Low Severity Extraction of Coal for Production of Carbon Fuel for Direct Carbon Fuel Cells

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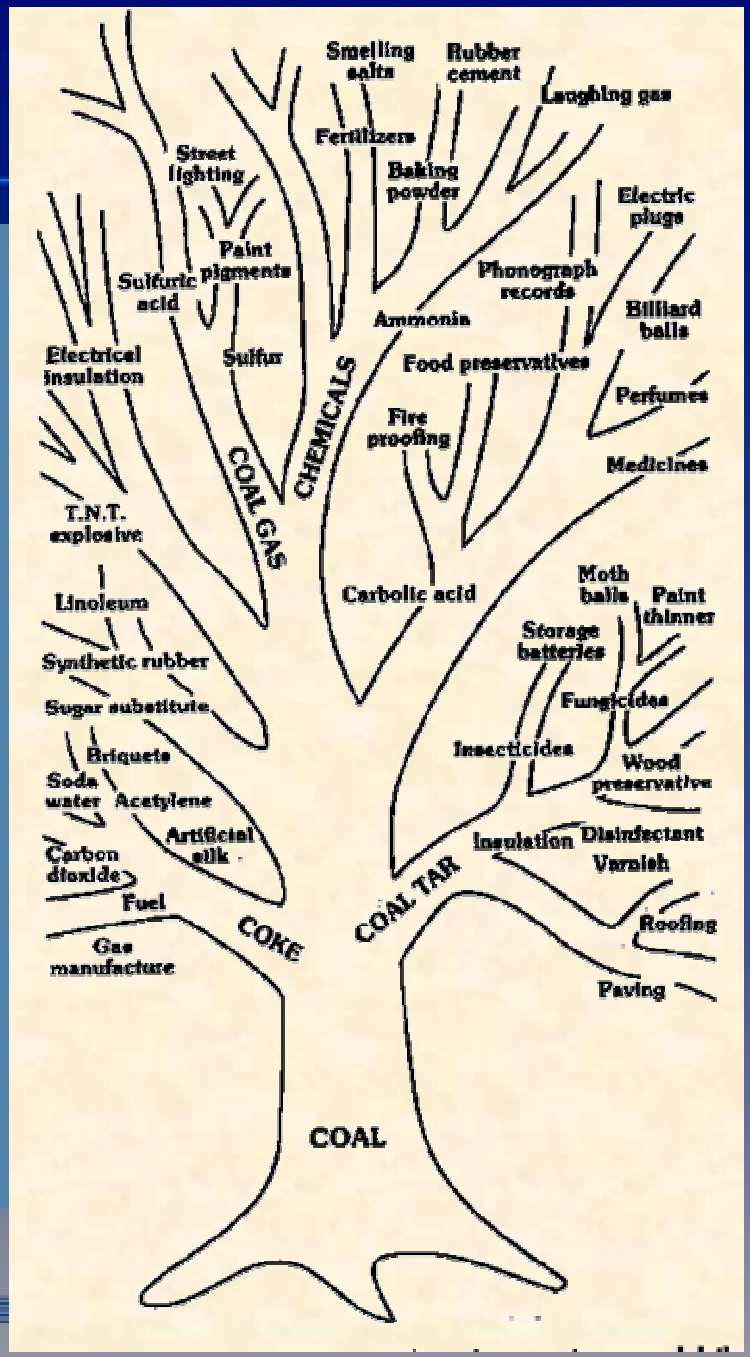
Center for Applied Energy Research

Introduction

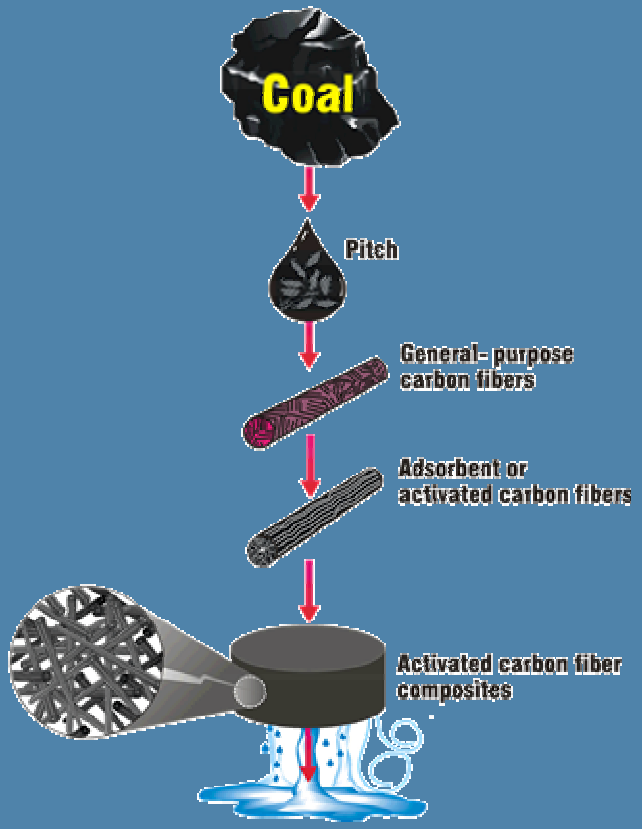
- Value-added products in light of:
  - Immerging technologies in carbon materials;
  - Diminishing supply of coal tar pitch from traditional sources;

- Coal extract pitches as a feedstock for a variety of carbon materials.



Introduction *continued*

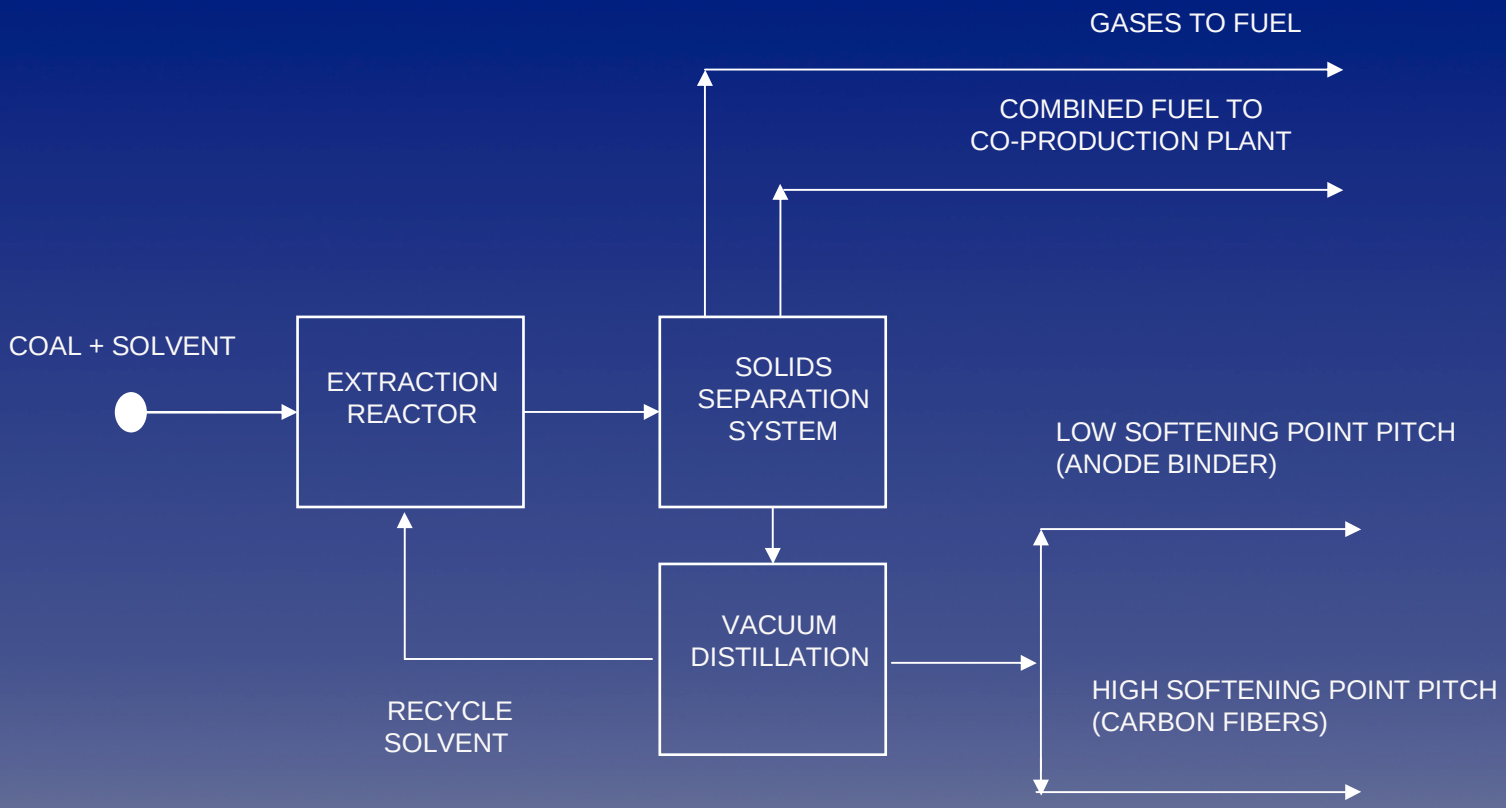
- Tailor pitches to suite application;
  - Carbon fibers;
  - Binder pitches;
  - C/C composites;
  - Fuel cell applications?



Objectives / Approach

- CAER solvent extraction method;
  - No exotic solvents;
  - Low temperature;
  - Self generated atmosphere;
  - Non hydrogenated process;
  - No catalysts;
- Economic viability;
- Power plant integration.

Extraction Process



Process Conditions

- Coal and anthracene oil slurried (1:2 wt) into a 2L autoclave;
- Digestion Temperature = 425^{o}C;
- Digestion Time = 60 min;
- Digestion Pressure = 200 psi;
- After digestion reactor cooled to ~260^{o}C and the digest transferred to filtration apparatus;

Process Conditions *continued*

- Digest filtered at approximately 250°C at pressures ranging 10 to 15 psi, filtering rates measured;
- Filtrate vacuum distilled to recover solvent and pitch (pot residue);
- Distillation pot temperature used to control softening point of the extracted pitch;
- Depending on application pitch softening point will range from 100 to 260 °C.

Coals

	Shoemaker Mine	W. Kentucky	Black Thunder
Moisture (%)	2.3	9.9	8.9
Ash (%)	11.5	10.1	5.8
Volatiles (%)	38.5	40.0	39.9
Fixed Carbon (%)	47.7	49.9	45.5
C (% daf)	82.8	70.2	65.8
H (% daf)	5.9	4.5	4.1
N (% daf)	1.6	1.7	0.9
O_{diff} (% daf)	6.3	9.9	19.7
Total S (% daf)	3.5	3.7	0.7
Pyritic S (% db)	1.3	2.0	-
Sulfate (% db)	0.04	0.02	-
Organic S (% db)	1.8	1.9	-

Anthracene Oil *ex Reilly Industries, Inc.*

Compound	%
Naphthalene	2
Acenaphthene	4
Fluorene	6
Phenanthrene	16
Anthracene	4
Carbazole	4
Fluoranthene	8
Pyrene	6

Anthracene Oil *continued*

H_2O *(max.)*	0.5 %
Density *(min)*	1.12 g cm^{-3}
Flash Point *(min)*	104 ^oC
DRY BASIS	
C	91.5 %
H	6.0 %
N	1.0 %
O	1.0 %
S	0.5 %

Temperature (^oC)	**Mass Distilled wt % *minimum***	**Mass Distilled wt % *maximum***
0-315	-	3.0
0-355	5.0	20.0
0-400	40.0	65.0
0-500	-	98.0

Digestion

	S.maker	W.Ky	B.T	*units*
Coal IN (daf) =	250.5	224.5	247.5	**g**
Solvent IN =	579.4	584.9	576.6	**g**
Slurry IN (daf coal) =	829.9	809.4	824.1	**g**
Extraction Distillates OUT =	41.5	53.3	139.0	**g**
Digest OUT (daf coal) =	769.6	727.3	676.9	**g**
QI =	18.3	21.3	32.1	**%**
THFI =	26.2	24.8	34.4	**%**
% Conversion [based on QI] (daf coal) =	76.9	68.7	60.8	**%**
% Conversion [based on THFI] (daf coal) =	67.0	63.5	61.8	**%**
Mass Balance Extraction (daf coal) =	97.7	96.4	98.0	**%**

Filtration

	Shoemaker	W.Ky	B.T	*units*
Filter Charge (daf coal) IN =	769.6	727.3	676.9	g
Cake (daf coal) OUT =	72.9	56.2	102.1	g
Filtrate (daf coal) OUT =	675.5	624.3	430.5	g
Distillates OUT =	0.8	4.7	3.9	g
Specific Cake Resistance =	4.2	2.1	4.4	10^{10}m/kg
Filter Rate =	170.0	214.5	96.8	kg/m^2/h
QI Filtrate =	0.6	0.8	0.4	%
Mass Balance (daf coal) =	96.5	97.6	97.5	%

Distillation

	Shoemaker	W.Ky	B.T	*units*
Distillation Charge IN =	675.5	624.3	430.5	g
Distillate OUT =	399.7	391.2	220.3	g
Pitch (daf coal) OUT =	273.2	230.4	205.5	g
Pitch Softening Point =	215	255	110	^{o}C
Mass Balance (daf coal) =	99.6	99.6	98.9	%

Solvent Balance

	Shoemaker	W.Ky	B.T	*units*
Solvent IN =	579.4	584.9	576.6	g
Distillate OUT =	441.9	449.2	363.2	g
Solvent Balance =	90.2	89.8	72.5	%

- Solvent losses:
  - Filter cake;
  - Aducted into pitch.

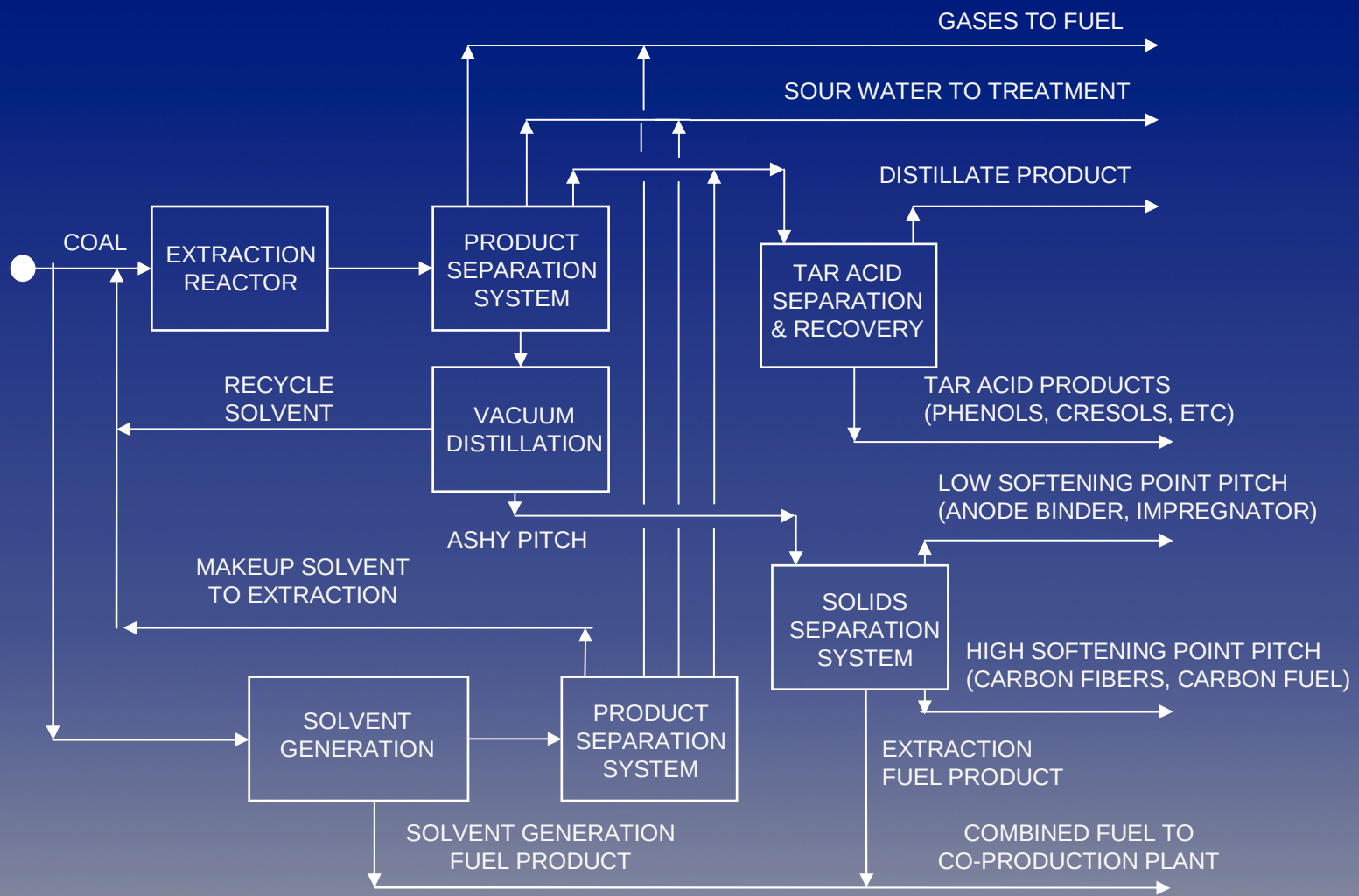
Pitch Properties

	Shoemaker	Western Kentucky	Black Thunder
S.Point (^{o}C)	215	260	110
Moisture (%)	0.03	0.11	0.04
Ash (%)	0.06	0.07	0.1
Volatiles (%)	52.9	53.5	71.2
Fixed Carbon (%)	47.1	46.5	28.8
C (% daf)	90.0	90.7	91.8
H (% daf)	4.7	5.4	5.0
N (% daf)	1.7	1.7	1.1
O_{diff} (% daf)	2.0	0.7	1.7
Total S (% daf)	1.7	1.5	0.5

Pitch Carbonization

Pitch	Carbon Yield (%)
Shoemaker	59-69
Western Kentucky	64-73
Black Thunder	47-63

Process Development



Summary

- CAER solvent extraction method;
  - Low temperature, low pressure, non-hydrogenative process;
  - Pitch can be tailored to suite a number of applications;
  - Amenable to carbonization;
  - ? Possible to produce carbon fuels.