Heat recovery from melted blast furnace slag using fluidized bed

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Blast furnace slag production in Japan

<u>Production of blast furnace slag</u>

290 kg-slag/1000 kg iron

→Annual production of slag is 24 Mt.

For one large scale blast furnace, production rate of melted slag (at about 1500℃) is 100 – 150t/hour.

Solidified by natural cooling in atmosphere or rapid cooling by water. →Heat recovery has not yet been done.

Potential of melted slag as heat source

Melted slag at 1500℃ has sensible and latent heat of about 400 – 500 cal/g.

If half of the heat of melted slag is to be recovered in Japan, the total heat recovery will be equivalent to about 1 Mt of coal.

=0.5% of annual coal import of Japan

=1.1% of coking coal consumption of Japan

Problem with heat recovery from melted slag

Phase change from liquid to solid by cooling.

- Accumulation of solid slag on to heat transfer surface if solidified.
- Insufficient heat recovery if heat removal in from only liquid phase (sensible heat of liquid) is to be done.
- Heat recovery after solidifying (cooling) reduces temperature difference

→Need to new technology to heat recovery

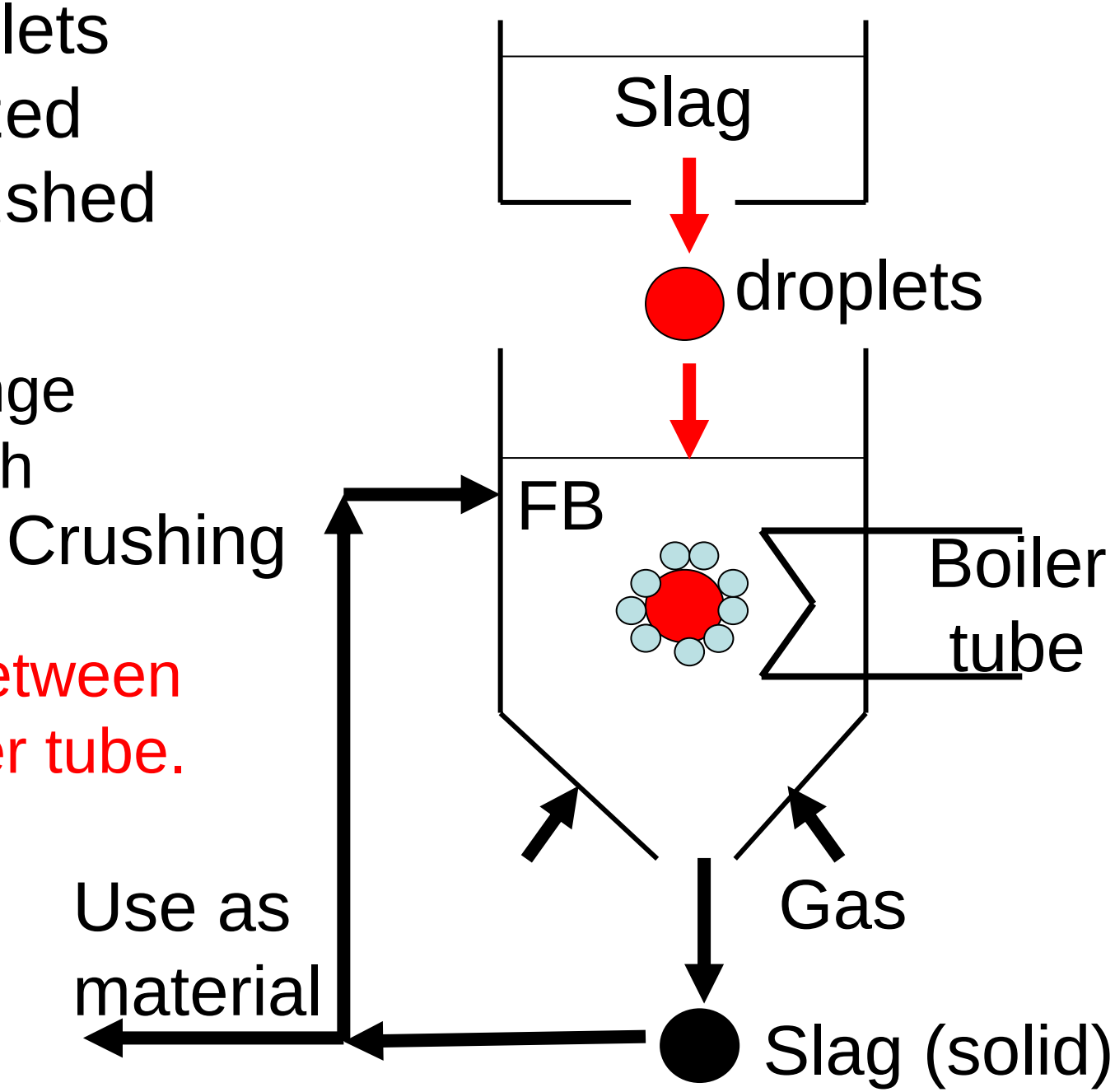
Proposed concept

Melted slag droplets are fed into fluidized bed consist of crushed solid slag.

Heat of phase change is recovered through boiler tubes.

No direct contact between liquid slag and boiler tube.

Removal of solidified slag from the bottom.



Process conceptual design

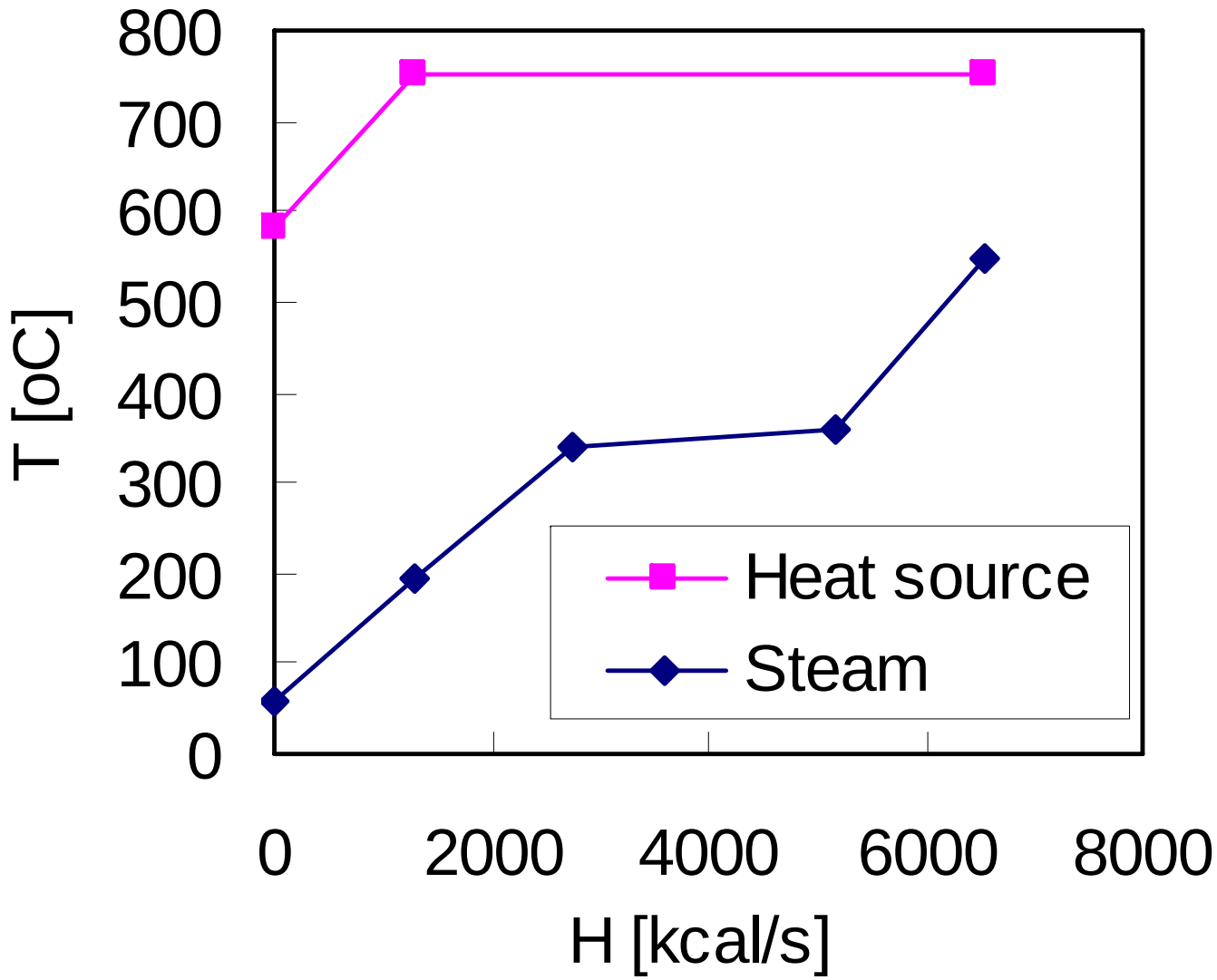
Feasibility of steam recovery is discussed.

- Target: Steam of 550℃, 150atm (for power generation)
- Temperature-Enthalpy diagram
- Required heat transfer surface area.

Feasibility of steam recovery

At a bed temperature of 750℃, steam recovery is possible at 550℃, 150atm.

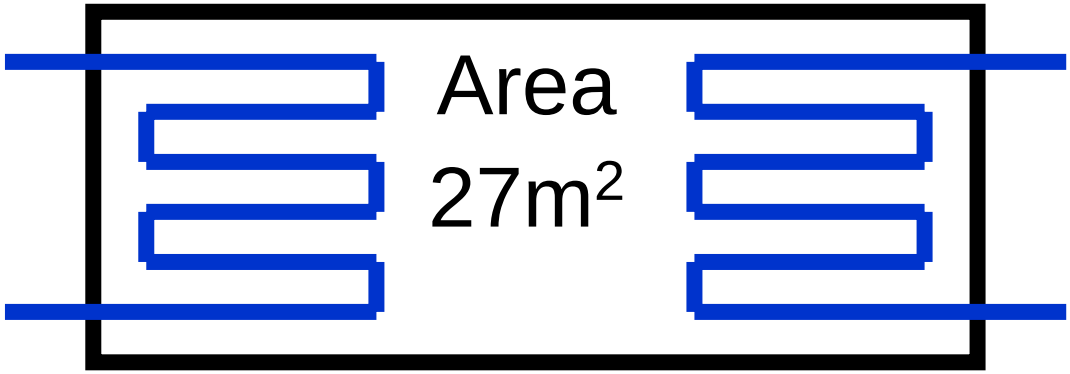
For a slag feed rate of 100t/h and 52% recovery, heat recovery rate is 27MW(11MWe).



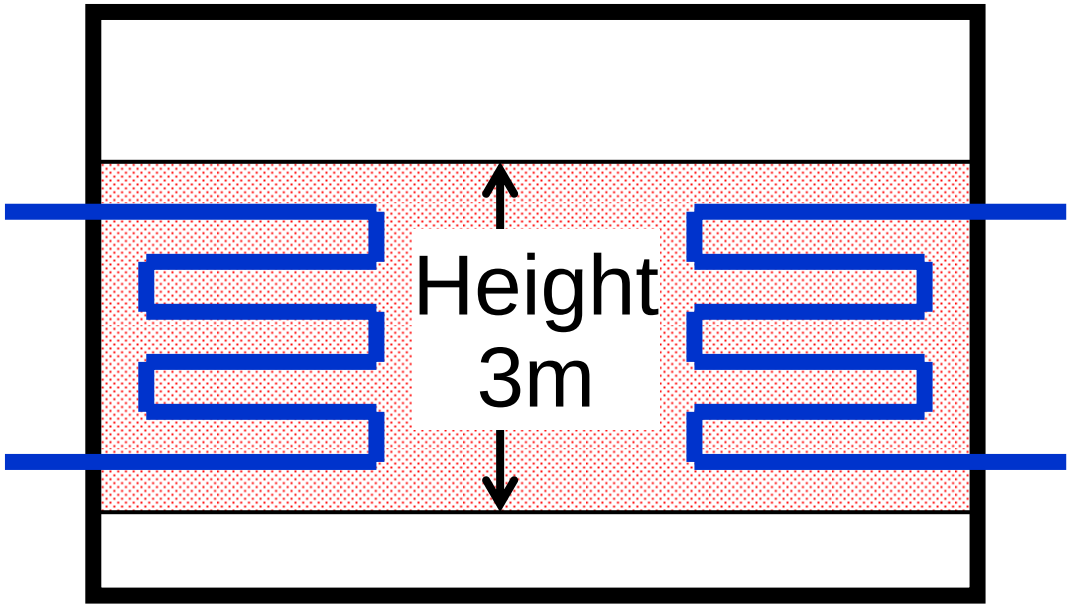
Arrangement of heat transfer surface

To provide necessary heat transfer area, a bed of 3 m in bed height and a horizontal cross sectional area of 27 m^2 is required. The volume of bed in which heat transfer tubes are immersed is 50m^3. For slag sedimentation, additional 30m^3 is required.

→ Practical size.



Top view



Side view

Basic study using FB cold model

Experiments to feed simulated melted slag (melted wax) were carried out.

- Continuous feed of melted was and withdrawal of solidified slag.
- Detection of solid accumulation in the bottom.

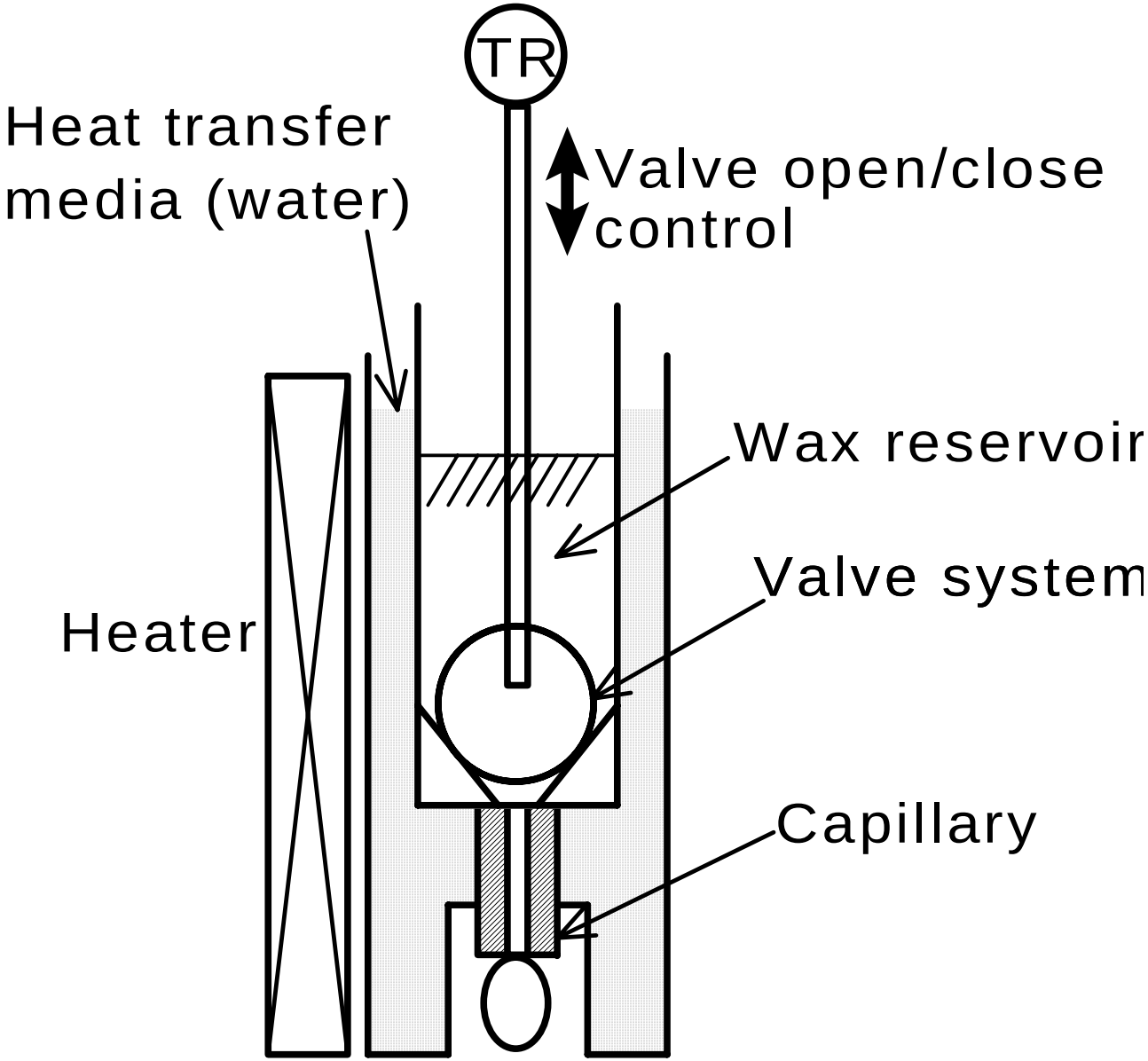
Apparatus

Wax feeder

1-hexadecanol (m.p.49℃, density 800kg/m^3)

Feed rate: 0.04g/s

Diameter of a droplet was about 5mm.



BFB Cold model

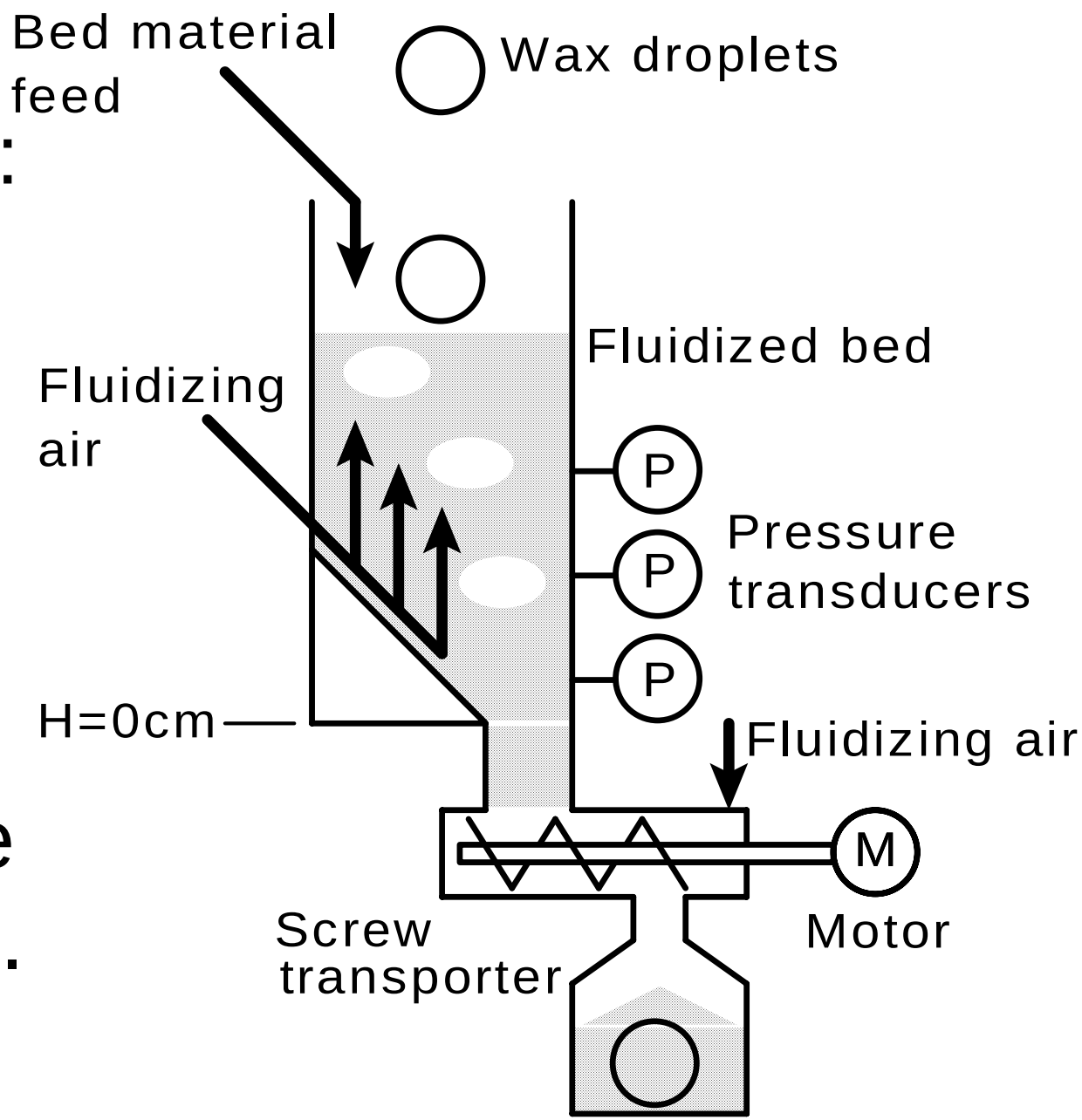
Cross sectional area: 10cm × 6cm

Height: 40cm

Feed of BM (light solid) from top.

Withdrawal of coarse material from bottom.

Gas vel.:12.5cm/s



Experimental procedures

Withdrawal from bottom: two different procedures

- Continuous withdrawal at a rate of 6g/min

- Intermittent withdrawal: 4 minutes wax feed followed by withdrawal at a rate of 24g/min without wax feed

Effect of withdrawal procedure on removal of bed material with coarse particles.

Results

Removal of BM with wax:

- Continuous withdrawal: 280g／100g-coarse
- Intermittent withdrawal: 80g ／100g-coarse

Bottom part worked as a classifier when operated under intermittent mode.

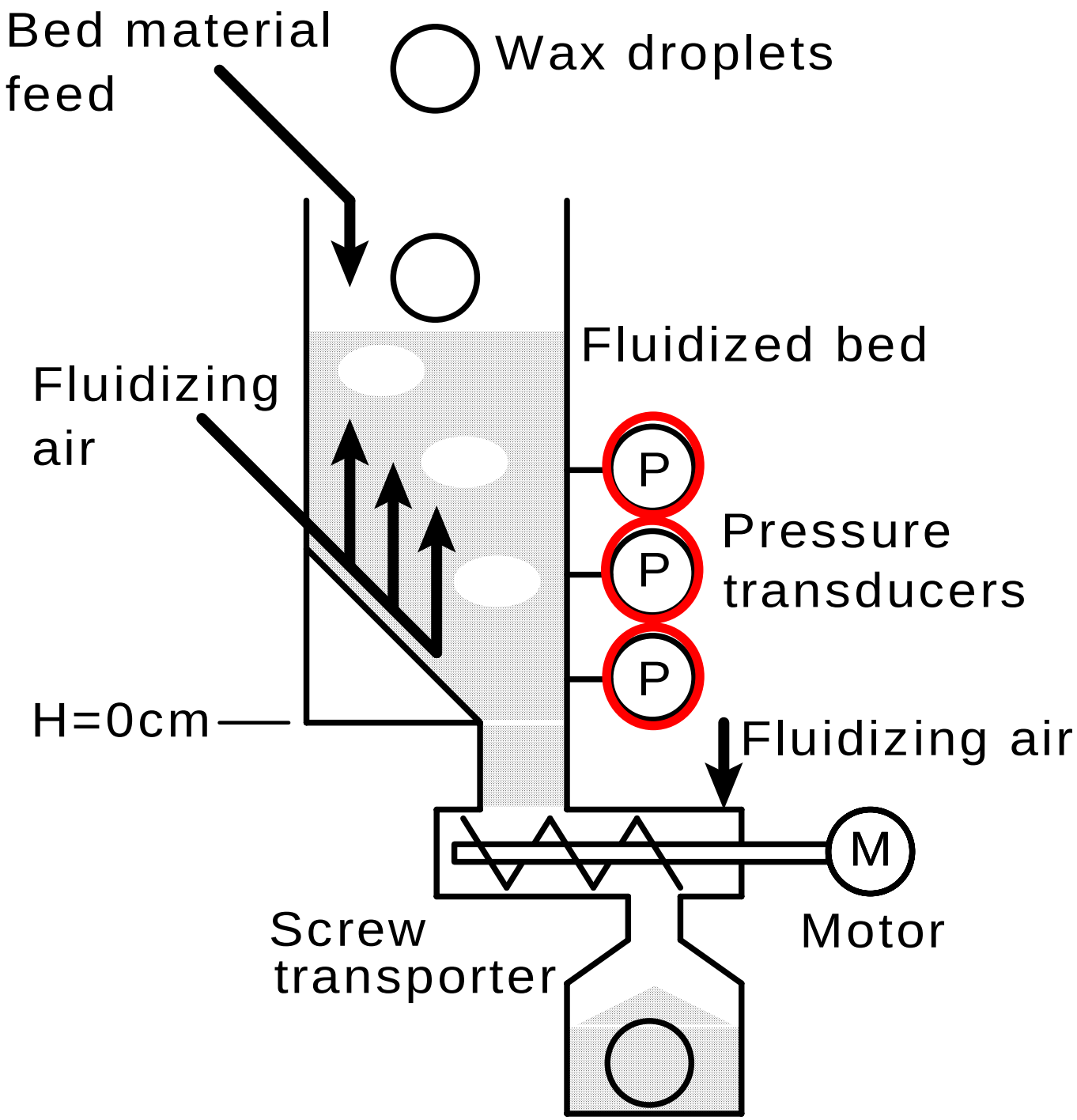
Excess accumulation in the bottom

→ Defluidization

→ Detection of solid accumulation in the bottom

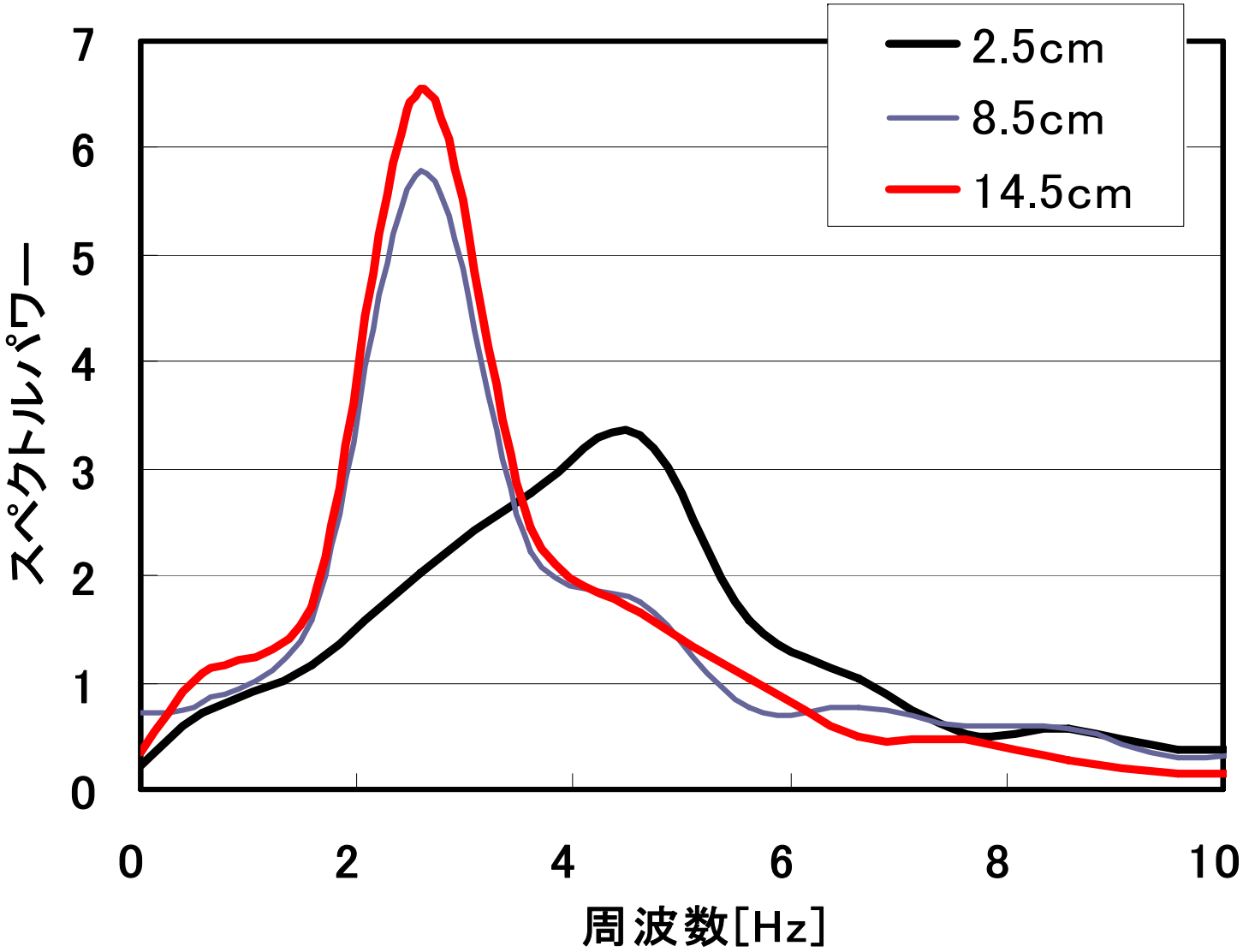
Experiments

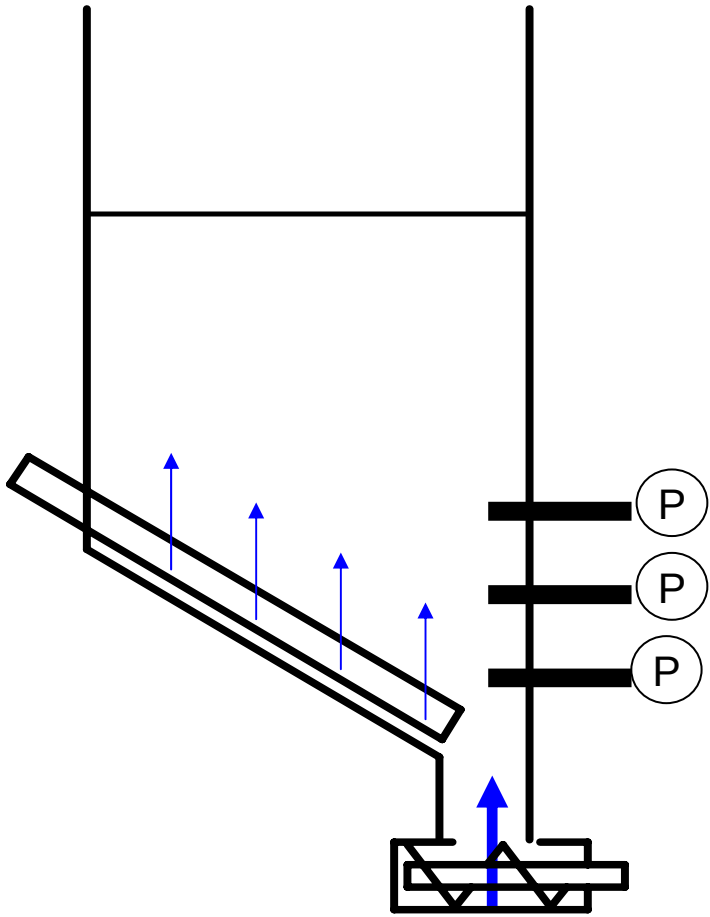
Measurement and analysis of pressure fluctuation in the bed with coarse solids accumulation in the bottom by Fourier transformation.



Without acclumuation

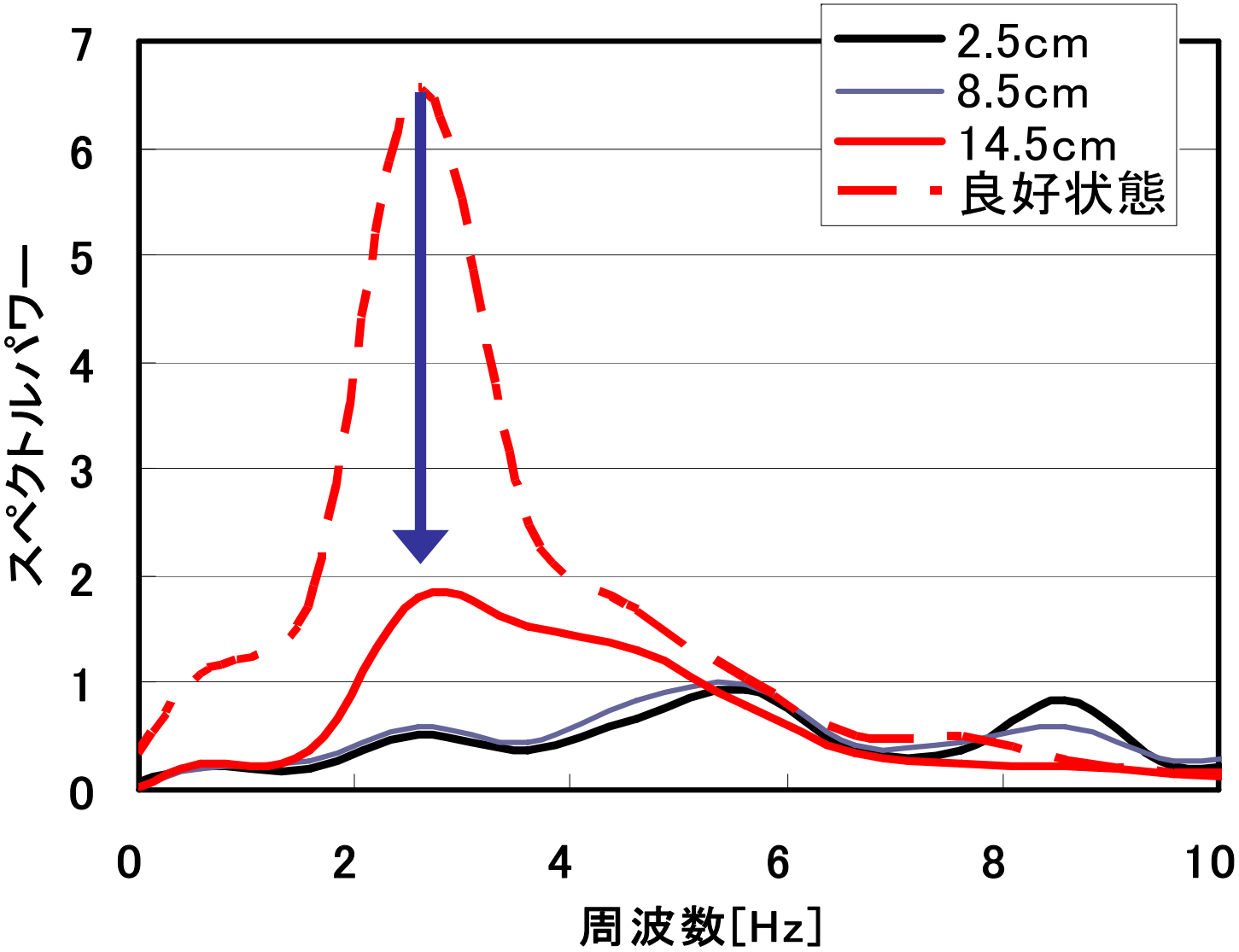
- Spectrum peak of 2~3Hz at height >8.5cm→Bubble

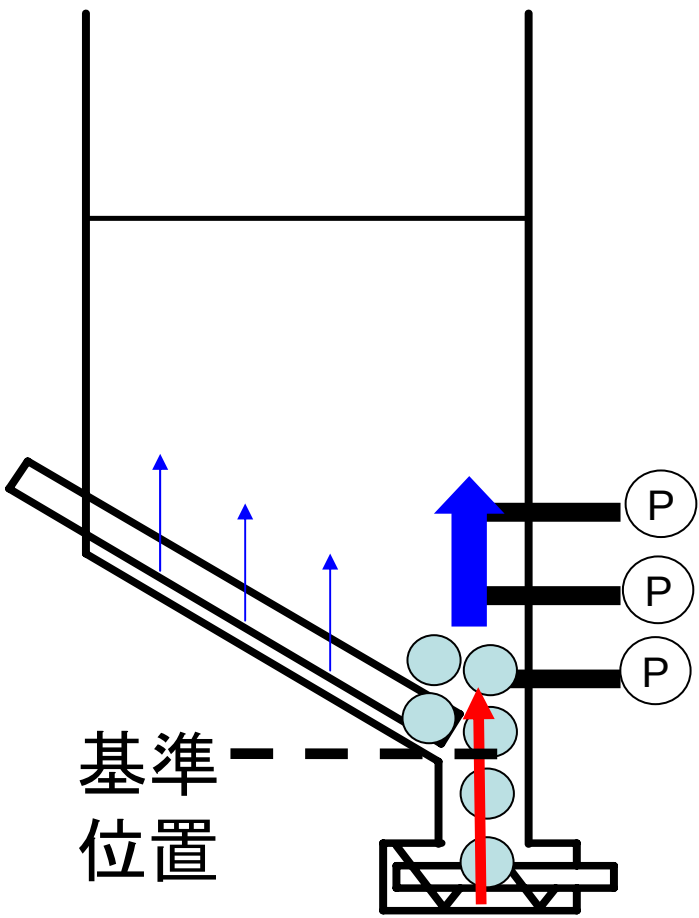




Accumulation of 50g

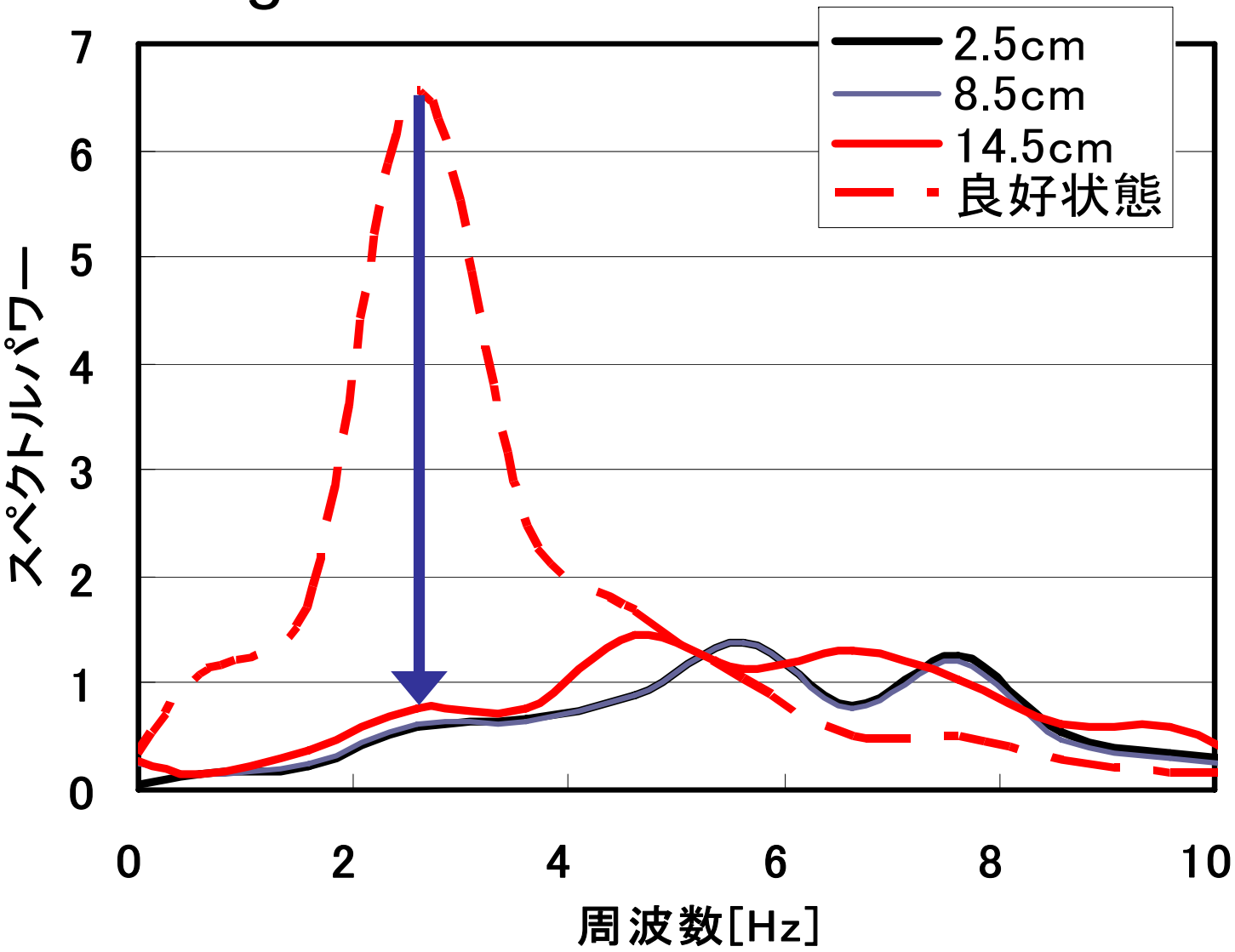
- Peaks decreased due to the change in the place of bubble formation.

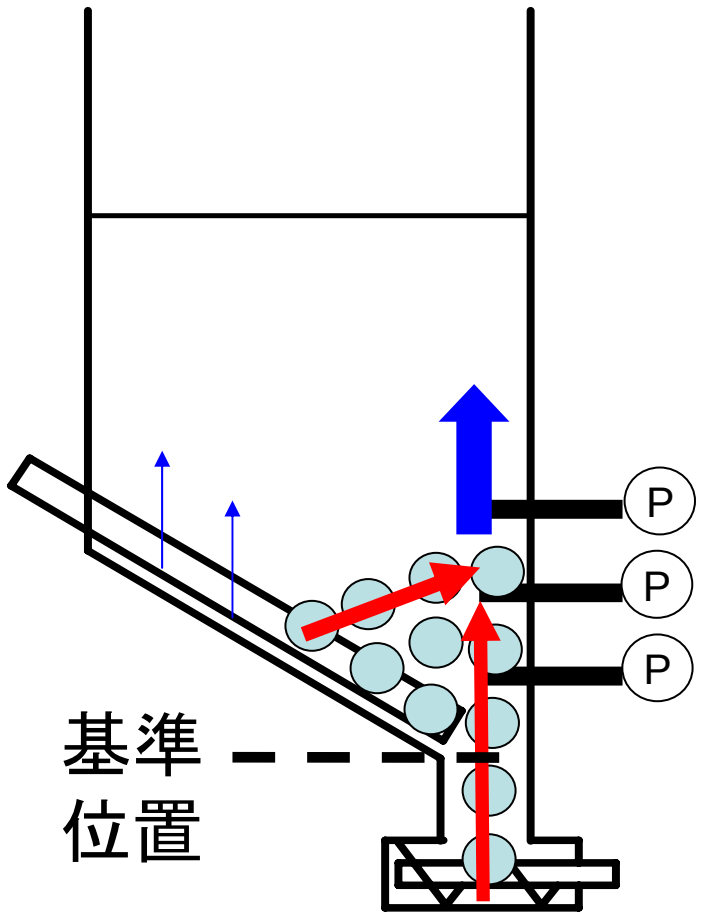




Accumulation of 100g

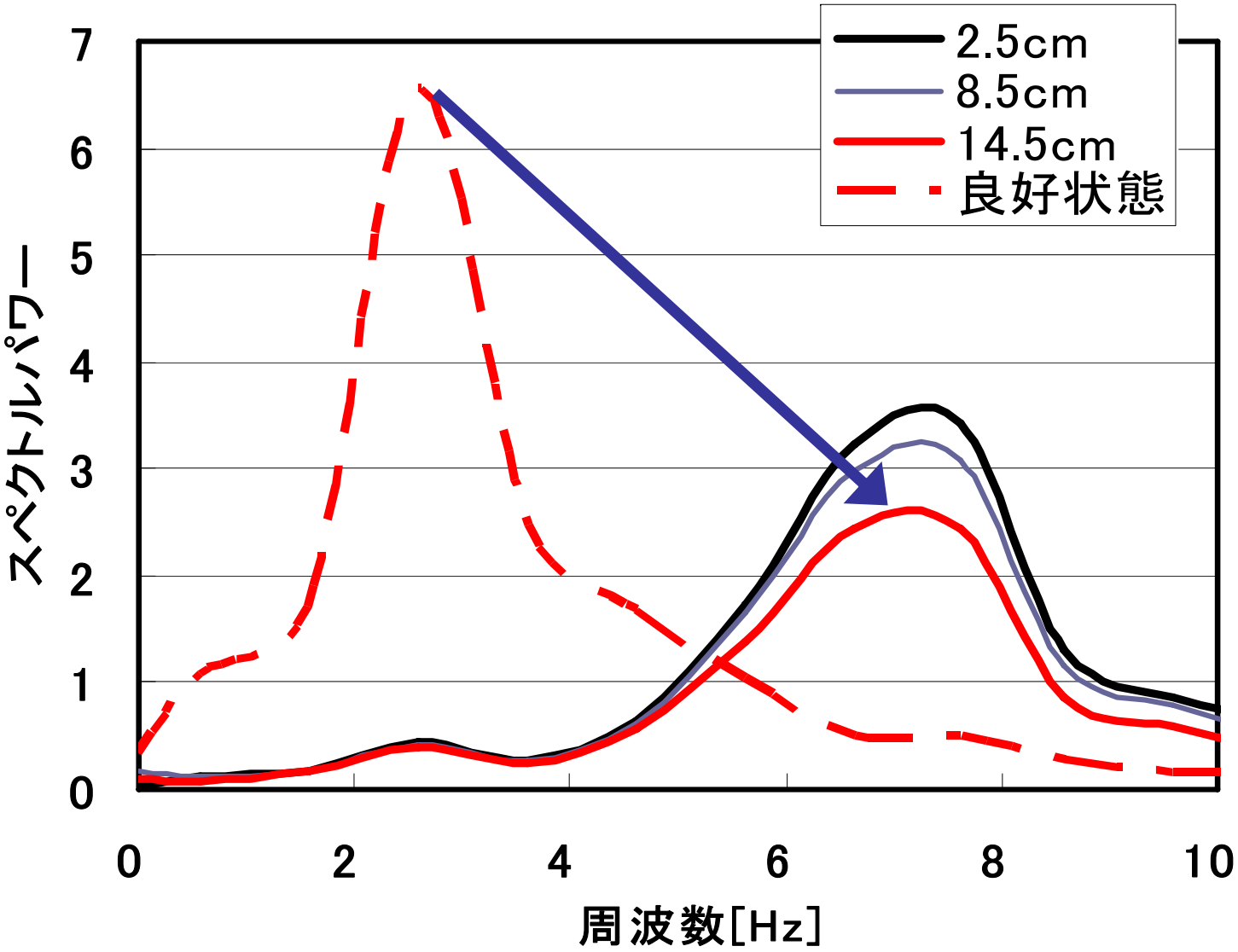
- Peak disappeared with the formation of channeling through accumulated coarse solids.

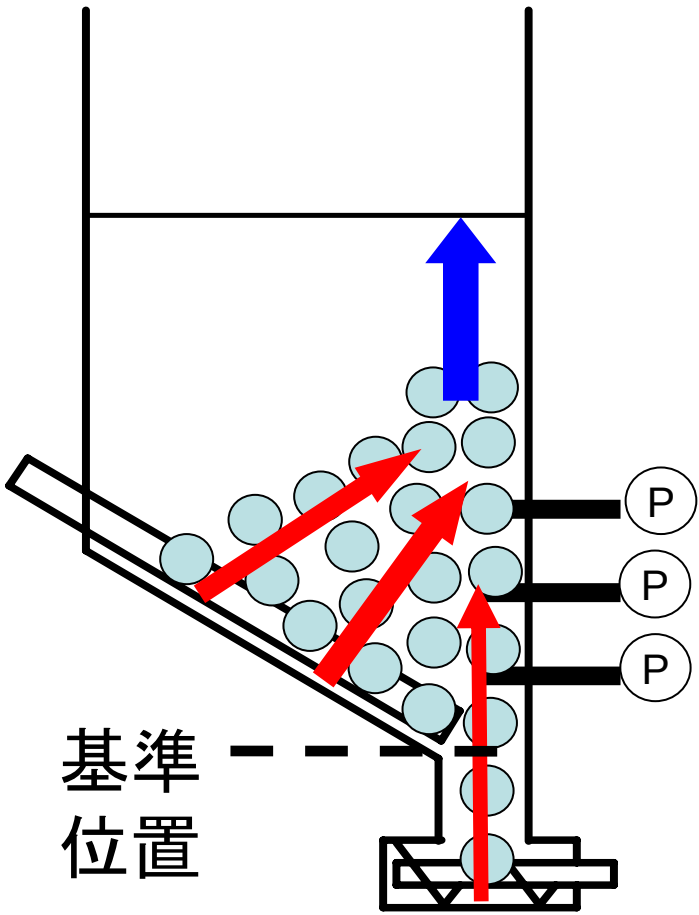




Accumulation of 150g

- Complete defluidization. Peak at 7Hz appeared.
  →Solid fluidization in fixed bed.





Summary

●If half of heat of blast-furnace slag is to be recovered in Japan, the heat will be equivalent to about 1 million tonnes of coal annually.

●The bed size to recover heat is estimated to be 6m×4.5m(cross sectional area) x 3 m height for 100t-slag/hour.

●Cold model experiments were carried out to remove solidified material from the bottom.

●Observation of frequency pressure fluctuation is considered to be an effective method to detect defluidization.

Acknowledgement

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