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A Pressure-drop Method

for Real-time Monitoring the Solid Flux in Circulating Gas-solid Processes

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FLUIDIZATION XVI

**Reporter*

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1. INTRODUCTION

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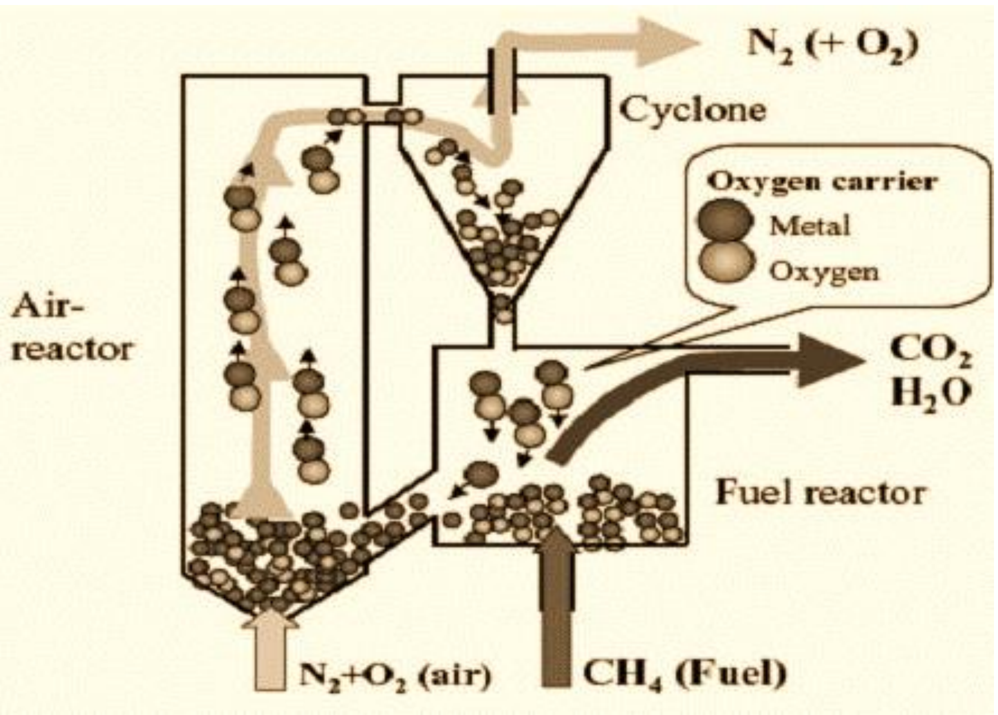
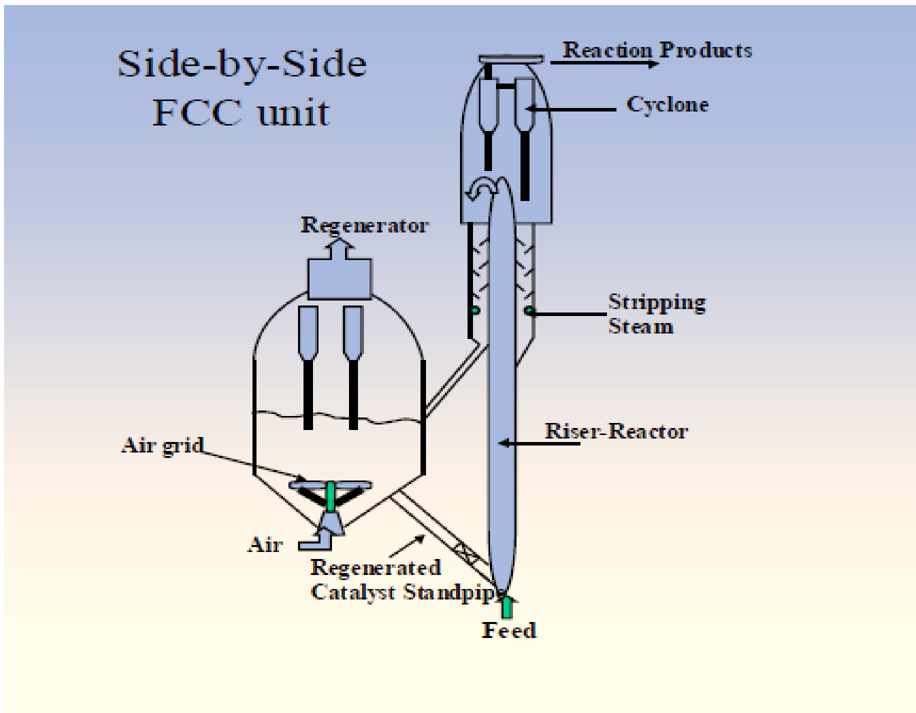
Background

■ Circulating Gas-solid Processes

- ➢ **CFB, Circulating Fluidized Bed**, **Applications:** CLC / FCC / IGCC / PFBC / BG … …
- ➢ **CGB, Circulating Granular Bed**, **Applications:** CR / (M)GBF… …



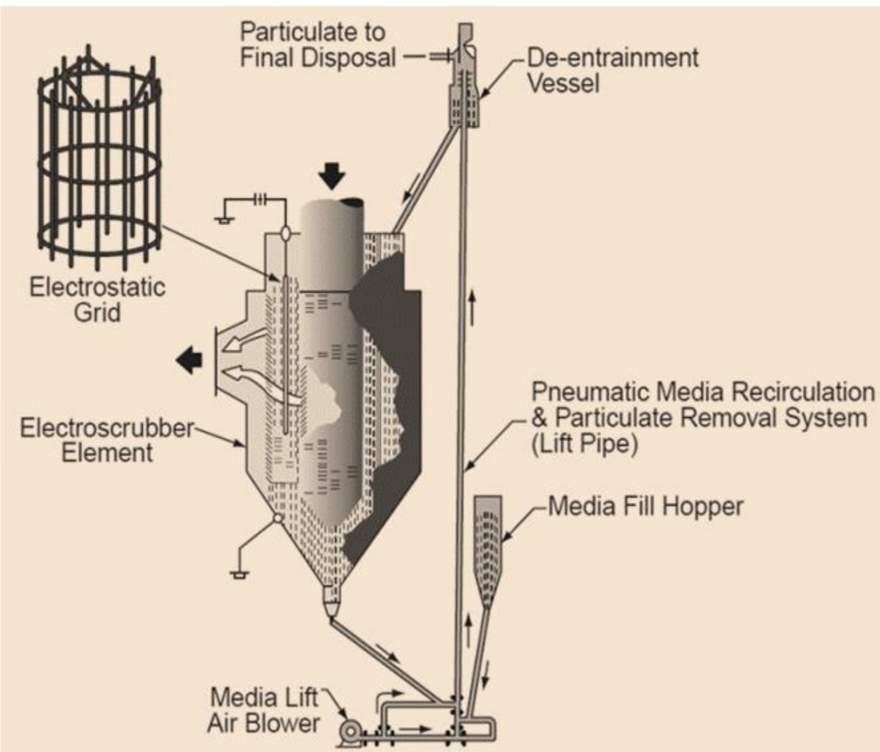


Chemical Looping Combustion **Fluidized Catalytic Cracking**

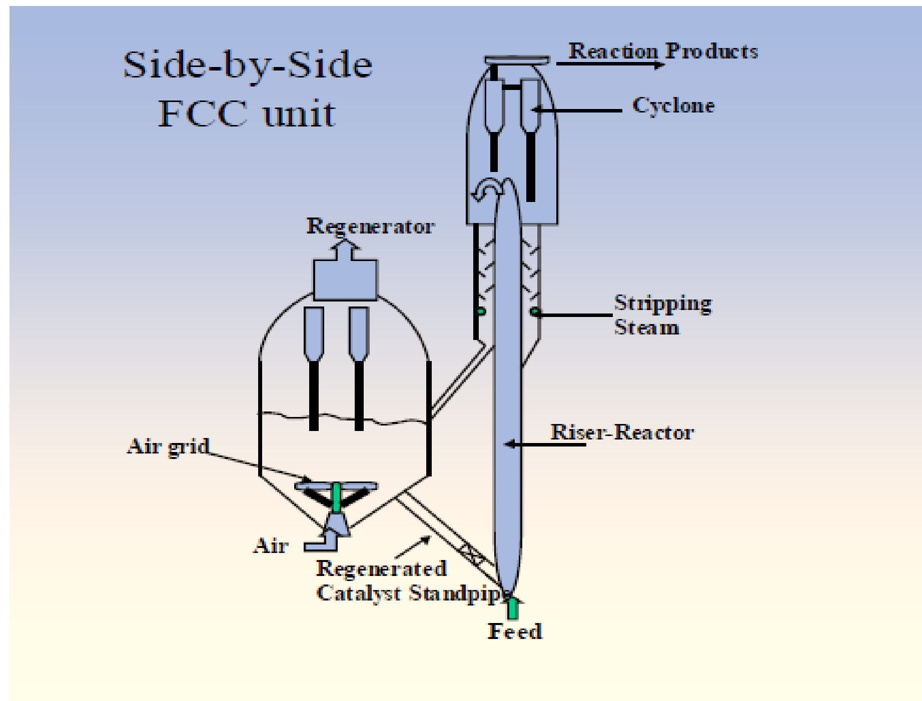
Background

■ Circulating Gas-solid Processes

- ➢ **CFB, Circulating Fluidized Bed**, Applications: CLC / FCC / IGCC / PFBC / BG … …
- ➢ **CGB, Circulating Granular Bed**, Applications: CR / (M)GBF… …



Electrostatic Granular Bed Filter



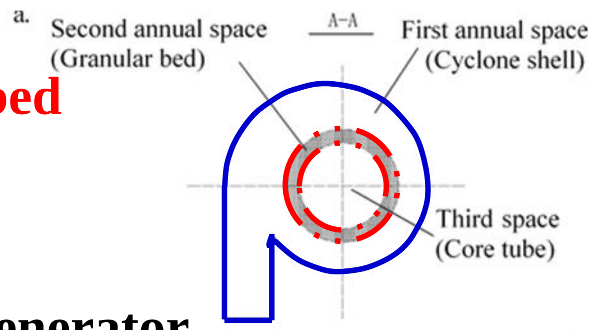
Fluidized Catalytic Cracking

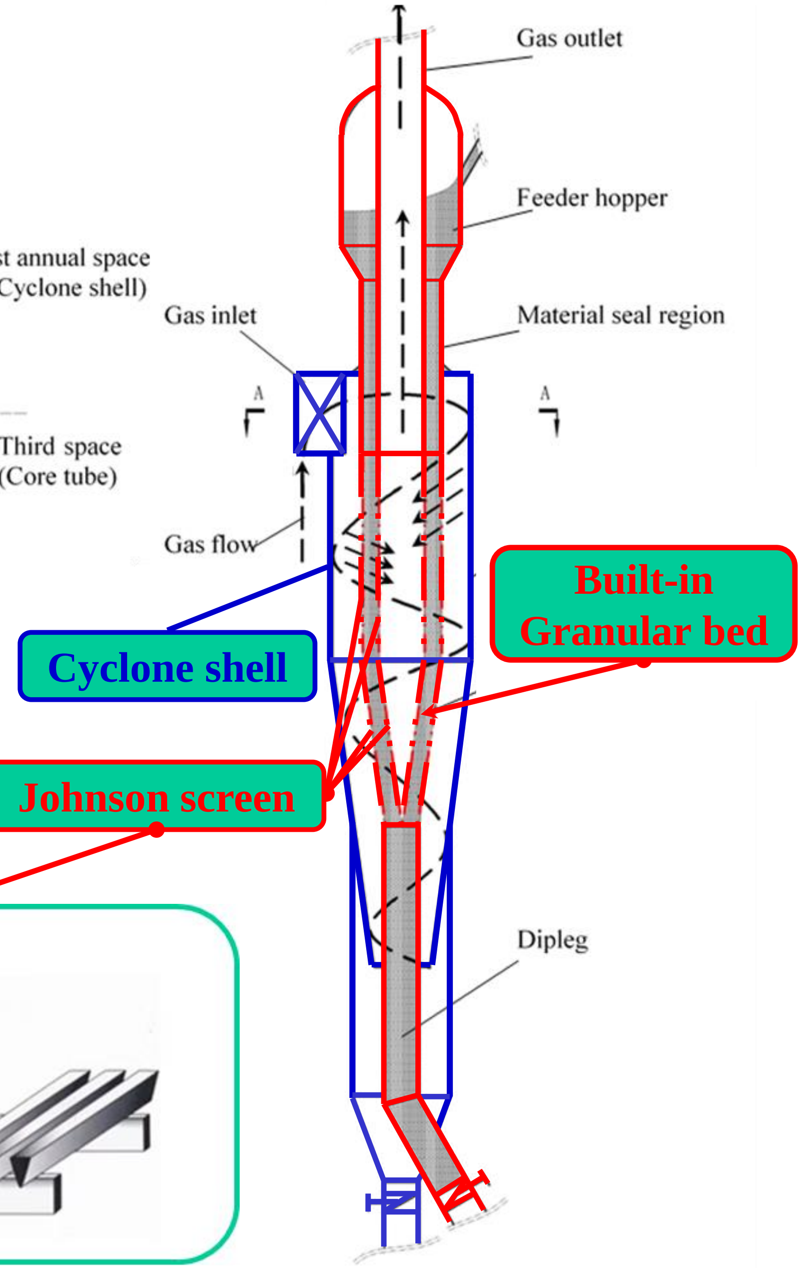
Background

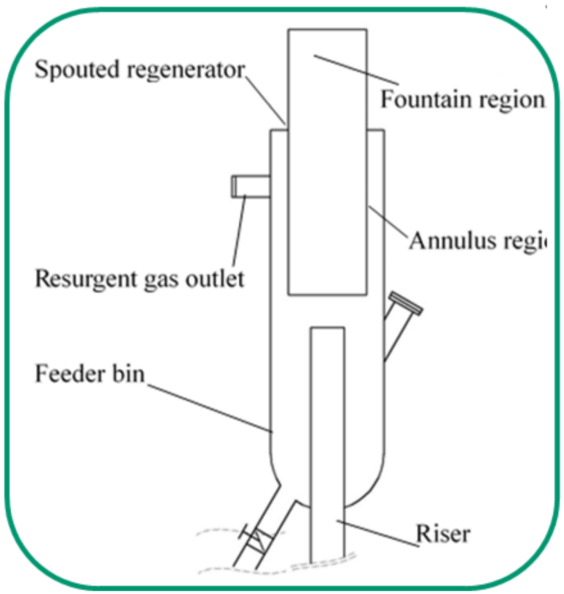
- **Solid Circulating Flux -- VITAL PARAMETER**
  - **Visual Observation** – original and basic
  - **Solid Accumulation (volume method)** –original and basic
  - **Fiber Optical Probe (particle velocity)** – low accuracy with many assumptions
  - **X-Ray Densitometry** – high cost and additional estimation
  - **Electrical capacitance tomography** – high cost and additional estimation
  - **Extraction/Sampling Probe (solid velocity distribution)** – intrusive
  - **Heat/Mass Transfer or Oxygen Balance** – limit and outline
  - **Tracer Method (magnetic/radioactive) –** intrusive and high cost
  - **Mechanical Meters (Impact /Spiral flow) –** online, sensitive but calibration and stability needed
  - **Pressure Drop Method – online, accurate, scalability, simple implementation.**

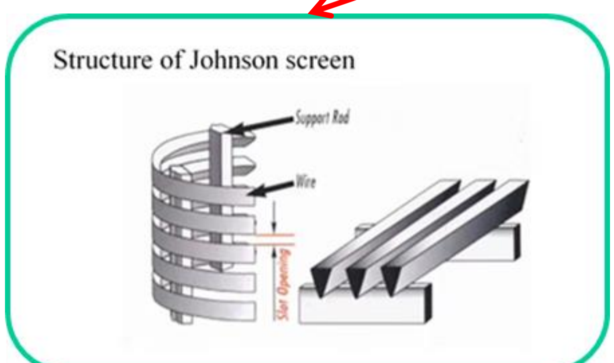
Background

- **Cyclone** & **Granular bed**
- **Johnson screen**
- **Riser-spouted bed regenerator**









Detailed structure of the C-CGBF system

2. EXPERIMENTAL SETUP

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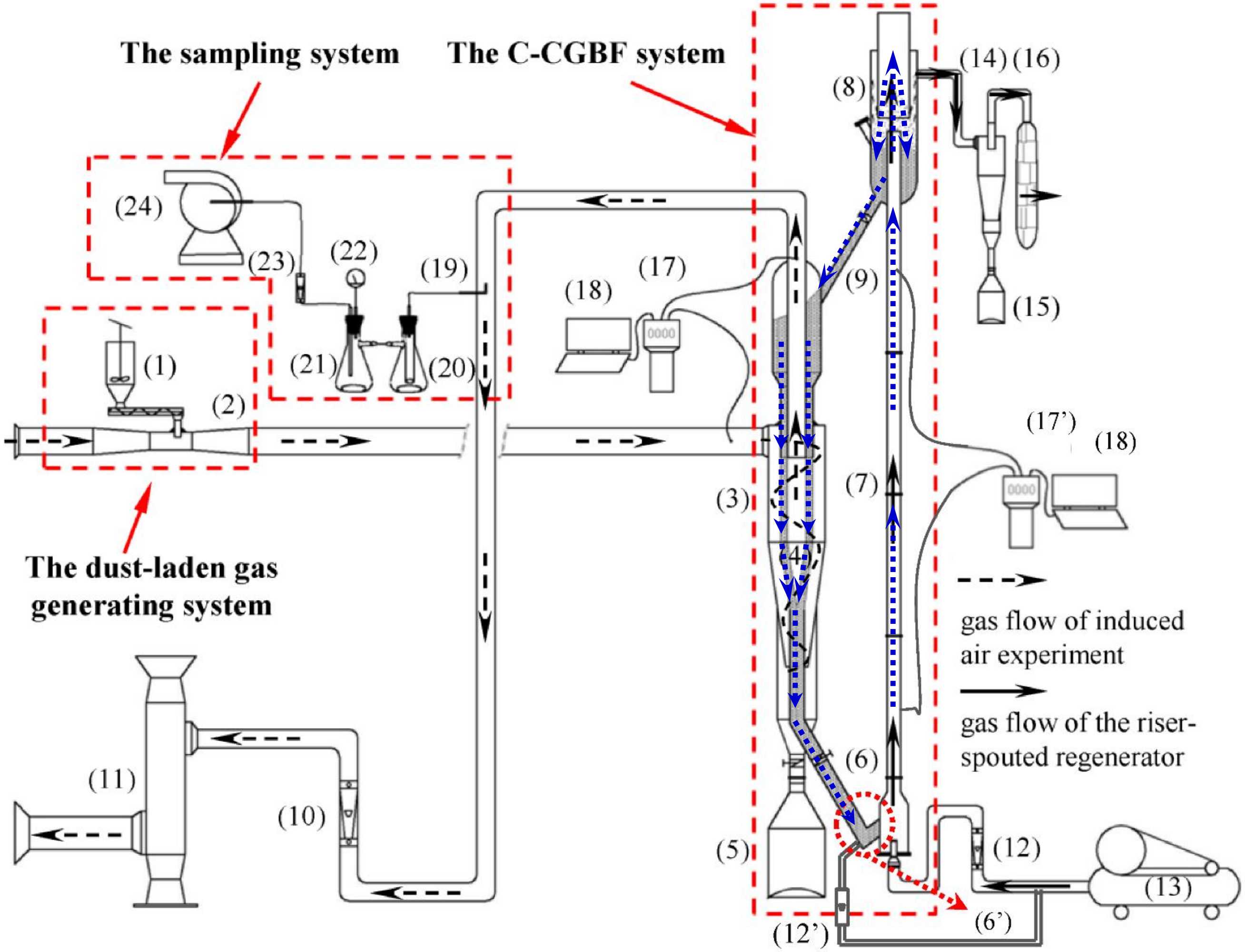
Setup



Schematic diagram of the experimental setup

Materials

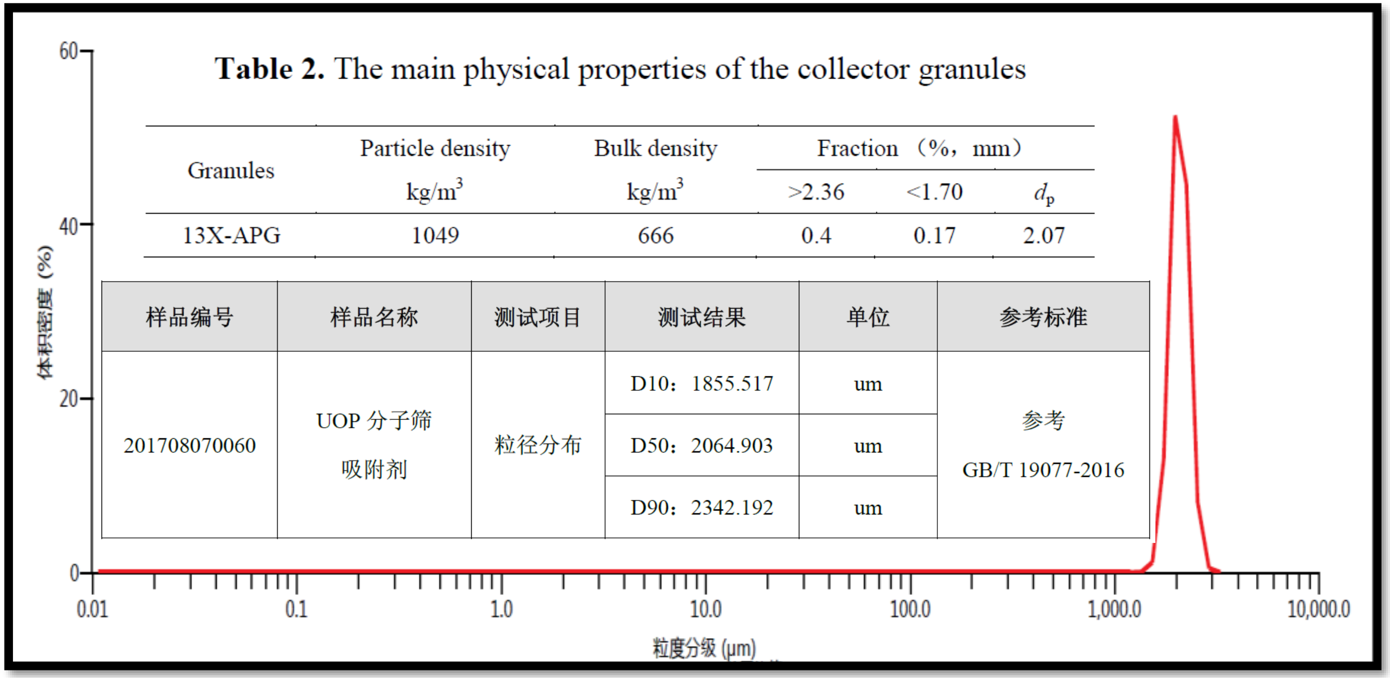
- **Collector Granules：**

- UOP 13X-APG adsorbent granules, d_p= 2.07 mm; ρ_b = 666 kg/m^3.

Table 2. The main physical properties of the collector granules

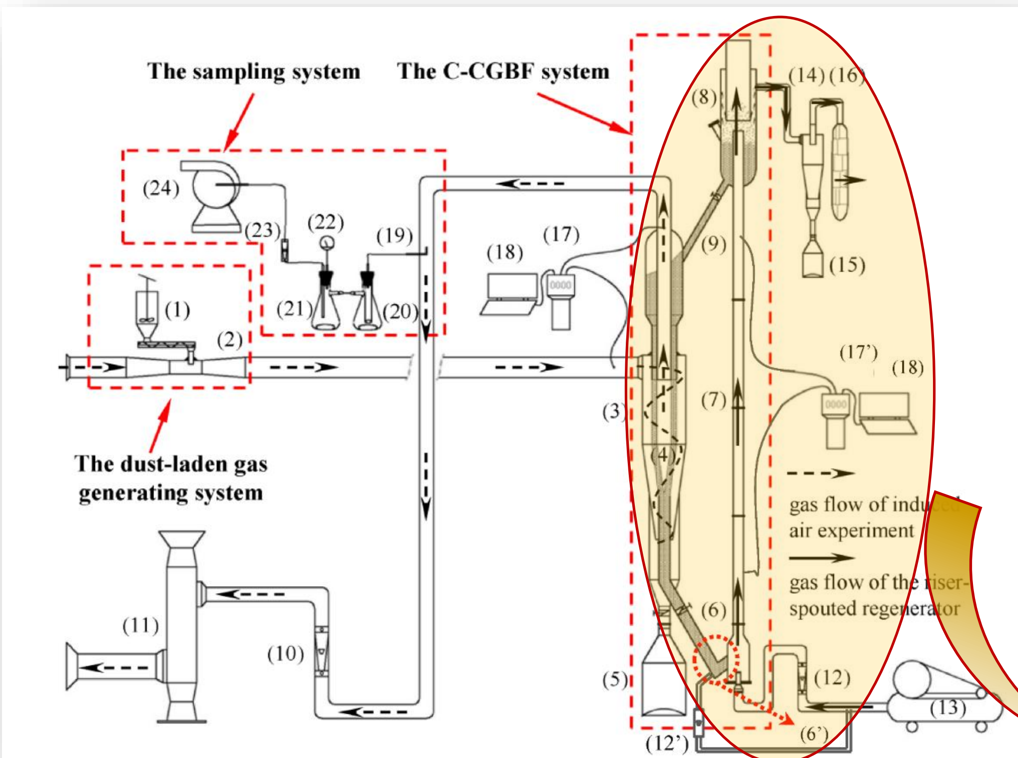
Granules	Particle density kg/m^3	Bulk density kg/m^3	Fraction （%，mm）		
			>2.36	<1.70	d_p
13X-APG	1049	666	0.4	0.17	2.07

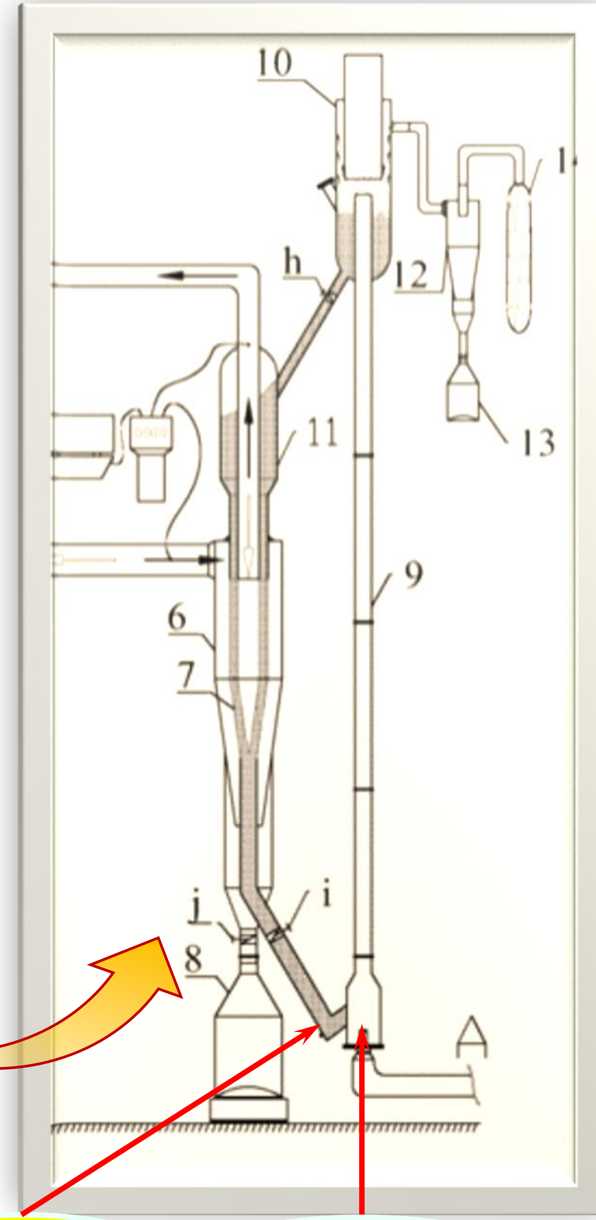
样品编号	样品名称	测试项目	测试结果	单位	参考标准
201708070060	UOP 分子筛 吸附剂	粒径分布	D10：1855.517	um	参考 GB/T 19077-2016
			D50：2064.903	um	
			D90：2342.192	um	



Size distribution of the UOP 13X-APG adsorbent granules（Mastersizer3000）

Measurement





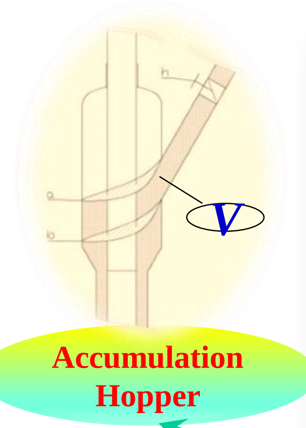
$$Q_r = Q_t + Q_l$$

Transporting Air, Q_t

Main Lifting Air, Q_l

Analysis

- ## Accumulation Method: $W_s = \rho_b V / t$
  - t means the time spent by a given volume V of the collector granules downward flowing out of the feeder hopper is recorded by a seconds-counter.



- ## Pressure-drop Method

- ## Pressure drop of the riser: $\Delta P_r = \bar{\rho} g h + f_g + f_s$
  - the average density of the gas-solids flow in the 4 m riser,

$$\bar{\rho} = k W_s / Q_r$$

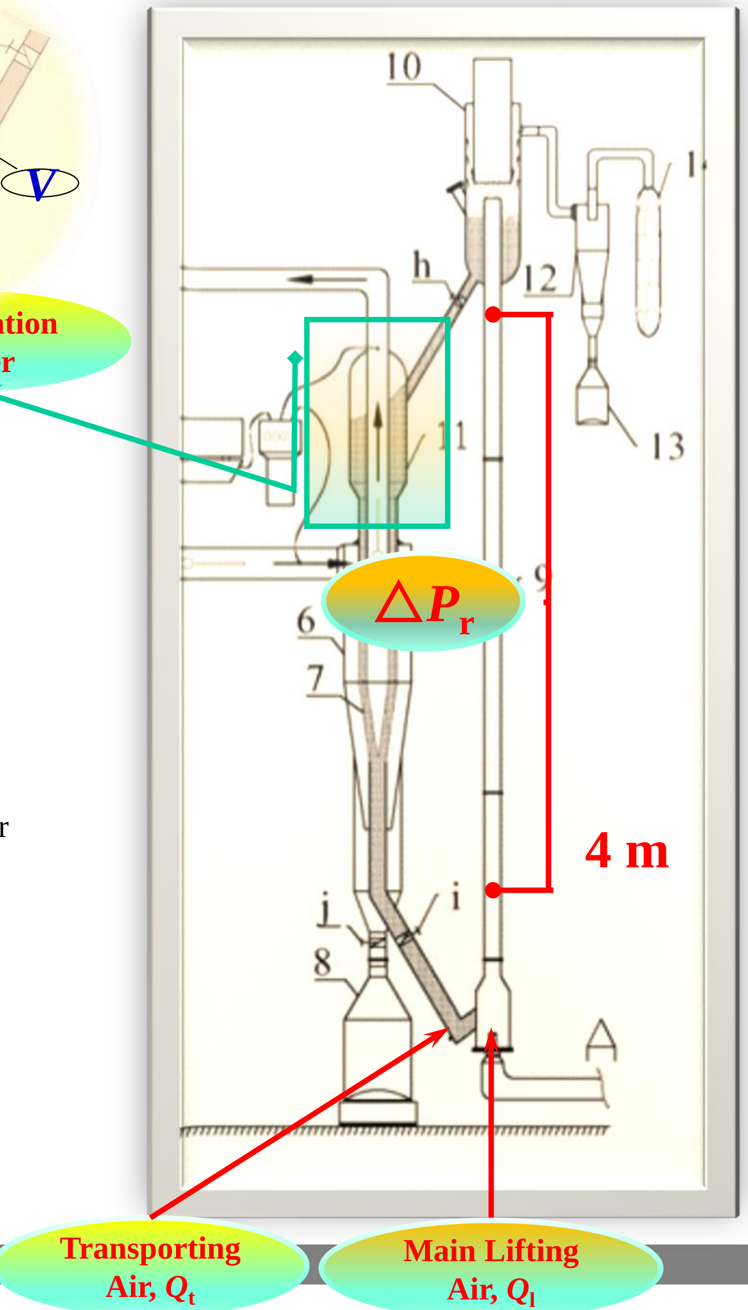
  - f_g is the friction loss caused by the pneumatic gas;
  - f_s represents the pressure loss due to the collision between the solids and the riser wall, as well as the collision between the solids themselves.

$$f_s = \xi_s \cdot \bar{\rho} u_t^2 / 2$$

  - Therefore:

$$\Delta P_r = W_s k \left(gh + \xi u_t^2 \right) / Q_r + f_g$$

  - there is a linear relationship between ΔP_r and W_s, with an intercept of f_g.



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3. RESULTS & CONCLUSIONS

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Results

- **Experimental conditions:**

Q_r m^3/h	Q_t m^3/h	$\triangle P_r$ kPa	W_s kg/s
68	0	0.698	0.022
	2	0.817	0.027
	4	0.889	0.034
	6	1.026	0.042
	8	1.161	0.058
	10	1.557	0.086
	12	3.020	0.194
	14	2.879	0.224
	16	2.908	0.242

Q_r m^3/h	Q_t m^3/h	$\triangle P_r$ kPa	W_s kg/s
98	0	0.409	0.029
	2	0.465	0.039
	4	0.547	0.048
	6	0.694	0.062
	8	0.971	0.091
	10	1.452	0.146
	12	2.383	0.274
	14	2.316	0.268
	16	2.297	0.275

Q_r m^3/h	Q_t m^3/h	$\triangle P_r$ kPa	W_s kg/s
128	0	0.026	0.417
	2	0.040	0.537
	4	0.051	0.585
	6	0.067	0.705
	8	0.091	0.872
	10	0.159	1.368
	12	0.254	2.125
	14	0.262	2.032
	16	0.290	2.320

Q_r m^3/h	Q_t m^3/h	$\triangle P_r$ kPa	W_s kg/s
158	0	0.012	0.496
	2	0.026	0.587
	4	0.046	0.709
	6	0.068	0.875
	8	0.142	1.438
	10	0.173	1.693
	12	0.228	2.263
	14	0.255	2.457
	16	0.291	2.642

Q_r m^3/h	Q_t m^3/h	$\triangle P_r$ kPa	W_s kg/s
98	0	0.409	0.029
	2	0.465	0.039
	4	0.547	0.048
	6	0.694	0.062
	8	0.971	0.091
	10	1.452	0.146
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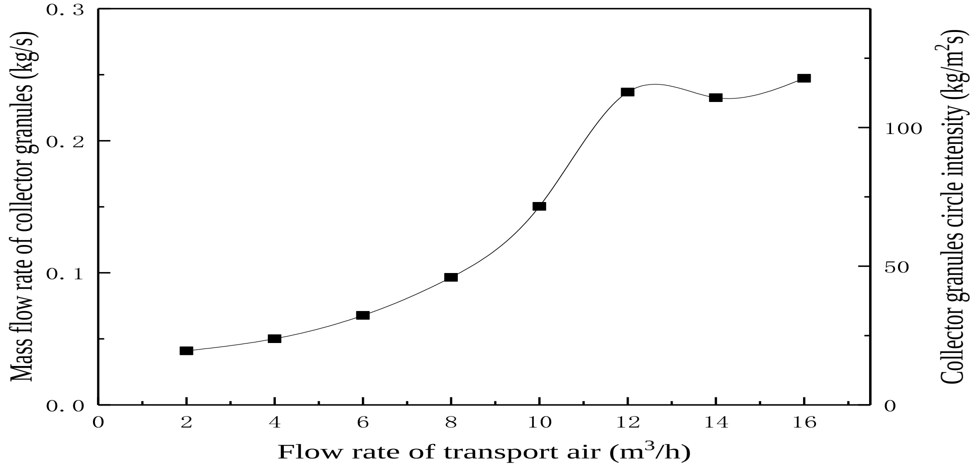
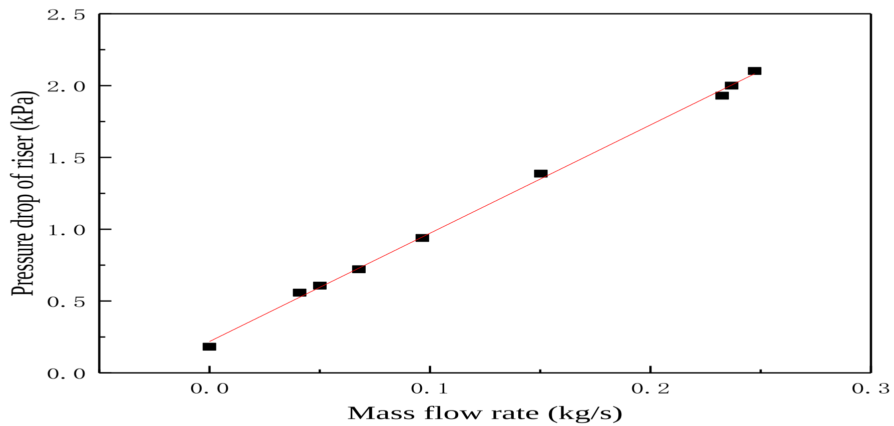
	16	2.297	0.275

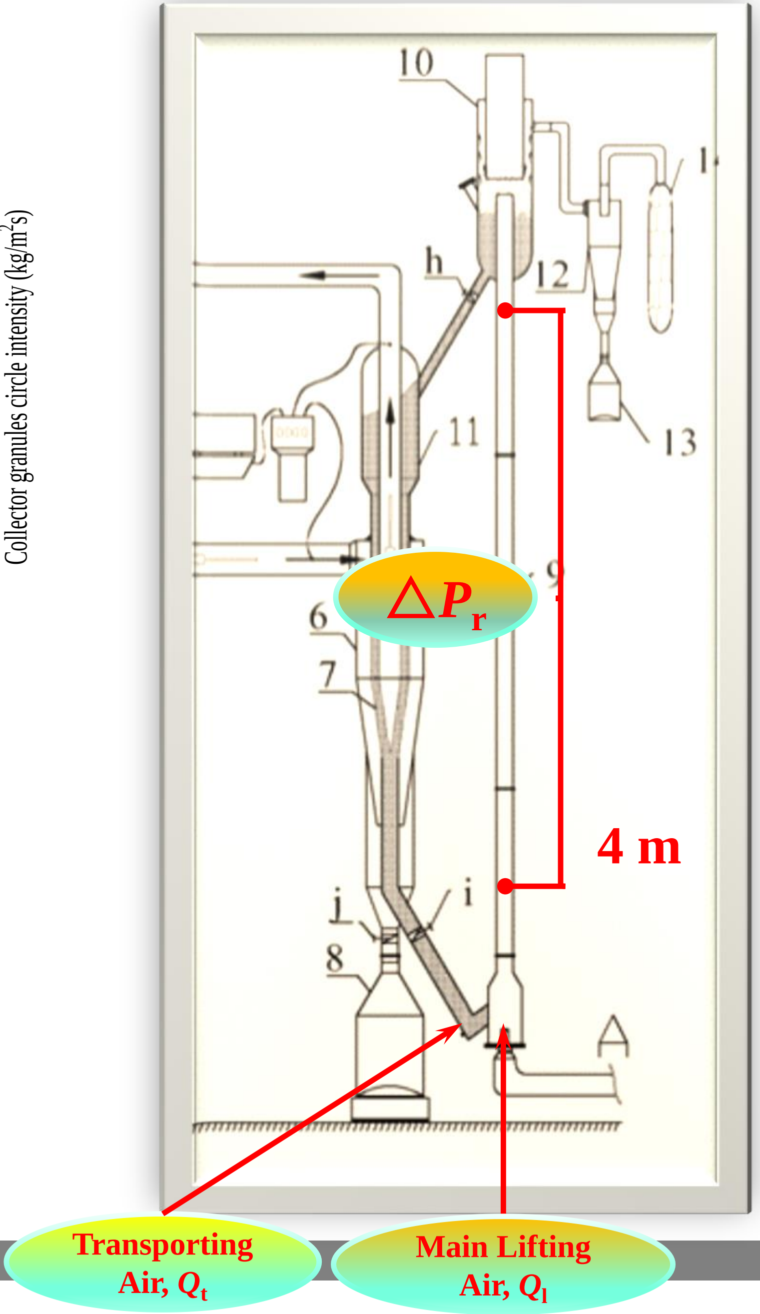
Results



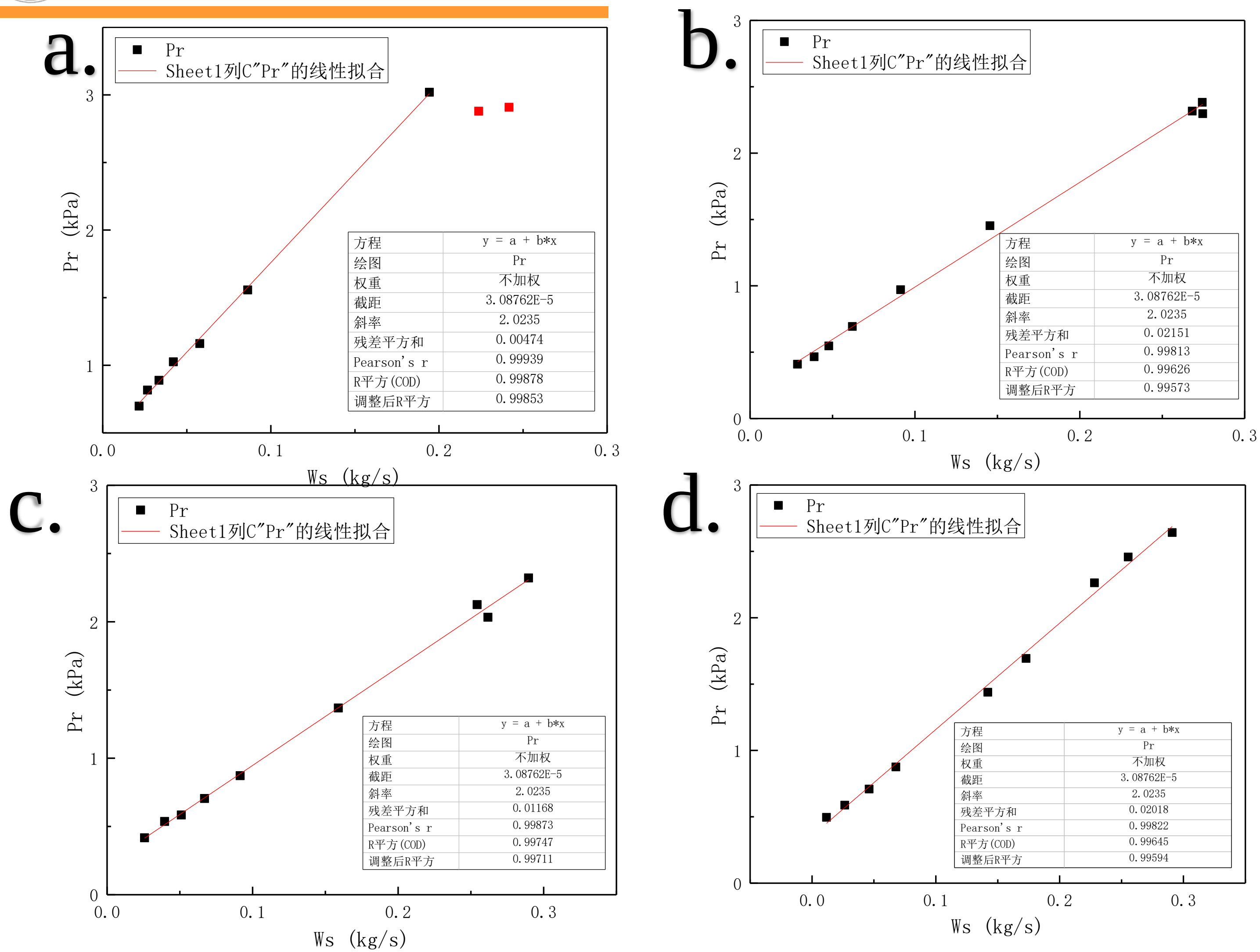
Granules circulation flux at different flow rates of the transporting air in the V valve, Q_r=98 m³/h



Relationship of the pressure drop of the 4 m riser and the granules circulation flux



Results



a. Q_t=68 m^3/h; b. Q_t=68 m^3/h; c. Q_t=68 m^3/h; d. Q_t=68 m^3/h.

Conclusions

- There is a linear relationship between $\triangle P_r$ and W_s, with an intercept of f_g.

$$\Delta P_r = K W_s + f_g$$

CONCLUSIONS

- The maximum circulation flux depends on the pressure balance between the material sealing in the moving bed and the riser-spouted bed regenerator;
- The real-time monitoring on the circulation flux by the pressure-drop method was accomplished;
- The theoretical meaning and accurate definition of the parameters in this correlation need further investigation.

W_s (kg/s)		△P_r (kPa)			
		68 m^3/h	98 m^3/h	128 m^3/h	158 m^3/h
	K	13.251	7.890	7.178	8.010
	f_g	0.175	0.202	0.230	0.357
0		0.43	0.20	0.23	0.36
0.020		0.70	0.36	0.37	0.52
0.040		0.96	0.52	0.52	0.68
0.060		1.23	0.68	0.66	0.84
0.080		1.49	0.83	0.80	1.00
0.100		1.76	0.99	0.95	1.16
0.120		2.02	1.15	1.09	1.32
0.140		2.29	1.31	1.23	1.48
0.160		2.55	1.46	1.38	1.64
0.180		2.82	1.62	1.52	1.80
0.200		**3.08**	1.78	1.67	1.96
0.220		**3.35**	1.94	1.81	2.12
0.240		**3.61**	2.10	1.95	2.28
0.260		**3.88**	2.25	2.10	2.44
0.280		**4.14**	2.41	2.24	2.60
0.300		**4.41**	2.57	2.38	2.76

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Thanks for Your Attention!

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