 4.4.2 indicate the test results. The followings are commented for the test objectives from this results.

(1) Regarding an effectiveness of SRC additions to increase coke strength, it was verified as shown in Figure 4.4.2 that an addition of SRC to the Indian blended coal resulted in an increase in the coke strength.

(2) Regarding a performance of SRC as a caking additive, an increase in fluidity and improvement of dilatation are verified as a result from an addition of SRC as shown in Figure 4.4.1.

(3) Regarding a selection of a feed coal for production of SRC, the present test results do not reveal any clear difference in performance of SRC addition due to the different varieties of SRC.

For reference, Figure 4.4.3 shows DI^{150}_{15} which was obtained at the tests conducted in Japan during 1977-82 using four kinds of SRC manufactured from four different coals. The then figure also indicates that no significant difference is noticed in performance of SRC addition irrespective of SRC from different coals.

4.5 Coke Production Test using SRC (2)

4.5.1 Objective

The objective of this test is to evaluate the possibility of blending non-coking coal with SRC for the substitute of coking coal.

4.5.2 Test Method

The blending ratio of coal blend used in the carbonization tests are shown in Table 4.5.1. According to the current coal blending ratio which is used in Rourkela Steel Plant, the base blend (A1) is decided as 30% of prime coking coal, 40% of medium coking coal and 30% of imported coal. "A" series tests were conducted in order to examine a substitute for coking coal by means of substitute of SRC and Indian non-coking coal for the imported coal which are reduced from the base blend of coal. Samla coal was used as non-coking coal. Furthermore in order to evaluate the possibility of enlargement of imported coal reduction, the substitute of medium coking coal instead of non-coking coal for imported coal was tested with an addition of SRC. This is termed as "B" series test.
SRC used were one produced from Assam coal by using 0.5 l autoclave.
Coke production tests are conducted using 500g carbonization oven.
Two kinds of coal blends, namely one is base blend "A1", the other is "A5" (10% of Samla coal and 5% of SRC) were tested by SCO.

4.5.3 Test Results

Table 4.5.2 shows the properties of single coals.
Compared with the coals used in the evaluation test for performance of SRC addition on the coke strength described

in the previous section, the imported coal has a little bit higher coalification. (Refer to Table 4.3.11)
The properties of coal blend, properties of 500 g carbonization coke and properties of SCO carbonization coke are shown in Table 4.5.3, Table 4.5.4 and Table 4.5.5 respectively.
Test results of "A" series which were conducted by substitution of Samla coal and SRC for the imported coal are shown in Figure 4.5.1. It is presumed from this figure that blending of SRC and Samla coal at a ratio of 1 to 2 can substitute for the imported coal. Even though no tests were conducted this time, it is supposed to be possible to substitute for all of imported coal (30%) by using 10% of SRC addition.
This test result is nearly same as the test result on the non-coking coal of lower coalification which was conducted in Japan during 1977-82 to study the possibility of using non-coking coal with an addition of SRC. Coke structure obtained by carbonization of non-coking coal having lower coalification is mostly optically isotropic texture. By the interaction in a carbonization process when the said coal is carbonized with SRC, optically anisotropic texture increases and coke strength is improved and reactivity is lowered. These performance were noticed by the previous research work.

The other hand it was indicated from the test result of "B" series (as shown in Table 4.5.4) to be able to obtain the same strength as the present coke strength by addition of 6% of SRC in case of substitute of medium coking coal for all of imported coal (30%). Although use of medium coking coal will result in increase of ash content in produced coke and be inferior to use of non-coking coal in view of cost position, performance of saving imported coal is larger.

At the SCO carbonization test, the respective coke strength of "A1" blend (base) and "A5" blend (10% of Samla coal and 5% of SRC) were more or less similar (Table 4.5.5). This result corresponds with that of 500 g carbonization test. The objective of SRC addition is to improve abrasion resistance of coke. The effectiveness in this respect has been proved by the 500 g carbonization test. Accordingly, it is reasonable to presume that whether or not the coke strength can be maintained as before, is judged by the 500 g carbonization test result.

When the coke strength of SCO coke (DI_{15}^{150} = 73.9) obtained by the base blend "A1" is converted to the value in terms of M_{10} by conversion equations 3 and 4 shown in the Chapter 4.2.1, (2) 2), it becomes 9.3. This means this coke strength easily reaches to the target strength of $M_{10} \leq 10.0$ shown in Table 4.3.10. Accordingly it can be presumed that the coke strength of 500 g carbonization test indicated the same or higher value than that of the base blend coke, reaches to the target strength.

Although tests of substitute of SRC and non-coking coal for Indian prime coking coal have not been conducted, it is anticipated that the possibility of substitute for Indian prime coking coal is similar to the case of the imported coal in consideration of analytical data of coals and test results of substitute of imported coal. However it can not be expected to save foreign currency as the case of imported coal and to decreases coke production cost.

4.6 Additional Study on Blending for Coke Production

During the 3rd visit of India (January, 1992), JICA was requested by Indian counterparts to conduct the additional study on blending for coke production.

JICA had done all techno-economic calculations in accordance with previously agreed Rourkela blend as the base blend. Indian side requested JICA to study the following two more cases:

Case-I:

Indian side paid its attention to the coking test results of B2 and B3 blends where no imported coal was used but more medium coking coal was used and thereby coke strength could be improved with addition of SRC in a blend. Consequently, Indian side requested JICA to conduct the study of two more blends viz. B5 and B6. These composition are given below:

	(C2)	(C1)
Bhojudih	5 %	15 %
Sudamdin	-	10 %
Chasnala	5 %	5 %
Kargali	20 %	10 %
Swang	20 %	10 %
Rajrappa	32.5%	27 %
High Volatile (Assam)	5 %	10 %
Imported	7.5%	8 %
SRC	5 %	5 %

(Note: In this report, C2 and C1 are named instead of B5 and B6 respectively and these are termed C series blend.)

Case-II:

Indian side felt that the base blend may be changed in future considering the requirement of hot metal industry in private sector. For the future hot metal industry, low volatile medium coking (LVMC) coal [Bituminous coal rank, VM: 18-20 %, Ash: 22-25 %, Ro: 1.1] will be used in admixture with imported coal. Considering the quality requirement of the coke for the hot metal manufacture, it is expected that the ratio of imported coal and LVMC coal will be around 50:50. From the study of B2 and B3 blends by JICA, it was noted by Indian side that addition of SRC will accommodate more medium coking coal in the sole Indian coking coal blend. With such consideration, Indian side felt that a good percentage of imported coal can be cut down by addition of SRC and LVMC coal in the ratio of 1:4. Typical blends were indicated below.

Name of coal	Base case-I	Base case-II	Blend with SRC (P1)	(P2)	(P3)
Imported %	60	50	39	30	25
LVMC (washed) %	40	50	58	65	70
SRC %	NIL	NIL	3	5	5

(Note: These blends are termed as P series.)

After return to Japan, JICA team has studied the above blending for coke production. However, because of no technical data such as test results and coal analysis data available, it is impossible for it to make the confident technical assessment. Therefore it should be noted that the following comments are quite preliminary.

Case-I (1): C1 Blend

This blend is a partially modified blend from A5 one, that is, imported coal is substituted for medium coking coal by 7 % and Samla coal for Assam coal by the whole 10 %. Since a coking property of Assam coal is better than that of Samla coal, this blend is considered being able to keep the same level of coke strength as A5 blend.

Case-I (2): C2 Blend

This blend is to be the one which reduces from B3 blend an admixture of prime coking coal and increases those of imported coal and Assam coal. Since Assam coal has a considerable level of coking property, this blend is considered being able to keep the same level of coke strength as B3 blend.

Case-II:

Use of low volatile medium coking (LVMC) coal. It is impossible to assess the technical effect accurately because of no analysis data of LVMC coal available. If Base case-I and II would be sufficient with respect to coke strength, three kinds of blend with SRC (P1,P2,P3) may be possible to adopt in light of the fact that coke strengths of A1 and B3 blends are mostly the same.

The financial and economic analysis on the above cases is conducted in the Chapter 8.

Table 4.2.1 BLENDING RATIO (%,d) OF COAL CHARGES FOR CARBONIZATION TESTS

Coal / Coal Blend	Prime coking coal			Medium coking coal			Imported coal
	Bhojudih	Sudamdih	Chasnala	Kargali	Swang	Rajrappa	
India I	20	14	6	15	7.5	7.5	30
India II	22.5	15.8	6.7	15	7.5	7.5	25
India III	25	17.5	7.5	15	7.5	7.5	20

Table 4.2.2 PROPERTIES OF COAL CHARGES FOR CARBONIZATION TEST

Product Quality / Coal Blend	Proximate Analysis (%, d)		TS	FSI	Fluidity				Dilatation					
	Ash	VM	(%,d)		Softening Tempera-ture (℃)	Max. Fluidity Tempera-ture(℃)	Solidifi-cation Tempera-ture (℃)	Log Maximum Fluidity	Softening Tempera-ture (℃)	Temperature of Maximum Contraction (℃)	Temperature of Maximum Dilatation (℃)	Cont rac-tion (%)	Dilata-tion (%)	Total Dilata-tion (%)
India I	18.6	24.8	0.56	5	394	441	481	3.25	347	438	475	24	31	55
India II	19.8	24.6	0.57	5	407	452	486	3.05	376	437	471	20	28	48
India III	19.3	24.3	0.57	5	406	457	487	2.93	392	438	470	22	17	39

Table 4.2.3 TEST RESULTS OF SCO CARBONIZED COKE

Product Quality / Coal Blend	Proximate Analysis(%,d)		TS	Size Distribution (%)						Mean Size	Drum Strength		Roga-drum Strength	CRI	CSR	True Specific Gravity	Apparent Specific Gravity	Porosity	JIS Reactivity	MSI
	Ash	VM	(%,d)	125～100	100～75	75～50	50～38	38～25	<25mm	(mm)	DI^{150}_{15}	DI^{30}_{15}						(%)	(%,AG)	
India I	23.7	0.4	0.5	15.4	37.1	35.4	7.7	1.1	3.3	76.1	74.0	91.0	78.0	24.6	41.4	2.04	1.12	45.1	10.5	47.4
India II	24.5	0.4	0.5	21.4	43.1	23.3	7.7	1.1	3.4	80.5	72.9	91.8	75.2	25.0	40.8	2.03	0.96	52.7	13.5	47.8
India III	25.1	0.5	0.5	17.3	36.6	33.0	7.7	0.8	4.6	76.3	70.5	89.4	77.1	24.1	41.2	2.03	0.98	51.7	13.2	46.9
Yawata	11.4	1.0	0.6	2.3	21.2	47.9	17.2	5.9	5.5	61.2	83.9	95.0	87.7	28.7	57.0	1.97	1.01	48.9	18.0	46.7
Nagoya	11.5	1.1	0.5	2.6	19.5	46.8	18.0	7.0	6.1	60.1	82.6	93.8	89.4	28.6	60.6	1.97	1.01	48.9	16.5	44.8
Kimitsu	11.6	0.9	0.5	1.0	15.1	51.6	19.3	7.8	5.2	58.2	83.2	94.2	87.8	30.3	54.2	1.97	1.02	48.3	14.8	46.3

Table 4.2.4 TEST RESULTS OF 500g CARBONIZATION OVEN COKE

Product Quality / Coal Blend	Roga-drum Strength	True Specific Gravity	Apparent Specific Gravity	Porosity (%)	JIS Reactivity (%,AG)	MSI
India I	65.6	2.04	0.87	57.4	28.2	43.6
India II	63.6	2.03	0.88	57.1	29.2	43.2
India III	76.7	2.04	1.08	47.1	28.0	44.4
Yawata	83.2	1.96	0.97	50.3	33.5	42.3
Nagoya	81.3	1.96	0.94	52.2	34.0	39.6
Kimitsu	81.8	1.95	0.94	51.9	34.2	41.1

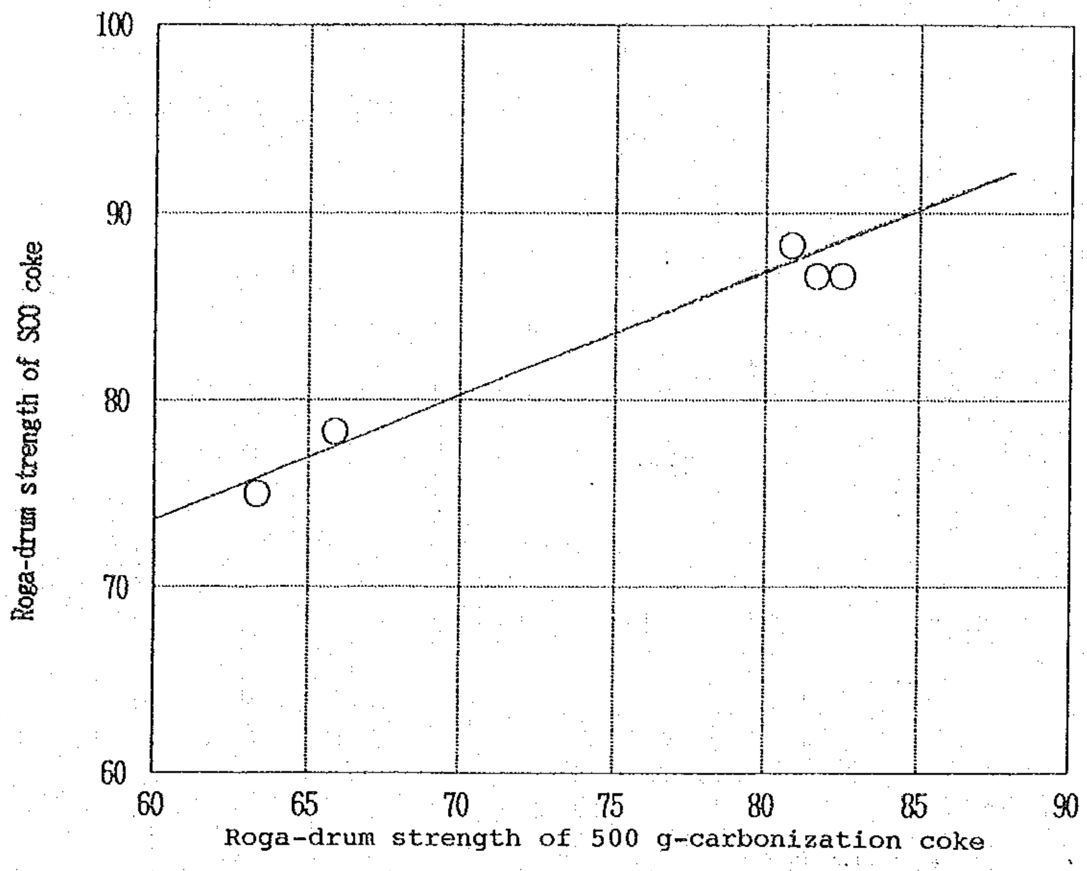

Figure 4.2.1 RELATIONSHIP BETWEEN ROGA-DRUM STRENGTH OF SCO COKE AND THAT OF 500 G-CARBONIZATION COKE

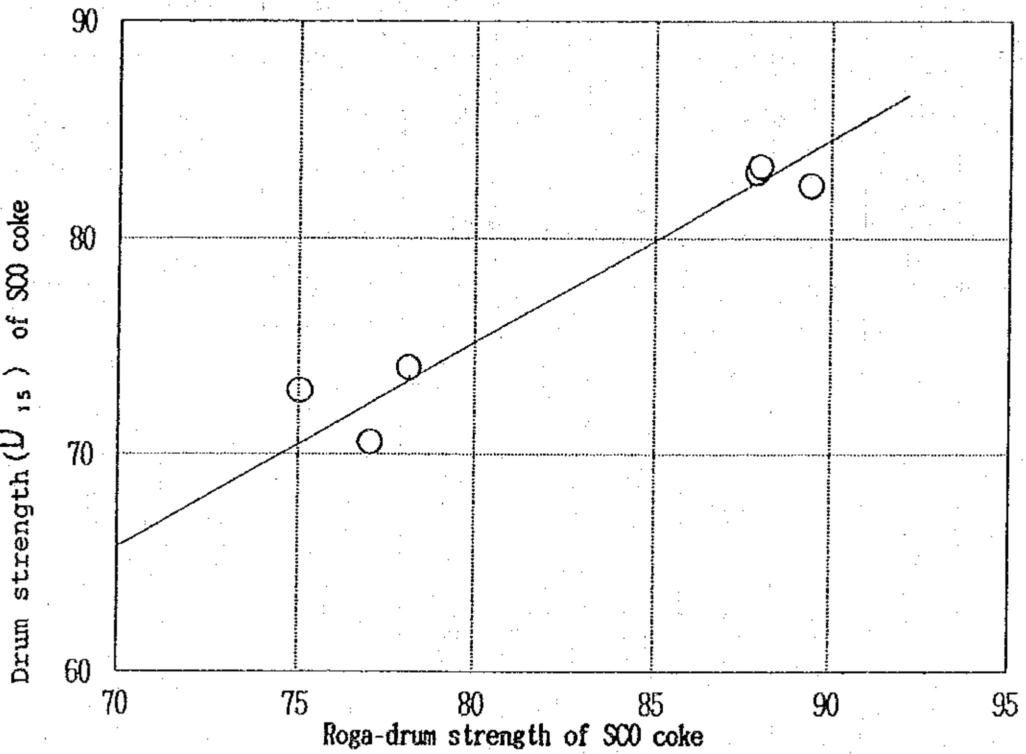

Figure 4.2.2 RELATIONSHIP BETWEEN DRUM STRENGTH AND ROGA-DRUM STRENGTH OF SCO COKE

Table 4.3.1 COKING COAL USED AT ROURKELA STEEL PLANT

(Apr., 1988 - Mar., 1989)

Coal Variety		Amount Used (t)
Prime Coking Coal	Dugda Coal	31,485
	Bhojudih Coal	317,564
	Chasnala Coal	74,284
	Sudamdih Coal	202,087
	Patherdih Coal	24,137
	Moonidih Coal	101,699
	Sub-total	751,256
Medium Coking Coal	Kargali Coal	146,744
	Kathara Coal	40,435
	Swang Coal	106,616
	Gidi Coal	130,685
	Nandan Coal	3,074
	Rajrappa Coal	260,457
	Sub-total	688,011
Imported Coal (Australia)		518,108
Total		1,957,375

Table 4.3.2 SCHEDULE FOR CONSTRUCTION AND OPERATION OF COKE OVENS AT ROURKELA STEEL PLANT

Battery No.	Date of Commissioning	Capital Repair	Rebuilding	Capital Repair
I A (35 ovens)	22.3.'60 Otto	1.12.'72～19.4.'74	6.4.'77～16.4.'78 MECON	30.4.'83～7.3.'84
I B (35 ovens)	5.4.'60 Otto	'73～'75	2.4'82～30.1.'85 MECON	-
II A (35 ovens)	3.12.'58 Otto	-	16.4.'74～18.8.'76 MECON	11.'85～5.'87
II B (35 ovens)	5.1.'59 Otto	'73～'78	18.4.'79～26.1.'82 MECON	-
IVA (40 ovens)	30.12.'66 Otto	'76～'77	15.4.'84～28.1.'87 RSP thro HSCL	-
IVB (40 ovens)	5.2.'69 Otto	'77～'78	15.4.'84～18.3.'88 RSP thro HSCL	-
VA (40 ovens)	28.9.'74 Otto	5.'77～12.'78	-	-
VB (40 ovens)	26.12.'83 Otto	1.'90～12.'90	-	-

Note: Battery No.3 (70 ovens)is under rebuilding.

Table 4.3.3 SPECIFICATIONS OF COKE OVENS IN ROURKELA STEEL PLANT

Battery No.	No. of subbatteries per battery	No. of ovens per battery	Oven dimension
I	2	35 x 2	13,590 x 4,500 x 400mm
II	2	35 x 2	13,590 x 4,500 x 400mm
IV	2	40 x 2	13,590 x 4,500 x 400mm
V	2	40 x 2	13,590 x 4,500 x 400mm

Table 4.3.4 AMOUNT OF COAL CHARGES OF ROURKELA STEEL PLANT COKE OVENS

(Apr., 1989 - Mar., 1990)

	Amount (t)	Share of Total
Prime Coking Coal	707,940	38.0%
Medium Coking Coal	647,120	34.7%
High Volatile Coal	24,450	1.3%
Imported Coal	483,480	26.0%
Total	1,862,990	100.0%

Table 4.3.5 PROPERTIES OF COAL CHARGES OF ROURKELA STEEL PLANT COKE OVENS

(Apr., 1989 - Mar., 1990)

Moisture	6.46 wt%
Ash Content (dry)	17.01 wt%
Volatile Matter (dry)	25.05 wt%

Table 4.3.6 COKE YIELD OF ROURKELA STEEL PLANT

(Apr., 1989 - Mar., 1990)

		Amount per Oven	Yield per Coal Charge (%)
Coal Charge (dry basis)		16.75 t/oven	—
Coke Yield	Total Yield	12.72 t/oven	75.9%
	Hard Coke	10.60 t/oven	63.3%
	Nut Coke	0.76 t/oven	4.5%
	Breeze Coke	1.36 t/oven	8.2%

Table 4.3.7 PROPERTIES OF ROURKELA STEEL PLANT COKE

(Apr., 1989 - Mar., 1990)

Moisture	5.5 wt %
Ash Content	22.7 wt %
Volatile Matter	0.8 wt %
M_{40}	80.6 %
M_{10}	11.2 %

Table 4.3.8 VARIATION OF COKE QUALITY (FROM DAILY REPORTS OF RSP)

Date of Production	Coke Ash Content (w t %)			M_{40} (%)	M_{10} (%)
	Max.	Min.	Avg.		
'90.9.17	22.8	20.9	22.1	80.6	10.6
18	22.6	21.0	22.0	80.8	10.8
19	22.9	22.3	22.6	80.8	11.6
20	22.6	21.4	22.3	78.6	13.0
21	25.3	22.6	24.1	80.4	11.6
Average	—	—	22.6	80.1	11.5

Table 4.3.9 ANALYTICAL DATA OF ROURKELA STEEL PLANT COKE (TEST IN JAPAN)

(SAMPLES COLLECTION: September, 1990)

Samples	Ash Content (wt%) (dry base)	Volatile Matter (wt%) (dry base)	Total Sulphur (wt%) (dry base)	M_{40} (%)	M_{10} (%)
Rourkela coke	24.6	1.0	0.6	80.2	11.6

Table 4.3.10 COKE QUALITY TARGETS TO DETERMINE PERFORMANCE OF SRC ADDITION

Coke Quality	Ash Content (wt%) (dry base)	Volatile Matter (wt%) (dry base)	M_{40} (%)	M_{10} (%)	CSR (%)	CRI (%)
Target Values Determined in September, 1990	≦23.0	≦1.0	≧80.0	≦11.5	-	-
Target Values Revised in September, 1991	22.5±0.5	≦0.9	≧83.0	≦10.0	50~55	25~30

Table 4.3.11 PROPERTIES OF SINGLE COALS

Brand Name	Proximate Analysis (%, d)		TS	Ultimate Analysis (%, daf)					FSI	Fluidity				Dilatation					
	Ash	VM	(%, d)	C	H	N	S	O		Softening Temperature (℃)	Max. Fluidity Temperature (℃)	Solidification Temperature (℃)	Log Maximum Fluidity	Softening Temperature (℃)	Temperature of Maximum Contraction (℃)	Temperature of Maximum Dilatation (℃)	Contraction (%)	Dilatation (%)	Total Dilatation (%)
Bhojudih	22.6	21.7	0.54	85.6	5.1	1.9	0.6	6.8	3	415	463	490	2.26	398	442	467	18	8	26
Sudamdih	22.6	21.7	0.53	86.6	5.1	1.9	0.6	5.8	3	412	453	482	2.48	348	445	465	20	-2	18
Chasnala	20.5	23.2	0.52	86.8	5.3	2.0	0.6	5.3	4	420	462	488	1.69	365	442	467	26	8	34
Kargali	23.3	23.9	0.55	84.9	5.3	1.8	0.6	7.4	2	416	451	482	2.39	357	437	450	22	-14	8
Swang	20.1	27.2	0.60	84.1	5.4	1.9	0.6	8.0	3.5	405	448	471	2.39	385	434	447	20	-8	12
Rajrappa	23.1	28.7	0.60	82.7	5.6	1.7	0.7	9.3	2.5	400	440	471	2.86	393	437	450	21	-18	3
Imported coal	8.6	28.3	0.62	86.2	5.4	2.2	0.7	5.5	9	402	451	494	3.20	371	412	505	25	242	267
Argada-Sirka	17.9	32.9	0.70	79.4	5.5	1.5	0.8	12.8	1	387				392	480	-	30	-30	0
Samla	14.0	34.6	0.48	78.5	5.5	2.4	0.5	13.1	1	(Coal briquetting not possible)				315	480	-	14	-14	0
Assam	2.2	41.6	1.67	81.9	5.9	1.2	1.7	9.3	8	397	448	470	2.30	338	420	449	30	59	89
Neyveli	3.9	51.2	1.21	69.0	5.0	0.6	0.9	24.5	0	(Coal briquetting not possible)				315	480	-	12	-12	0
O/A Middlings	21.3	33.6	1.17	86.1	6.5	1.6	1.5	4.3	1	368				334	419	-	10	-10	0

Table 4.3.12 TEST RESULTS OF ACTUAL OVEN COKE

	Proximate Analysis(%,d)		TS	Size Distribution (%)						Mean Size	Drum Strength		Micum Strength		I type	CRI	CSR	True Specific Gravity	Apparent Specific Gravity	Porosity	JIS Reactivity	MSI
	Ash	VM	(%,d)	125～100	100～75	75～50	50～38	38～25	<25mm	(mm)	DI^{150}_{15}	DI^{30}_{15}	M_{40} (%)	M_{10} (%)	Strength					(%)	(%,AG)	
India (RSP)	24.6	1.0	0.6	5.5	27.6	41.7	23.0	1.0	1.2	67.0	67.5	90.4	80.2	11.6	78.4	26.8	44.7	2.00	1.16	41.8	29.5	43.4
Yawata	11.5	1.1	0.6	0.4	8.3	35.1	34.9	19.7	1.6	51.4	86.1	96.3	86.6	7.8	86.4	27.9	60.1	1.95	1.01	48.2	23.2	47.6
Nagoya	11.6	0.9	0.5	0.0	4.1	33.4	33.1	28.0	1.4	48.0	85.1	96.0	85.0	8.4	85.8	30.4	55.9	1.96	0.96	51.1	22.0	44.8
Kimitsu	11.6	0.5	0.5	0.7	8.2	38.1	32.6	18.5	1.9	52.2	85.1	95.6	84.3	8.5	85.4	29.4	55.4	1.95	1.00	48.5	29.5	45.9

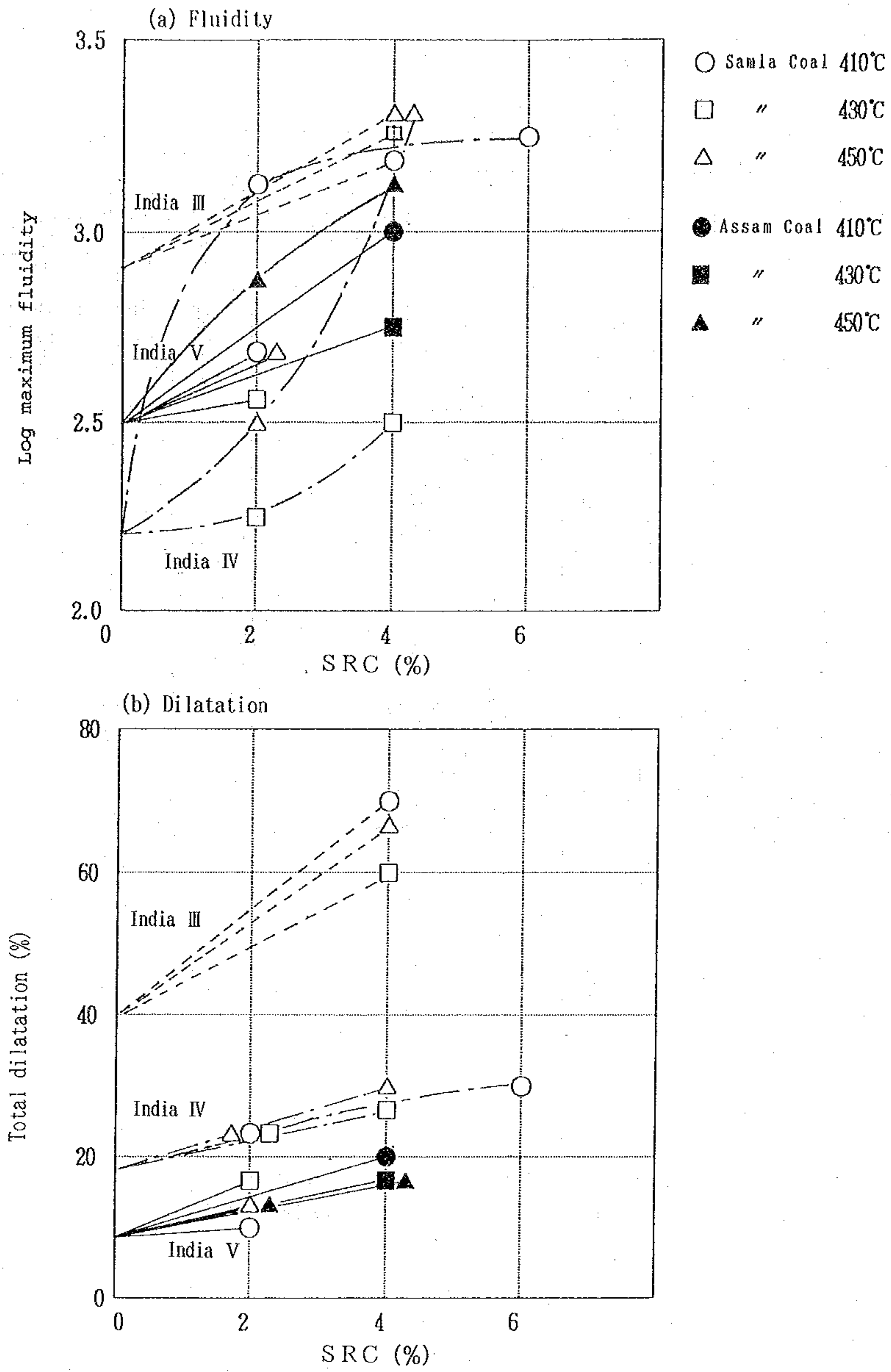

Figure 4.4.1 EFFECT OF SRC ADDITION ON CAKING PROPERTIES

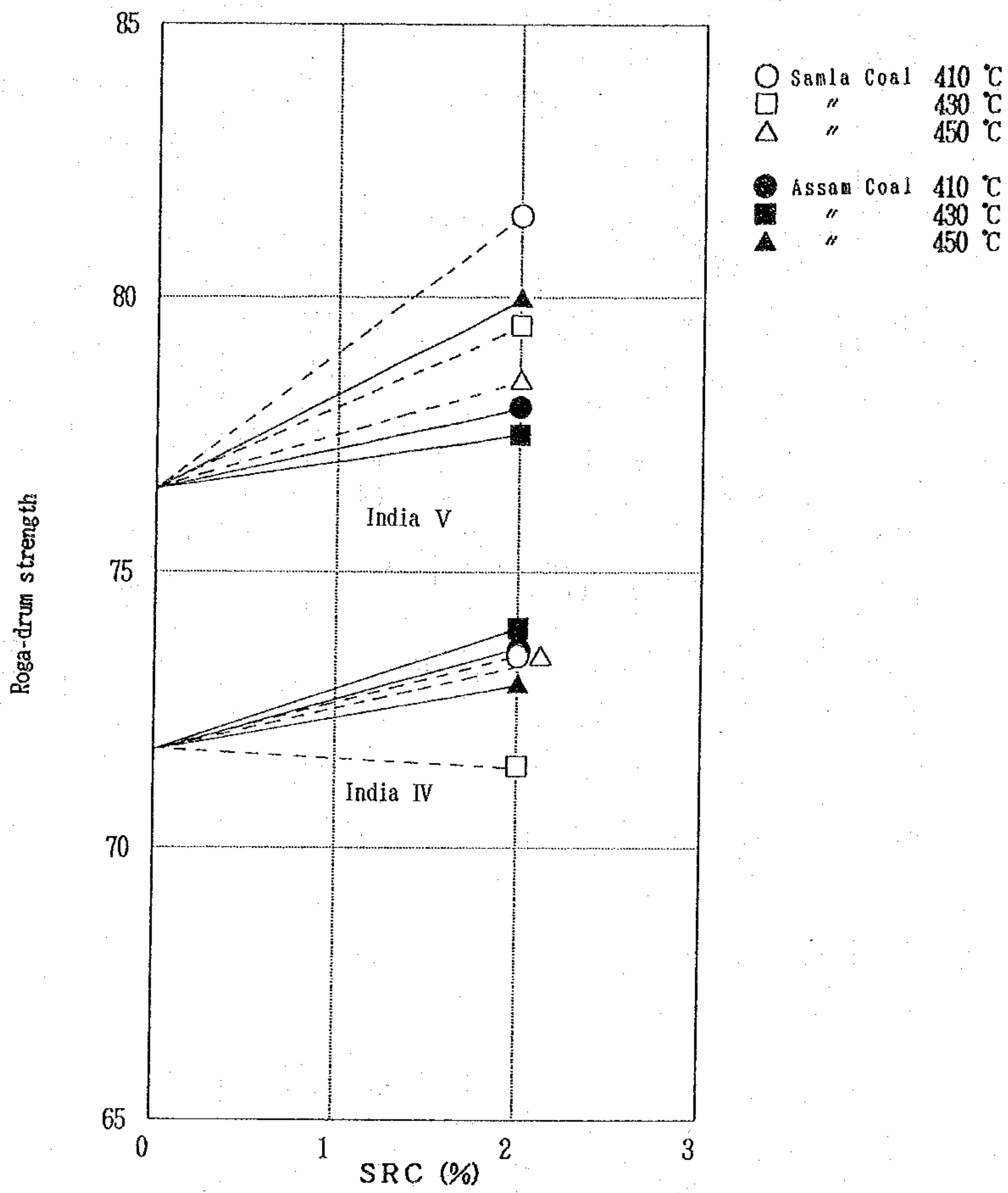

Figure 4.4.2 EFFECT OF SRC ADDITION ON ROGA-DRUM STRENGTH

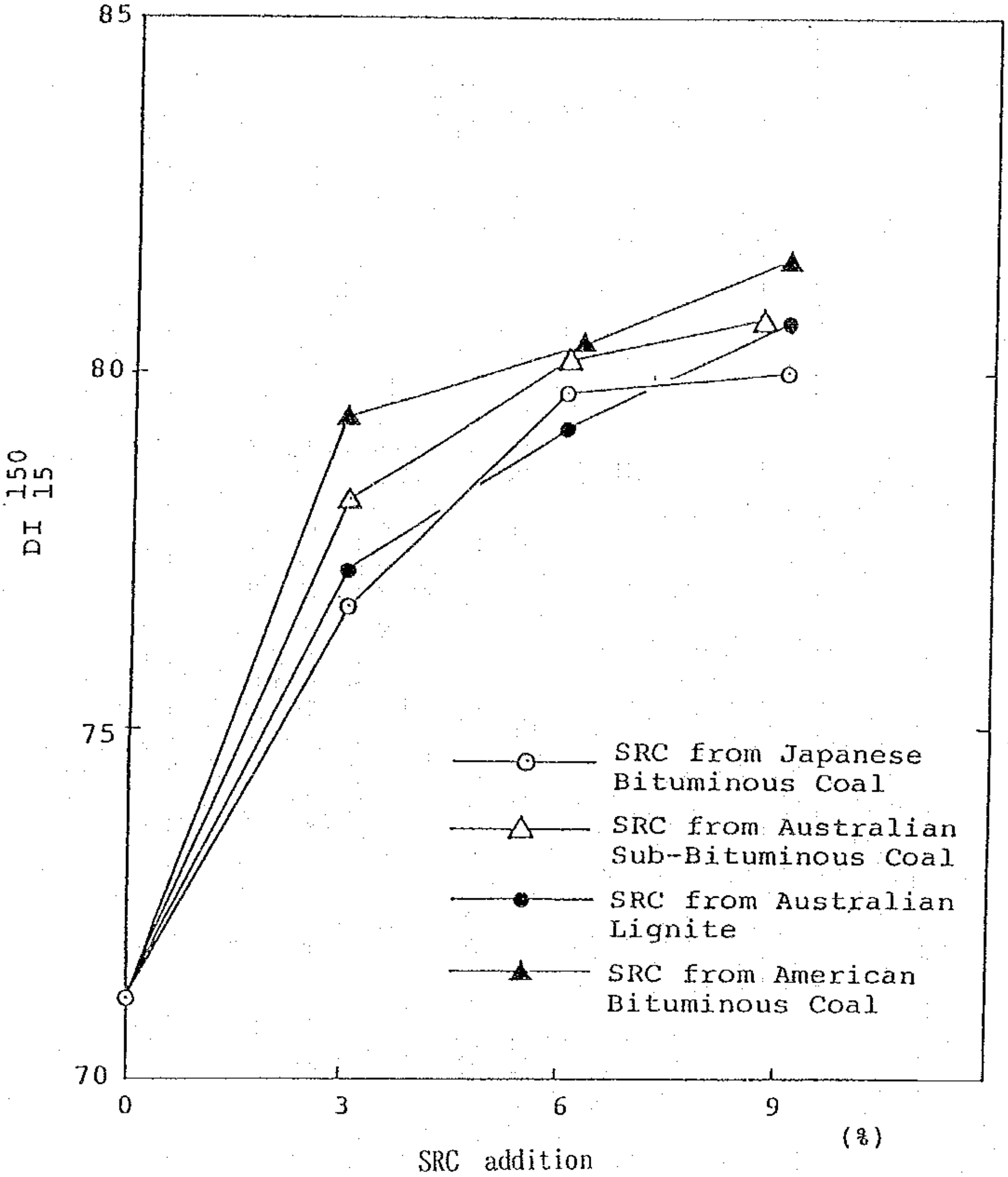

Figure 4.4.3 COKE STRENGTH BEFORE REACTION WHEN SRC MANUFACTURED FROM FOUR KINDS OF COAL WHERE ADDED TO STANDARD COAL FOR TEST

Table 4.5.1 BLENDING RATIO (%) OF COAL BLEND USED IN THE CARBONIZATION TEST

Brand Name	A1	A2	A3	A4	A5	A6	A7	A8	A9	B1	B2	B3
Bhojudih	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.55	14.1
Sudamdih	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	9.70	9.4
Chasnala	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.85	4.7
Kargali	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	20.0	19.40	18.8
Swang	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	20.0	19.40	18.8
Rajrappa	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	30.0	29.10	28.2
Imported Coal	30.0	22.5	20.0	17.5	15.0	12.5	10.0	7.5				
Samla		5.0	5.0	10.0	10.0	10.0	15.0	15.0	22.5			
SRC		2.5	5.0	2.5	5.0	7.5	5.0	7.5	7.5		3.00	6.0

Table 4.5.2 PROPERTIES OF SINGLE COALS

Brand Name	Proximate Analysis (%, d)		TS (%, d)	Fluidity				Dilatation						Ro (%)	TI (%)
	Ash	VM		Softening Temperature (℃)	Max. Fluidity Temperature (℃)	Solidification Temperature (℃)	Log. Max. Fluidity	Softening Temperature (℃)	Temperature of Max. Contraction (℃)	Temperature of Max. Dilatation (℃)	Contraction (%)	Dilatation (%)	Total Dilatation (%)		
Bhojudih	24.00	20.3	0.50	420	463	495	2.07	388	452	470	21	-7	14	1.32	44.1
Sudamdih	24.20	21.7	0.56	481	449	488	3.08	370	438	448	25	-17	8	1.20	47.9
Chasnala	17.80	24.8	0.51	400	441	479	2.64	383	442	463	23	-3	20	1.16	50.9
Kargali	19.50	24.4	0.60	414	452	491	2.62	373	439	448	25	-19	6	1.15	49.9
Swang	21.80	22.3	0.55	395	446	481	3.30	373	435	471	23	23	46	1.19	51.3
Rajrappa	20.90	29.5	0.71	394	429	465	3.29	370	438	448	25	-17	8	0.85	48.7
Imported Coal	9.10	23.8	0.57	413	458	493	2.61	392	440	480	25	78	103	1.19	41.1
Samla	13.80	34.6	0.45	(Coal Briquetting Not Possible)				365	480	-	16	-16	0	0.56	27.5

Table 4.5.3 PROPERTIES OF COAL BLEND FOR 500g CARBONIZATION TEST

No.	Proximate Analysis (%, d)		TS (%, d)	Fluidity				Dilatation					
	Ash	VM		Softening Tempera-ture (℃)	Max. Fluidity Temperature (℃)	Solidification Temperature (℃)	Log. Max. Fluidity	Softening Temperature (℃)	Temperature of Max. Contraction (℃)	Temperature of Max. Dilatation (℃)	Contraction (%)	Dilatation (%)	Total Dilatation (%)
A1	18.0	24.2	0.59	411	458	493	2.85	388	439	455	24	16	40
A2	17.8	25.7	0.59	384	439	478	3.35	355	427	464	25	10	35
A3	17.7	25.6	0.59	394	447	492	3.53	364	426	463	25	8	33
A4	18.3	25.7	0.58	406	453	494	2.95	370	436	457	24	-8	16
A5	18.0	26.6	0.58	397	446	490	3.37	365	428	453	23	-6	17
A6	18.0	27.0	0.57	363	429	479	3.94	343	423	456	22	-1	21
A7	18.4	26.7	0.57	396	446	488	3.24	366	435	453	24	-15	9
A8	18.2	27.2	0.59	377	430	478	3.62	347	426	451	23	-15	8
A9	18.7	28.0	0.59	374	428	470	3.56	363	436	436	25	-25	0
B1	21.6	24.5	0.60	397	441	476	2.83	385	443	459	25	-11	14
B2	20.9	25.3	0.61	403	450	486	3.41	343	425	456	23	-4	19
B3	20.4	25.7	0.62	370	435	480	4.70	364	430	454	22	-4	18

Table 4.5.4 RESULTS OF 500g CARBONIZATION TEST

No.	Proximate Analysis (%, d)		TS (%, d)	Roga-Drum Strength	True Specific Gravity	Apparent Specific Gravity	Porosity (%)	JIS Reactivity (%, AG)	MSI
	Ash	VM							
A1	23.2	0.7	0.4	70.9	2.01	1.03	48.7	18	25.6
A2	23.2	0.6	0.4	72.8	2.02	1.07	47.0	20	25.4
A3	23.3	0.8	0.5	75.5	2.02	1.13	44.1	21	25.3
A4	23.4	0.7	0.4	65.6	2.02	1.00	50.4	25	26.9
A5	23.8	0.5	0.4	71.3	2.05	1.10	46.4	26	25.9
A6	23.5	0.8	0.5	72.8	2.02	1.14	43.6	24	24.6
A7	24.2	0.6	0.4	65.3	2.02	1.01	49.8	31	25.9
A8	23.7	0.6	0.5	71.7	2.01	1.08	46.2	27	25.4
A9	24.8	0.7	0.4	63.8	2.02	1.05	48.3	35	27.0
B1	27.9	0.5	0.4	67.6	2.05	1.05	48.9	21	26.9
B2	26.5	0.7	0.5	68.8	2.04	1.08	47.2	17	25.9
B3	26.4	0.7	0.5	70.2	2.05	1.04	49.0	15	25.4

Table 4.5.5 RESULTS OF SCO TEST

	Proximate Analysis (%, d)		TS	Size Distribution (%)						Mean Size	Drum Strength		CRI	CSR
	Ash	VM	(%, d)	125~100	100~75	75~50	50~38	38~25	<25mm	(mm)	DI^{30}_{15}	DI^{150}_{15}		
A1	23.4	0.7	0.5	4.0	23.4	36.9	23.1	4.4	8.2	60.6	91.0	73.9	23.7	38.8
A5	23.2	0.6	0.5	12.3	21.3	39.5	15.4	4.5	7.0	66.2	91.1	73.0	25.3	40.9

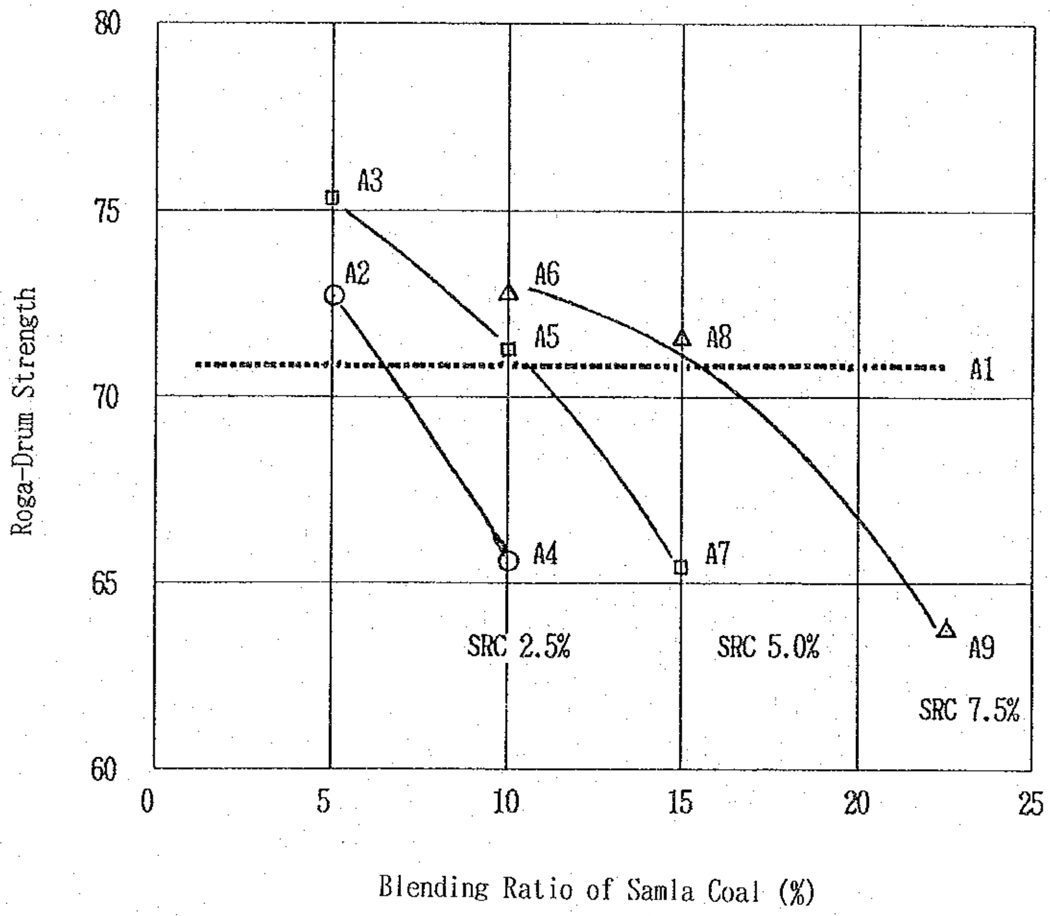

Figure 4.5.1 ROGA-DRUM STRENGTH OF COKE PRODUCED WITH BLENDING SAMLA COAL AND SRC

Chapter 5 POLLUTION CONTROL STUDY

Chapter 5 POLLUTION CONTROL STUDY

5.1 Review of Laws and Regulations for Environmental Protection

5.1.1 History of Environmental Protection Policy in India

In India laws for the protection of the environment had already been formulated and enacted in the later half of the 19th century but these were very rarely applied.

In the middle of current century the Factories Act of 1948 and the Industries (Development and Regulation) Act of 1951, containing provisions for regulating the siting of factories in view of environmental protection, were also not sufficient in operation.

Until the early 1970s the main environmental concern was focused on forest destruction, soil erosion and desertification, etc. and industrial pollution was only beginning to be recognized in the large metropolitan areas.

Industrial managers and entrepreneurs at this time did not therefore view environmental pollution as a serious concern.

On the other hand, at the same time in the advanced industrial nations the pollution which had accompanied the rapid industrialization of the 1960s resulted in a dramatic worsening of environmental qualities and the strengthening of legal regulations and control was initiated in response. The United Nations Conference on the Human Environment held in Stockholm in 1972 effected a global recognition of environmental protection issues and concerns.

Also in 1972 the ILO expressed a strong interest in environmental protection issues.

The norms set for the working environment in the Factories Act of India were judged to meet the standards set by the ILO and were found in no way inferior when compared to those of the advanced industrial nations.

Despite this parity an effective response to the problem of industrial pollution was delayed since the actual industrialization of the country not fully evolved.

The core of India's current legal system for environmental protection is embodied in the 1976 constitution amendment which is directly inspired by the Stockholm declaration mentioned above.

In Article 48A of this under the heading "Protection and improvement of environment and safeguarding of forests and wild life" the phrase "The State shall endeavor to protect and improve the environment and to safeguard the forests and the wild life of the country." was inserted. Further, in Article 51A under the heading "Fundamental Duties" which states "It shall be the duty of every citizen of India.", the clause (g) "to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures" was added.

Previous to the above, detailed attention had already been accorded to environmental concerns in the Fourth Five Year Development Plan (1969-74) which advocated a development program in harmony with safeguarding the environment.

Until this time environmental regulation had been unsystematically enforced by the authorities of the central government or by individual states. In order to coordinate these various activities a National Committee on Environmental Planning and Coordination (NCEPC) was set up inside the Department of Science and Technology. The duties and functions of the NCEPC were taken over by the Department of Environment (DOE) when this was founded in 1980. At present the DOE is attached to the Ministry of

Environment and Forests.
The principal Indian legislation concerning environmental protection to date are the Water (Prevention and Control of Pollution) Act of 1974, the Air (Prevention and Control of Pollution) Act of 1981 and the Environment (Protection) Act of 1986.

5.1.2 Outline of India's Current Environmental Legislation and Measures

In the present section the outlines of the three above mentioned environmental acts will be considered.

(1) The Water (Prevention and Control of Pollution) Act, 1974

This Act is the counterpart to the Japanese Water Pollution Control Law. The main aims of the Indian Act are stated to be as follows:

1) That the Central Government and each individual State shall establish a Board for the Prevention and Control of Water Pollution. This Board is accorded the necessary powers to ensure that problems of water pollution are effectively handled.

2) To establish the fines and penalties for offenses or illegal actions.

3) To establish water testing laboratories which will be employed to verify the situation regarding water pollution and to set water standards.

The Central Board is responsible for handling problems of water pollution nationwide and is to advise the Central Government in formulating all the policies and plans and their executions. It is also responsible for providing guidance to the State Boards and ensuring the coordination of their activities, and in the Union Territories the Central Board performs the same duties as the State Boards.

In addition to having the same duties and functions as the Central Board within their respective jurisdiction the State Boards are empowered to enter and inspect factories, to bring charges against any offenses, to issue improvement orders, etc.

Moreover, this Act applies in cases of soil pollution.

(2) The Air (Prevention and Control of Pollution) Act of 1981

This corresponds to the Japanese Air Pollution Control Law.

Although the present Act was passed seven years after the Water Act of 1974 its basic thinking and organization are almost the same as those of the earlier Water Act. The Central and State Boards for the Prevention and Control of Water Pollution were charged with carrying out the duties prescribed in this Air Act of 1981.

However, the present Act identifies twenty industrial sectors which are the main source of air pollution.

1) For factories in the above twenty industrial categories it is necessary to obtain the prior approval of the State Board before operations can commence, and operations must conform to the conditions of the approval.

2) Factories in the concerned categories are obliged to ensure that waste pollutants do not exceed the norms and levels set by the State Board and are obliged to cooperate with on the entry and inspections by authority officials.

The above duties and obligations are innovations with respect to the conditions of the Water Act of 1974. Further, the present act includes controls on the exhaust gas of automobiles. The Act as it now stands also includes regulations on noise.

(3) The Environment (Protection) Act of 1986

This corresponds to the Japanese Basic Law for Environmental Pollution Control.

Legislation to this point had been focused on specific targets as in the case of the Water Act of 1974 or the Air Act of 1981. However, the need for a comprehensive policy on environmental protection felt by the Indian government provided the main motive for the establishment of the present Act.

Further, the powers of the Central Government with regard to environmental protection were strengthened by this Act.

That is, the Central Government was empowered to establish rules and regulations for environmental protection at a national level. The Central Government was also empowered to issue the following directions

a) the closure, prohibition or regulation of any industry, operation or process; or

b) stoppage or regulation of the supply of electricity or water or any other service.

Moreover, fines and penalties were rendered extremely rigorous. The Act also included safety regulations concerning the management and handling of toxic or hazardous substances. The Act is the bases of the Environmental (Protection) Rules of 1986, the Hazardous Waste (Management and Handling) Rules of

1989 and the Manufacture, Storage and Import of Hazardous Chemicals Rule of 1989, etc.

Minimum National Standards (MINAS) were established on the basis of the Environment (Protection) Rule of 1986. It was accepted that individual States could apply more stringent environment quality and emission standards than the MINAS but any relaxation of these standards was prohibited. In fact, however, no State has adopted standards which exceed those of the MINAS in terms of severity. The concrete levels and figures for MINAS are discussed in the following chapter.

(4) Other Measures

The present section considers the fiscal incentives for promotion of pollution control investment and the various guidelines for environmental safeguard and safety relating to industrial sites which exist in addition to the three Acts outlined above.

1) Fiscal Incentives to Investment in Pollution Control

The following incentive systems are established by the Indian government to promote investment in pollution control.

(a) Grant of higher rate of depreciation for pollution control equipments and facilities

(b) Grant of higher rate of investment allowance for pollution control equipments and facilities

(c) A tax exemption on capital gains arising from the relocation of factories from metropolitan areas to outlying regions.

(d) Grant of rebate of cess levied on consumption of water used for firms installing waste water treatment facilities.

The above incentives are judged to be sufficiently substantial.

2) Environmental and Safety Guidelines on Industrial Sites

The Ministry of Environment and Forests published its environmental and safety guidelines relating to the location of industrial sites in 1985.

According to these guidelines it is necessary for entrepreneurs in twenty specified industrial sectors to secure the approval of the State or Central Government with regard to the environmental measures (for pollution and safety) envisaged before an industrial licence is granted. For projects requiring the support of the Central Government or of International Agencies it becomes necessary to obtain an approval from the Department of Environment of the Central Government.

Moreover, in the case of special locations entrepreneurs are required to submit an environmental impact assessment report and a plan for environmental management.

The present guidelines aim at freeing those metropolitan areas where there is already an over-concentration of industries and at eliminating areas of high environmental sensitivity from further or even existing industrial sites. The guidelines therefore represent extremely wide ranging and concrete standards for industrial sites.

The demands set by these standards are very rigorous and it would be impossible to meet such exigencies for example in a country like Japan given its limited national territory and cramped conditions.

(5) Comparison of Legal Provisions concerning Environmental Matters in India and Japan

It is certainly no easy matter to compare the environmental legislation of two countries with such differing legal systems as India and Japan. However, it is our opinion after considerable evaluation that the underlying philosophy and aims of environmental legislation in both cases are similar. Nevertheless there are slight differences in terms of the actual legal provisions in the two cases.

The following are the differences observed.

1) The concept of "the accumulative nature of pollution" is still weak in the Indian context. Therefore, although there are regulation standards concerning the concentration of pollutants there are no regulations on overall total volumes of them.

2) There seems no adequate provision for the legal compensation of damage done by pollution in India.

3) There seems no adequate provision in Indian law for settling of disputes concerning pollution.

4) There seems no adequate provision in Indian law concerning the pollution control managing systems in specified factories.

5.1.3 Problem Points of Environmental Protection

As mentioned in the previous section a comprehensive legislative system regarding environmental protection already exists in India and this system is observed and