[illegible] 5

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] (1 εm [illegible] 10^{-3} εm) [illegible]

[illegible] van der Waals.

[illegible] **(coagulation).** [illegible] ůɡůůɤ ɛ ŬŰɤ ɛ ƳŰɤ ɜ ɛ ɘəɡəɑ ɜ. ɇ Ŭ ɛ ɘə ɟ Ƴ ɧɛ ɤ ɠ ůɡůůɤ ɛ ŬŰí ɛ ŬŰŬ (əɟ ɞəɑ̃Ůɠ) ´ ɞɡ ´ɟ ɞəɨ ´ Űɛɡɜ əŬŰƳ Űɖɜ əɟ ɞəɑ̃ɤ ůɖ ŭŮɜ ɏɕɞɡɜ Ŭəɧɛɖ ɘəŬɜɞ´ɞɘɖŰə ɏɠ ŭəŬůŰƳůŮɜɠ ɔəŬ Űí Ŭɡ Ůɐ Űɛɡɠ ɛ Ůə Ŭɖɑɖůɖ. ŭəŬ ɜ Ŭ Ŭ ɞəŰɐ ůɞɡɜ ɛ ŮəŬəɨ ŰŮɟ Ůɠ ŭəŬůŰƳůŮɜɠ ɡ´ ɞɓƳəəɜŰŰə ůŮɛ ɘ Ŭ ŭəŮɟ ɔŬůɖ Ŭɟ ɔɐ ɠ ŬɜƳŭŮɡůɖɠ ɩ ůŰŰɜ Ŭ Űɛɡɠ ŭɑŮŰŰə Ůɡə Ŭɟ ɖ Ŭ ɜ Ŭ ɏɟ ɕɞɜŰŰə ůŮŮ Űíɐ əŬə ɜ Ŭ əɞəəƳŮə əŬŰƳ əƳ ɞɜɜ Űɟ ɧ´ ɞ Űɛ ɏɜ Ŭ ´ Ƴɜɤ ůŰɛ Ƴəə. ȺƳɜ Űɛ Ů ɑ́ Ůíɞ ŬɜƳŭŮɡůɖɠ Ůɑ Ŭə ´ Ƴɜɤ Ŭ ɧ əƳ ɞəŬ Űɛɐ Űɧ ŰŰ Ŭɟ ɕɑɛŮə ɜ Ŭ Ůəŭɖə ɜ ŰŰə ŰƳůɖ ɔəŬ ŭəƳů ´ Ŭůɖ Űɤ ɜ ůɡůůɤ ɛ ŬŰɤ ɛ ƳŰɤ ɜ. ¢ ŭəŮɟ ɔŬůɖŬ Űɖɠ ɓɟ Űí ŮɖŬɠ ŬɜƳŭŮɡůɖɠ ´ ɞɡ Ŭəɞəɞɡɖ Ůɑ Űɖɜ ŭəŮɟ ɔŬůɖŬ Űɖɠ əɟ ɞəɑ̃ɤ ůɖɠ əŬə ɏɕŮə ůŬɜ Ŭ ɞŮɏəŮɛ Ŭ Űɖɜ ŭɖɛ ɘɡɟ ɔɖŬ **ɖɟ ɧɛ ɓɤ ɜ** (ůɡůůɤ ɛ ŬŰɤ ɛ ƳŰɤ ɜ ɘəŬɜɞ´ɞɘɖŰəɩ ɜ ŭəŬůŰƳůŬɤ ɜ ɔəŬ ´ Ůɟ Ŭ ɏɟ Ŭ əŬɖɑɖůɖ) ɞɜɞɛ ƳɛŮŰŰə **ɖɟ ɧɛ ɓɤ ůɖ** **(flocculation).**

ɸəŬəɡŰƳ ůɡůŰŰŰəƳ ůŰɛ ɜŮɟ ɧ ɧ´ ɤ ɠ´ .ɢ. Űɛ Ŭůɓɏůŭɛ əŬə Űɛ ɛ Ŭɜɐůɐ ŮɑŬə ŭɡɜŰŰɧɜ ɜ Ŭ ɛ ŮŰŰŮɟ Ŭ ɞɨ ɜ ůŮ Ŭɜɖɟ Ŭəɘɧ Ŭůɓɏůŭɛ əŬə ɡŭɟ ɞɜ-Ůŭɑɛ Űɛɡ ɛ Ŭɜɖůɑɡ ŮƳɜ ɔɑŮə əŬŰƳəəɖəɖ ´ɟ ɞůɖɐ əɖ ɡŭɟ ɞɜ-Ůŭɑɡ Űɛɡ ŬůɓŮůŰɑɡ. ɇ ɞ Ŭɜɖɟ Ŭəɘɧ Ŭůɓɏůŭɛ əŬə Űɛ ɡŭɟ ɞɜ-Ůŭɑɛ Űɛɡ ɛ Ŭɜɖůɑɡ ŮɑŬə ůɕŮŰəƳ ŭɡůŭəƳəɡŰŰɠ Ůɜɩ ůŮɠ əŬə ŮɑŬə ŭɡɜŰŰɧɜ ɜ Ŭ ´ɏůɞɡɜ (əŰŰŬə ɟ ɖɛ ɜəůɖɞɨ ɜ) ůŬɜ ɘɐɐ ɛ ŰŰŰ. ¢ **əŬŰŰə ɟ ɐ ɛ ɜəůɖ** ɧɛ ɤ ɠ ɖŬ ´ ɟ ɏ´ Ůə ɜ Ŭ ŮəɏɔɕŮŰŰə ɏŰůə ɩ ůŰŮ ɜ Ŭ ɞŭɖɔŮɑ ůŮ ɘəŬɜɞ´ɞɘɖŰəɐ ɛ ŮŰŰíɞɟ Ƴ Űɤ ɜ ŭɡůŭəƳəɡŰɤ ɜ ɞɡůəɩ ɜ ůŰɛ ɑɖɛ Ŭ (ůŰɛɜ ´ ɡɖɛ ɏɜ Ŭ ´ .ɢ. ɛ ɘŬɠ ŭŮəŬɛ Ůɜɐ ɠ əŬɖɑɖůɖɠ) əŬə ůŰɖɜ ´ Ŭɟ Ŭɛ ɞɜɐ Űɖɠ ŮəƳɕəůŰɖɠ ŭɡɜŰŰɧɜ ɖɞəɧŰɖŰŰɠ ůŰɛ ɡ´ Ůɟ əŮɛ Ŭɜɞ ɡɔɟ ɧ. ŌŰŮə ɑ̃ɤ ɠ ɢɟ ŮəŬůɖŮɑ ɜ Ŭ Ůɛ´ əŬəɞɨ ɜ ŭəŮɟ ɔŬůɖŮɠ Űí ´ ɞɡ ɖɟ ɧɛ ɓɤ ůɖɠ ɐ Ŭəɧɛɖ ɑ̃ɤ ɠ əŬə ɜ Ŭ ´ ɟ ɞɖɔɖɖɞɨ ɜ ŭəŮɟ ɔŬůɖŮɠ əɟ ɞəɑ̃ɤ ůɖɠ ɩ ůŰŮ ɜ Ŭ Ů əŰŮɡɕɖŮɑ Ŭ ɞŰŮəŮɛ ŬŰŰəɐ Űí Ŭɡ Ůɖɖ ůɡůŰŰŰəɩ ɜ ɛ ŮŰƳ Ŭ ɧ ɕɖɛ ɘɐ əŬŰŰə ɟ ɐ ɛ ɜəůɖ.

Ƀ ɧɟ ɞɠ **ɘɕɖɛ ŬŰɛ´ ɞɑɖůɖ** ŭŮɜ ŬɜŬŭɏɟ ŰŰŰə Ŭ ɞəəŮůŰəƳ ůŰɛɜ ůɕɖɛ ŬŰŬůɛ ɧ ɘɕɖɛ ƳŰɤ ɜ ɛ ŰŮƳ Ŭ ɧ ɕɖɛ ɘɐ əŬŰŰə ɟ ɐ ɛ ɜəůɖ Ŭəə Ƴ ŬɜŬŭɏɟ ŰŰŰə Ů ɑůɖɠ əŬə ůŰɛɜ ůɕɖɛ ŬŰŬůɛ ɧ ɘɕɖɛ ƳŰɤ ɜ əŬŰƳ Űɖɜ ŬɜŰŭɟ ŬůɖəŬɟ ɞəəŬɤ Űəɩ ɜ (ůɡɜɐɖɤ ɠ ŬəƳŰɤ ɜ Űɛɡ Ŭɟ ɔəɑɡ əŬə ůəɐɟ ɞɡ) ɛ ŮŰɖɜ Ŭəə ŬəɘɧŰɖŰŰ Űɛɡ ɡɡůɘɞɨ ɜŮɟ ɞɨ.

5.1 Ƭ ɡɟ əɧŰŮɟ Ŭ ɢŬɟ Ŭə Űɖɟ əůŰəƳ Űɤ ɜ əɞəəɞŮəŭɩ ɜ ůɤ ɛ ŬŰŭɑɤ ɜ

ɇ Ŭ əɡɟ əɧŰŮɟ Ŭ ɛɖ ŭəŬəɡŰƳ ůŰŮɟ ŮƳ ´ ɞɡ Ŭ ŬɜŰ ɜŰŰə ůŮűɡůəƳ ɡŭŬŰəƳ Ŭ ɞɖɏɛ ŬŰŰ ŮɑŬə ŰŮ ɛ Ŭɕɑ̃əŬ Ƴɛ ɛ ɞɡ, ŰŮ ɛ Ŭɕɑ̃əŬ ŮíŬíɘɞɨ ɡəɘɞɨ, ŰŮ ɛ Ŭɕɑ̃əŬ ŭəŬíɧɟ ɤ ɜ ɢɟ ɔŬɜɘɩ ɜ ɡəɘɩ ɜ, əŬɖɩ ɠ əŬə ɓŬəŰɐ ɟ əŬ, ɘɑ əŬə Ƴəəɞ Ŭɤ ɟ ɞɨ ɛ Ŭɜɞ ɐ əɞəəɞŮŭɏɠ ɡəɘɧ. ɇ ɡ´ ɘɏɠ ŭəŬůŰƳůŮɜɠ ɔəŬ ŰŰ ŭəƳíɞɟ Ŭ ůɤ ɛ ŬŰŭɑəŬ ´ ɞɡ Ŭ ŬɜŰ ɜŰŰə ůŮűɡůəƳ ɡŭŬŰəƳ Ŭ ɞɖɏɛ ŬŰŰ ŭɑɞɜŰŰə ůŰɛ Ƀ ɑŬə Ŭ 5.1.

[illegible] 5.1 [illegible]

[illegible]	[illegible] (ε m)
[illegible]	0,005-0,01
[illegible]	0,3-3,0
[illegible]	0,001-0,1
[illegible]	0,1-1
[illegible]	1-100
[illegible]	500
[illegible]	100-2000

[illegible] 1 ε m [illegible] 1 ε m (10^{-3} mm) [illegible] 0.001 ε m (10^{-6} mm = 1 nm). [illegible] **van der Walls** [illegible] **Brown**.

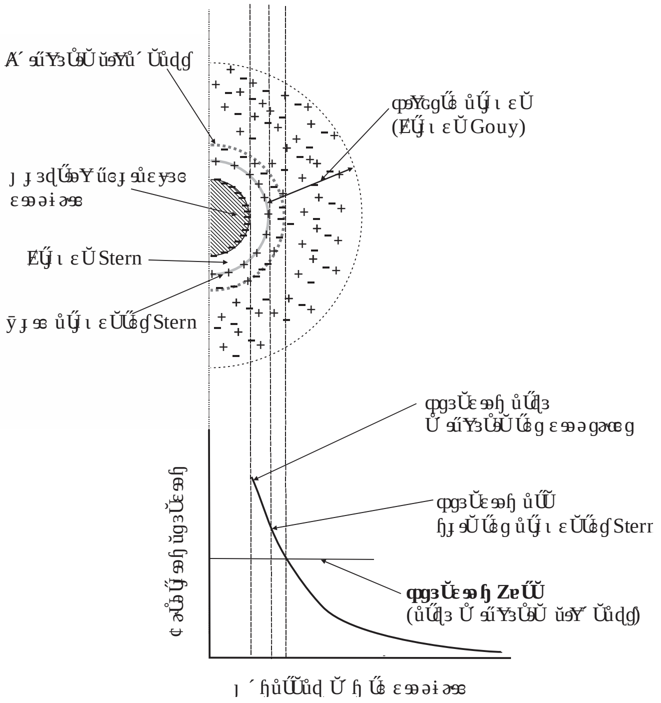
[illegible]

əɞə´ɧɜ ɛŮŰŸŰɗɜ Ŭəəɗəŭɞɡŭ ŮŰɟɣůɗ Űɣɜ ɛəəɡəɑɜ ŬɜŰɗɣŰɞɡ ŰɞɟŰɞɡ ŮəŬəɞəɞɡɗɞɨɜ ɜŬ´ŮɟŬɛɣɜɞɡɜ ůŰɞ əɞəəɞŮŭɣɡ ůɨůŰɗɛŬ ɛəəɨəŬ´ɞɡ ŮɞŬə ŰɞɟŰůɛɣɜŬɛŮŮəŮɞɞ Űɞ ŰɞɟŰɞ ´ɞɡ ɓɟɑəŮŰŰə ůŮ´ŮɟɑůŮəŬ. ɇŬ ɛəəɨəŬ ŬɡŰŸ ŮɞŬə ɞɞɩ ɜɡɛɞɡ ŰɞɟŰɞɡ əŬə Ŭɣɗɞɨɜ Űŭə ɛŮŰŰɜɨ Űɞɡɠ əŬə ɣŰə Űɞ əɞəəɞŮŭɣɠ ůɨůŰɗɛŬ ŮɛŰŬɞŰŰə ůŰŰɗŮɟɧ.

Ɇɗɛ Ůə ɜŮŰŰə ɧŬə ůŰɗɜ ´Ůɟɑ Űɣůɗ Űɣɜ əɞəəɞŮŭɩ ɜ ůɡůŰɗɛŸŰɣɜ ´ɞɡ ŬɜŰůŰɞɞɨɜ ůŮ ŰɡůəŸ ɡŭŰŰəŸ Ŭ ɞɗɣɛŬŬŬ ɣɞŮ ´ŮɟŬŰɗɟɗɗŮɑ ɧŬə ŰŰ ɛəəɨəŬ ŮɞŬə ´ŸɜŰŰ Ůɟɜɗŭəɣ ŰɞɟŰůɛɣɜŬ.

¢ Ůɟɜɗŭəɣ ŰɞɟŰůɛɣɜɗ ŮɛíŸɜŮəŬ Űɞɡ əɞəəɞŮŭɞɨɠ ůɣɛŬŭŭɞɡ ɣəəŮ ŬɜŰəɧɜŰŰ (ɗŮŰəŸ ɛɧɜŰŰ) əŬə ůɞɗɛŬŰɞŰŰə ɣɜŬ ůŰɩ ɛŬ Ŭ ɧ ɗŬŰəŸ ɛɧɜŰŰ ´ɞɡ ŮɞŬə ɔɜɣůŰɧ ɣɠ **ůŰɩ ɛŬ Stern**. ɆŰŰ ɡŭɟɧŰəŬ əɞəəɞŮŭɐ əŬə Ŭ ɧ Űɗɜ ´ŮəɞɐŰɞɡ ůŰɩ ɛŬŰɞɠ Stern ɣəəɞɜŰŰə Ůɑɗɠ əŬə ɛɧɟəŬ ɜŮɞɨ əɧɔɣ Űɗɠ Űůɨɛɛŭɟɗɠ əŬŰŰɜɞɛɐɠ Űɣɜ ɗəŮŰɟəɩɜ ŰɞɟŰɑɣɜ ůŰɞ ɛɧɟə Űɞɡ ɜŮɞɨ. ŌɜŬ ŭŮŰɟɞ ůŰɩ ɛŬ Ŭ ɧ ɛɧɜŰŰ ´ɞɡ ŮɞŬə ɔɜɣůŰɧ ɣɠ **ŭəŸɞɡŰɞ ůŰɩ ɛŬ** ´Ůɛ͵ŸəəŮ Ůɑɗɠ Űɞ əɞəəɞŮŭɣɠ ůɣɛŬŰŭə. ɇɞ ŭəŸɞɡŰɞ ůŰɩ ɛŬ ɗŰɣɟŮŰŰŰəɧŮŬ ɞŰŰəŮŰŰəŬ ɧ ɣɜŬ ŮɣŰŰɟəɧ ɛɣɟɞɠəŬɜɣŬɗɞɠ´ɞɞɣɞɜ ɧɟə Űɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ (ɆɞɐɛŬ 5.1). ɀ ɣɞɟə Űɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ ŰŰ ɛɧɟəŬ Űɞɡ ɜŮɞɨ ´ɞɡ ɡŰɑŰŰɜŰŰə Űɞɠ Ů ɛŭɟŸůŮɠ Űɞɡ ɗəŮŰɟəɞɨ ´ŮɑɞɡɞŬ Űɞɡ əɞəəɞŮŭɞɨɠ ůɣɛŬŰɞɡɞɡ ůɡɛ´ŮɟŰɨɟəɞŰŰə əŬə Ŭəɞəəɞɡɗɞɨɜ Űɗɜ ´ɞɟŮŬ Űɞɡ ůɣɛŬŰɞɡɞɡ Ůɜɩ ŰŰ ɛɧɟəŬ Űɞɡ ɜŮɞɨ ´ɞɡ ɓɟɑəŮəɞŰŰə ´ɣɟŬ Ŭ ɧ Űɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ ŮɞŬ ŮɗŮɣůŰɩ ŮɡɜŭŬŭŮɜɣŬ ɛŮ Űɞ əɞəəɞŮŭɣɠ ůɣɛŬŰɞɡɞ əŬə ŭŮɞ ŮɞŬ ŭɡɜŬŰɧɜ Ŭɜ ɡɡɛ´ŮɟŬɡɗɞɨɜ Ŭ ɧ Űɡɟɧ əŬɗɑ ɠəɞŮŰŰŰɞ. To ɗəŮŰɟəɞɧ ŭɡɜŬŰɞɧ ɡɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ ɞɜɞɛŸɞŰŰə əŬə **ŭɡɜŬŰɞɧ Ȼɐ ŰŰ**. ɆŰɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ ɡ´ŸɟɣŮə ɣɜŬ əŬɗŬɧ Ůɟɜɗŭəɧ ŰɞɟŰɞ ůɞɞ ɞ´ɞɐ ŬɜŰůŰɞɞɗŮɞ ɗəŮŰɟəɞɧ ŭɡɜŬŰɞɧ ůɡɗɜ Ů ɛíŸɜŮɜ Ŭɡɐ. Ɐ´ŮŬɐ ŰŰ ŮəɜŰɞɟəŸ ɧɟəŬ Űɞɡ əɞəəɞŮŭɞɨɠ ůɣɛŬŰɞɡɞɡ (əŬŰɠ ɠəɞŮŰŰə) ŮɞŬə ůŰɗɜ Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ Űɞ ŰɞɟŰɞ Űɗɠ Ů ɛíŸɜŮɜɠ ŭəŸŮ´Űůɗɠ əŬə Űɞ ŬɜŰŬəŰɞɞŮɞɞ ŭɡɜŬŰɞɧ ŮɞŬ ŮɞŮŬ ŰŰ ɛŬɣɗɗ ´ɞɡ Ů ɗɟŮŸɞɞɡɜ Űɗɜ ɗəŮŰɟəɞɞəɜŮɐ ůɡɛ´ŮɟɛíɞɟŸ Űɞɡ ůɣɛŬŰɞɡɞ. ɇŬ ŭəɞ ůŰɩ ɛŬŰŰ ´ɞɡ ´ŮəɞŸəəɞɡɜ Űɞ əɞəəɞŮŭɣɠ (ůŰɩ ɛŬ Stern əŬə ŭəŸɞɡŰɞ ůŰɩ ɛŬ) ɞɜɞɛŸɞɜŰŰə ůɡɞɜŸ **ŭə´ əɧ ůŰɩ ɛŬ**. H Ů ɛíŸɜŮɜ ŭəŸŮ´Űůɗɠ ɓɟɑəŮŰŰə ŬɜŰɧɠ Űɞɡ ŭəŸɞɡŰɞɡ ůŰɩ ɛŬŰɞɠ əŬə Űɞəŭŭɞ ŬŰɜɗŭɣɠ Űɗɜ Űɞ´ɞɗŰɞɡɜ ůŰɗɜ Ůɟɐ Űɞɡ ŭəŸɞɡŰɞɡ ůŰɩ ɛŬŰɞɠ ɐ ůŰŰ ŬɜɣŰɟəŸ ɧɟəŬ Űɞɡ ůŰŰɗŮɟŸ ´ɟɞůŭŰəɞɛɣɜɞɡ ůŰɩ ɛŬŰɞɠ ŬɜŰəɧɜɣɜ (ůŰɩ ɛŬ Stern)

ŌɜŬ ŰɞɟŰůɛɣɜɞ ůɣɛŬŰɞɡ ɛ´ɞɟɞəɜ əɞɗɗŬɛɣůŬ ůŬɣɜ ɗəŮŰɟəɞɧ ´ŮŬɐ ´ɞɡ ŭɗɛɡɣɔŮɞəŰŰə ɛŮŰŰɜɨ ŭɨɞ ɗəŮŰɟəɞŭəɑɜ ůŰŰɞ´ɞŮŬ Ů ɛíŸəəŰŰə ɛɜ ŭəŰŭɞɟŸ ŭɡɜŬŰɛəɞɨ. ɇɞ ɔŬɞɜɧɠ Ŭɡɧɗ ɡɟɗůɛɞ´ɞəɑəŰŰə ɔəŰ Űɗ ɛŮəɣŰɗ ŭəŰɧɟɣɜ ɞŭɟŬəɗɟəůŬəŬɜ ŰɞɟŰůɛɣɜɛɜ ůɣɛŬŰɞɑɜ ɛŬŰɗ ɛɣɗɞŭɞ Űɗɠ **ɗəŮŰɟəɞɧ ɡŬɞɟɧɗɛɗɠ** ¢ əɛɗŭəɧŰɗŰŰ Űɞɡ

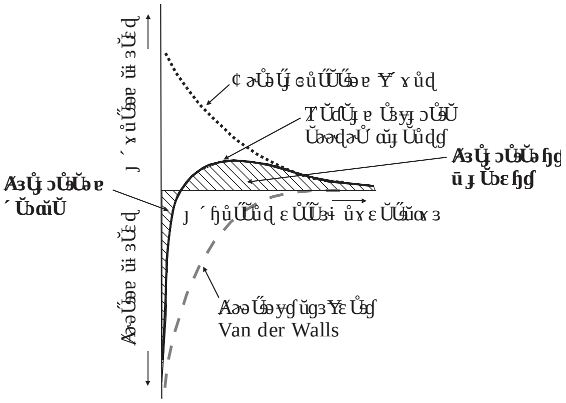

Ⱥ´ ɘűƳɜŮǝŬ ŭɘƳů´ Ŭůɖɠ
ɕɒƳɢɡŰǝ ůŰɟ ı ɛŬ
(ƎŰɟ ı ɛŬ Gouy)
ɟ ɟ ɜɖŰǝƳ űɕɟ ɘůɛ ɏɜɕ
ɛ ɘǝ ǝ ɨ ǝɜ
ƎŰɟ ı ɛŬ Stern
ȳ ɟ ɜ ůŰɟ ı ɛŬŰǝɠ Stern
ɕɒɡɜŬɛ ɘǝ ɧ ůŰɖɜ
Ů ɘűƳɜŮǝŬ Űǝɡ ɛɘǝ ǝ ɡǝɕ ɡ
ɕɒɡɜŬɛ ɘǝ ɧ ůŰŰ
ɧɟ ɘŬ Űǝɡ ůŰɟ ı ɛŬŰǝɠ Stern
ɕɒɡɜŬɛ ɘǝ ɧ ZɐŰŬ
(ůŰɖɜ Ů ɘűƳɜŮǝŬ ŭɘƳ´ Ŭůɖɠ)
¢ ǝŮǝ Űɟ ɘǝ ɧ ŭɡɜŬɛ ɘǝ ɧ
ɪ ´ ɧůŰŰůɖ Ŭ ɧ Űǝ ɛɘǝ ǝ ɨ ǝɜ

ƎɕɐɛŬ 5.1: ɕɒŬɓɟŬɛ ɛŬŰǝɐ ´ ŬɟƳůŰŰůɖ ǝɕǝǝɕŮǝŭɕɨ ɠ ůɤ ɛŬŰǝŭɑɕɡ ǝŬǝ Űǝɡ ŭɘ´ ǝɕɨ ůŰɟ ı ɛŬŰǝɠ (´ Ƴɜɤ : Ŭɟ ɜɖŰǝɧ ɛɘǝ ǝ ɨ ǝɜ ǝŬǝ ɖǝŮǝ Űɟ ɘǝ ɧ Űǝɡ ´ Ůŭɑɜ, ǝƳŰɤ : ɛ ŰŰɓɕǝɐ Űǝɡ ɖǝŮǝ Űɟ ɘɕɨ ŭɡɜŬɛ ɘɕɨ)

ůɤ ɛŬŰǝŭɑɕɡ ůɕŰǝŰŰǝ ɛŮŰɖ ŭɘɖǝŮǝ Űɟ ɘɐ ůŰŰɖŮɟ Ƴ ǝŬǝ Űǝ ɘɪ ŭŮɟ Űɖɠ ɡŭŬŰǝɐɠ űƳůɖɠ ǝŬɖı ɠ ǝŬǝ ɛŮ Űǝ ɖǝŮǝ Űɟ ɘǝ ɧ ŭɡɜŬɛ ɘǝ ɧ ůŰɖ ŭɘŮ ɘűƳɜŮǝŬ ɛŮŰŰǝɨ Űǝɡ ǝɜɕɡɛɏɜɕɡ ůɤ ɛŬŰǝŭɑɕɡ ǝŬǝ Űǝɡ ɡɔɟɕɨ (ɖ ŭɘŮ ɘűƳɜŮǝŬ Ŭɡűǝ ůŰɖɜ ´ Ůɟ ɑ Űɤ ůɖ Űɤ ɜ ǝɕǝǝɕŮǝŭı ɜ ůɤ ɛŬŰǝŭɑɤ ɜ ŮɞŬǝɖ Ů ɘűƳɜŮǝŬ ŭɘƳů´ Ŭůɖɠ ǝŬǝ Űǝ ŭɡɜŬɛ ɘǝ ɧ ŮɞŬǝ Űǝ ŭɡɜŬɛ ɘǝ ɧ ɕɐ ŰŬ).

¢ ɖŮɤ ɟ ɖŬ DLVO (űɏɟ Ůǝ ŰŰ Ŭɟ ɕɘǝ Ƴ Űɤ ɜ Ůɟ Ůɡɜ ɖŰ ɜ ´ ɕɡ Űɖɜ ´ ɟ ɧ ŰŰǝŮɞŬɜ Derjaguin, Landau, Verwey ǝŬǝ Overbeek) ŭɑŮǝ Űɖɜ ǝǝŬůůɘɐ Ůǝɐ ɔɖůɖ ɔǝŬ Űɖɜ ůŰŰɖŮɟ ɧŰɖŰŰ Űɤ ɜ ǝɕǝǝɕŮǝŭı ɜ ŬǝɤɟɖɛƳŰɤ ɜ. Ǝɨ ɛűɤ ɜŬ ɛŮ Űɖɜ ɖŮɤ ɟ ɖŬ Ŭɡűǝ ɛŮŰŰǝɨ Űɤ ɜ ǝɕǝǝɕŮǝŭı ɜ ůɤ ɛŬŰǝŭɑ ɜ Ŭůǝɕɨ ɜŰŰǝ ŭɨ ɕ ŬɞŰɖŮŰŰůɠ ŭɡɜƳɛŮǝɠ. Ƀǝ ŭɡɜƳɛŮǝɠ Ŭɡűɏɠ ŬɞŬíɏɟ ɕɜŰŰǝ ůŰɖɜ ɖǝŮǝ Űɟ ɕůŰŰŰǝɐ Ƴ ɤ ůɖ ǝŬǝ ůŰɖɜ ɏǝɜɖ ´ ɕɡ ɕűŮǝŰŰŰǝ ůŰǝɠ ŭɘŬɛɕɟ ɘŬǝɏɠ ŭɡɜƳɛŮǝɠ van der Walls. ¢ Ůǝǝ Űǝɐ ŭɨ ɜŬɛɖ ɛŮŰŰǝɨ ŭɨ ɕ ǝɕǝǝɕŮǝŭı ɜ ůɤ ɛŬŰǝŭɑ ɜ ´ ɕɡ ɕűŮǝŰŰŰǝ ůŰǝɠ ŭɘŬɛɕɟ ɘŬǝɏɠ ŭɡɜƳɛŮǝɠ van der Walls ŮɞŬǝ ůŰɖɜ ɕɡůɖŬ ɖ ůɡɜɘůŰŰɛɏɜɖ Űɤ ɜ Ůǝǝ Űǝı ɜ ŭɡɜƳɛŬɤ ɜ ´ ɕɡ Ŭůǝɕɨ ɜŰŰǝ ɛŮŰŰǝɨ Űɤ ɜ ɛɕɟ ɑ ɜ Űɤ ɜ ŭɨ ɕ ůɤ ɛŬŰǝŭɑ ɜ. ŌɜŬ ŭɘƳɔɟ Ŭɛ Ŭ´ ɕɡ ŭŮɕɜŮǝ Űǝɠ Ůǝǝ Űǝɏɠ ŭɡɜƳɛŮǝɠ ǝŬǝ Űǝɠ Ŭ ɤ ůŰǝɏɠ ŭɡɜƳɛŮǝɠ ´ ɕɡ Ŭůǝɕɨ ɜŰŰǝ ɛŮŰŰǝɨ ŭɨ ɕ ǝɕǝǝɕŮǝŭı ɜ ůɤ ɛŬŰǝŭɑ ɜ ůŮ ůɡɜƳɟ Űɖůɖ ɛŮ Űɖɜ Ŭ ɧůŰŰůɖ ɛŮŰŰǝɨ Űɤ ɜ ůɤ ɛŬŰǝŭɑ ɜ ŬɡŰı ɜ űŬŮɞŰŰǝ ůŰǝ ƎɕɐɛŬ 5.2. ɇɕ ɨ ɣɕɠ Űǝɡ ŮɞŮɟ ɔŮǝŬǝɕɨ űɟ Ŭǝɛɕɨ ŭŮɕɜŮǝ ´ ɧůɕ ůŰŰɖŮɟ ɧ ŮɞŬǝ ɏɜŬ ǝɕǝǝɕŮǝŭɏɠ ůɨ ůŰɖɛŬ. ŭɘŬ ɜŬ ɔɑŮǝ ůɡůůɤ ɛƳŰɤ ůɖ ǝɕǝǝɕŮǝŭı ɜ ůɤ ɛŬŰǝŭɑ ɜ ɖŬ ´ ɟ ɏ´ Ůǝ ɜŬ ɏɕɕɡɜ ɘŬɜɕ´ ɕɑɖŰǝɐ ǝɘɖŰǝɐ Ůɜɏɟ ɔŮǝŬ (ŮǝŬɟ ŰƳŰŰǝ Ŭ ɧ Űɖɜ

[illegible]) [illegible]. [illegible] .G. [illegible] pH [illegible].



[illegible]5.2: [illegible]

[illegible] Brown [illegible] Brown. [illegible] Van der Walls [illegible]. [illegible] Brown [illegible].

[illegible].

5.2 [illegible]

[illegible] ([illegible]) [illegible]

[illegible]

[illegible] p(OH)q [illegible] pH [illegible]

[illegible] (1) [illegible], (2) [illegible], (3) [illegible], (4) [illegible] (5) [illegible].

[illegible] 5.1 [illegible] Van der Waals [illegible]

[illegible] 5.2 [illegible] $AlCl_3$ [illegible]

[illegible] 3:1, [illegible] $Al_2(SO_4)_3$ [illegible] 3:2.

[illegible] 5.2 [illegible]

[illegible]	[illegible]
$NaCl$	1
Na_2SO_4	1
Na_3PO_4	1
$BaCl_2$	33
$MgSO_4$	30
$AlCl_3$	1000
$Al_2(SO_4)_3$	>1000
$FeCl_3$	1000
$Fe_2(SO_4)_3$	>1000

[illegible] [illegible] Van der Waals.

[illegible] [illegible]

[illegible] [illegible]

[illegible] [illegible]

5.3 [illegible]

[illegible]

[illegible]

[illegible]

[illegible].

5.4 [illegible]

[illegible].

[illegible] jar tests ([illegible]) [illegible].

5.4.1 [illegible]

[illegible].

[illegible]:

$$\text{[illegible]} = G = \frac{dv}{dy} \qquad \mathbf{5.1}$$

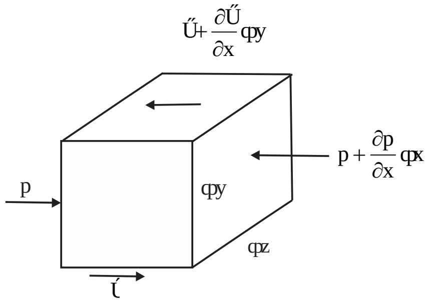
[illegible]: dv [illegible] dy [illegible] ([illegible])$^{-1}$.

Ʈɟ ɢǝ ɑǚɣ ủɗ, Ʈ ǙǗǛǝɟ ɐ ɛ ɜɘủɗ, Ƚɕɗɛ ǙǗǚ´ ɢɑɭủɗ, Ūɟ ɧɛ ɓɣ ủɗ, Ʈ Ǚí ƳǝǛɞ 5

¢ ǝɚɑủɗ ǗǛɢɨ Ǘɗ ǗǛɠ ǚɞǛǝ ɛ ɘǛ ủɗɛ ǛɜǗɘɐ ´ Ǜɟ Ƴɛ Ǚǰ ɢɠ ɔɘǛ Ǘɞ ủɢǙɨɘǛủɛ ɧ ủgủǗɗɛ ƳǗɣ ɜ ǛɜƳũǙgủɗɠ ǝǛɘ ủɢǗǗɕǗǗǛɘ ɛ Ů Ǘɗɜ ɘủɢɨ ´ ɢg ǙɞǛɘ Ǜ Ǜɟ ǛɑǗɗǗɗ ɔɘǛ Ǘɗɜ ǛɜƳũǙgủɗ ǛɜƳ ɛ ɢɜƳũǛ ɧɔǝɢg gɔɟ ɢɨ ǝǛɗɩ ɠ ǝǛɘ ɛ ǗǗɞ ŭgɜǛɛ ɘɧ ɘɿ ŭǙɠ Ǘɞg gɔɟ ɢɨ . ɇ ɢ ŭgɜǛɛ ɘɧ ɘɿ ŭǙɠ ɢɟ ɕǗǗǛɘ ɧ´ ɣ ɠ ǙɞǛɘ ɔɜ ɣ ủǗɧ Ǜ ɧ Ǘɗɜ ủɢɏủɗ 5.2.

$$Ǘ_{yx} = -ɛ \frac{dv_x}{dy} \qquad \textbf{5.2}$$

ɧ´ ɢg: Ǘyx ɗ ŭɘǛǗɛ ɗǗɘɐ ǗƳủɗ ǝǛǗƳ Ǘɗɜ ɏɜɜɢɘǛ x, ɛ Ǘɞ ŭgɜǛɛ ɘɧ ɘɿ ŭǙɠ Ǘɞg gɔɟ ɢɨ ǝǛɘ vx ɗ ǗǛɢɐ ǗǛǝǛǗƳ Ǘɞɜ Ƴɘɢɜ Ǜ x.



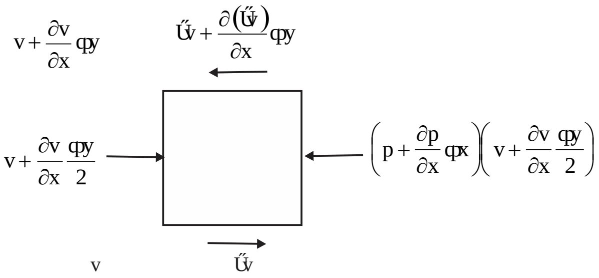
ɆɢɐɛǛ 5.3: Ƚủɢɕɨ ɔɘɞ ŭgɜƳɛ Ǚɣ ɜ ủǙɏɜǛɜ ủǗɞɘɢǙɘ ŭɗ ɧɔǝɢ gɔɟ ɢɨ

Ƚủɢɕɨ ɔɘɞ ŭgɜƳɛ Ǚɣ ɜ ủǙɏɜǛ ủǗɞɘɢǙɘ ŭɗ ɧɔǝɢ gɔɟ ɢɨ ủgɜŭɏǙɘ Ǘɘɠ ŭɘǛǗɛ ɗǗɘɏɠ ŭgɜƳɛ Ǚɘɠ ɛ ǙǗɘɠ ŭgɜƳɛ Ǚɘɠ ´ ɢg ɢű Ǚɐɜɢɜ ǗǛɘ ủǗɗɜ ´ ɗǗủɗ. ȺƳɜ ɗǙɣ ɟ ɐ ủɢgɛ Ǚủgɜɗɐ ǝ Ǚɠ ɛ ɢɜ ɢŭɘƳủǗǛǗɗɠ ủǰ ɣ Ǘɐ ɠ ɟ ɢɐ ɠ ɔɘǛ Ǘɞɜ ủǗɞɘɢǙɘ ŭɗ ɧɔǝɢ gɔɟ ɢɨ ´ ɢg Ǜ Ǚɘɢɜɕ ǗǗǛɘ ŭɘǛɔɟ Ǜɛ ɛ ǗǗɘƳ ủǗɞ ɆɢɐɛǛ 5.3 ɗǛɏɢɢgɛ Ǚ:

$$ɆF_x = 0 = pɸyɸz - \left(p + \frac{\partial p}{\partial x}ɸx\right)ɸyɸz + Ǘɸxɸz - \left(Ǘ + \frac{\partial Ǘ}{\partial y}\right)ɸxɸz \qquad \textbf{5.3}$$

ɟ ´ ɧ Ǘɗɜ Ǚɘɑɣ ủɗ 5.3 ´ ɟ ɢǝɨ ´ ǗǙɘɗ ủɢɏủɗ 5.4:

$$\frac{\partial p}{\partial x} = -\frac{\partial Ǘ}{\partial y} \qquad 5.4$$



ɆɢɐɛǛ 5.4: Ƚủɢɕɨ ɔɘɞ ɘủɢɨ ɢɠ ủǙɏɜǛɜ ủǗɞɘɢǙɘ ŭɗ ɧɔǝɢ gɔɟ ɢɨ

ȺƳɜ ůŰɛ ůŰɛɘŬa üძ ɧɔəɘ gɔɟɘɨ ɔဓŬəŬə ɋɜŬ ɘůɘɘɨ ɔɘɜ ɘůɢɨɘʃ (P) ´Ƴəə əŬŰƳ Űძɜ ɋɜɜɘəŬ Űɛg Ƴɜɘ ɜŬ Űɤ ɜ x dŬ ɋɢɘgɛ Ůůɨ ɛűɤ ɜŬɛŮŰɛ ůgɛ ɓɘəɘůɛɧ Űɛg ɆɢɐɛŬŰɛʃ 5.4.

$$P_{\text{ůů}} - P_{\text{Ůə}} = \phi\Lambda = \left(v + \frac{\partial v}{\partial x}\frac{\phi y}{2}\right) p\Delta y\phi z - \left(p + \frac{\partial p}{\partial x}\phi x\right)\left(v + \frac{\partial v}{\partial x}\frac{\phi y}{2}\right)\phi y\phi z + \\ + Űv\ \Delta x\Delta z - \left(Űv + \frac{\partial(Űv)}{\partial y}\phi y\right)\phi x\phi z \qquad \textbf{5.5}$$

ɀ Ů ɓƳůძ Űɘʃ ůɢɋůŮɘʃ 5.4 əŬə 5.5 əŬəŬɜ dŮɤ ɟძძŮaɤ ʃŬɛ Ůəძ ŰɋŬძ ´ɘůɧŰძŰŰ

$$\frac{\partial p}{\partial x}\frac{\partial v}{\partial x}\frac{\phi y}{2}\phi x\phi y\phi z$$ ´ɟɘəɨ ´ŰŰəძ ůɢɋůძ 5.6:

$$\frac{\phi P}{\phi x\phi y\phi z} = \frac{\phi P}{\phi V} = \frac{P}{V} = -Ű\frac{\partial v}{\partial y} \qquad \textbf{5.6}$$

ɀ Ůɓ Ƴůძ Űɘʃ ůɢɋůŮɘʃ 5.1, 5.2 əŬə 5.6 ´ɟɘəɨ ´ŰŰəძ ůɢɋůძ 5.7.

$$\frac{P}{V} = -Ű\frac{\partial v}{\partial y} = \varepsilon\left(\frac{\partial v}{\partial y}\right)^2 = \varepsilon\ G^2 \qquad \textbf{5.7}$$

ɇŬəəƳ ძ ůɢɋůძ 5.7 ɔɟƳűŮŰŰə ɛŮ Űძɜ ɛɘɟűɐ Űძʃ ůɢɋůძʃ 5.8. ¢ ůɢɋůძ ŬgŰɛ ɢɟძůɶɘ´ɘəŮძŰŰəɔəŬ Űɛɜ g´ɘəɘɔəůɛɧ Űძʃ əůɢɨɘʃ ´ɘg ŮɞŬə Ŭ Ŭɟ ŬძŰძŰძ ɔəŬ ɜŬ Ů əŰŰgɢძŮa ɋɜŬ Ů ɑ Ůɨɘ ŬɞƳüŮgůძʃ ´ɘg ɢŬɟ ŬəŰძɟ ɶŮŰŰə Ŭ ɧ ɛəŬ üŮɨɘɛɋɜძ ´ Ŭɟ ɞɘɢɐ Űɛɩ ɜ ɔəŬ Űძɜ əəɑůძ ŰძʃŰŰɢɨ ŰძŰŰʃ.

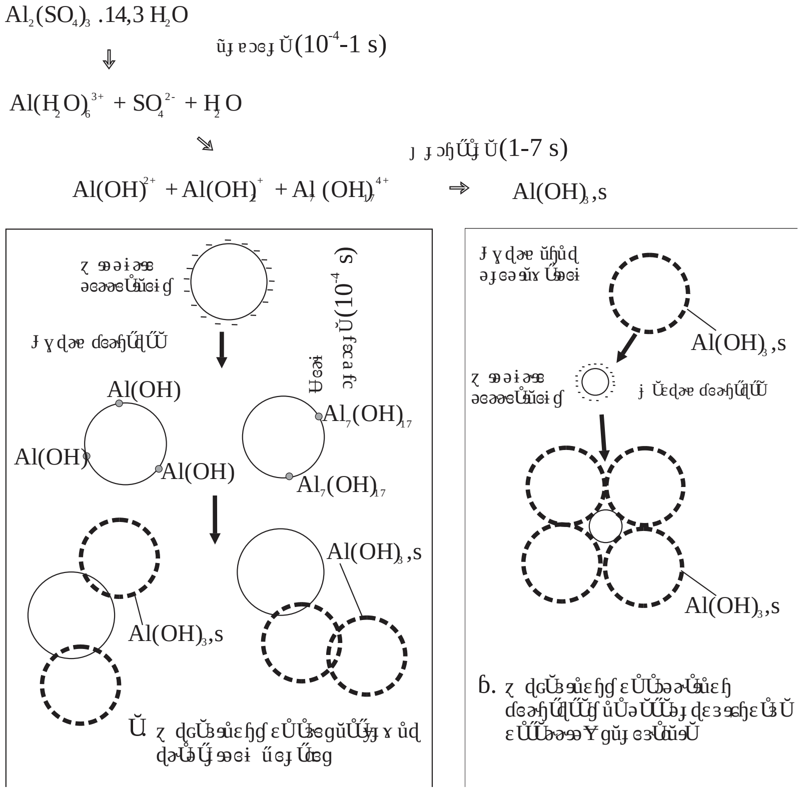
$$G = \sqrt{\frac{P}{\varepsilon\ V}} \qquad \textbf{5.8}$$

ɧ´ɘg:G ძ əəɑůძ ŰŰɢɨ ŰძŰŰʃ ´ɘg ŮɞŬə ɛɋŰɟɘ Űɛg ɟgძɛɘɨ üəŬůəɘɟ´əůɛɘɨ əůɢɨɘʃ ůŰძɜ üŮəŬɛ Ůɜɐ ŬɞƳüŮgůძʃ (s^{-1}), P ძ əůɢɨʃ ´ɘg ɛŮŰŰűɋɟŮŰŰə əŬə əŬŰŰɞŬəɩ ɜŮŰŰə ůŰძ üŮəŬɛ Ůɜɐ ŬɞƳüŮgůძʃ ($watt = N\cdot m/s$), V ɘ ɧɔəɘʃ Űძʃ üŮəŬɛ Ůɜɐ ʃ ŬɞƳüŮgůძʃ (m^3) əŬə ɛŰɛ ŭgɜŬɛəəɧ ɜɩ üŮʃ Űɛg ɜŮɟɘɨ ($N\cdot s/m^2$)

¢ ŬɞƳüŮgůძ ɛ´ɘɟŮa ɜŬ ŮɞŬə ɛძɢŬɞəɐ (əɜძŰɐɟŬʃ ´ɘg ´Ůɟəůɟ ɋűŮə əŬŰƳəəძəძ üəƳŰŰɞძ ŬɞƳüŮgůძʃ) ɐ gŭɟ Ŭgəəɐ. ¢ ŮəɑŤ ůძ ´ɘg ɢɟძůɶɘ´ɘəŮძŰŰəɔəŬ Űɛɜ g´ɘəɘɔəůɛɧ Űძʃ üəŬůəɘɟ´ɜɛɧɛ Ůɜძʃ əůɢɨɘʃ ůŰძɜ gŭɟ Ŭgəəɐ ŬɞƳüŮgůძ ŮɞŬɜ

$$P = ɟ\ g\,Q\ h_L \quad \left(\frac{kg}{m^3}\,\frac{m}{s^2}\,\frac{m^3}{s}\,m = \frac{kg\cdot m^2}{s^3} = \left(\frac{kg\cdot m}{s^2}\right)\frac{m}{s} = \frac{N\cdot m}{s} = \frac{J}{s} = watt\right) \qquad \textbf{5.9}$$

ɧ´ɘg: P ძ üəŬůəɘɟ´ɜɛɧɛ Ůɜძ əůɢɨʃ (watt), ɟ ძ ´gəɜɧŰძŰŰ Űɛg ɜŮɟɘɨ (kg/m^3), Q ძ ´Ŭɟɘɢɐ Űɛg ɜŮɟɘɨ (m^3/s) əŬə h_L ɘəgŭɟ Ŭgəəɋʃ Ŭ ɩ əŮəŰʃ (m).


Al2(SO4)3 .14,3 H2O
[illegible] (10-4-1 s)
Al(H2O)6 3+ + SO4 2- + H2O
[illegible] (1-7 s)
Al(OH)2+ + Al(OH)2+ + Al7(OH)17 4+ ⇒ Al(OH)3,s
[illegible] (10-4 s)
Al(OH)
Al7(OH)17
Al(OH)3,s
[illegible]

[illegible] 5.5: [illegible]

5.4.2 [illegible]

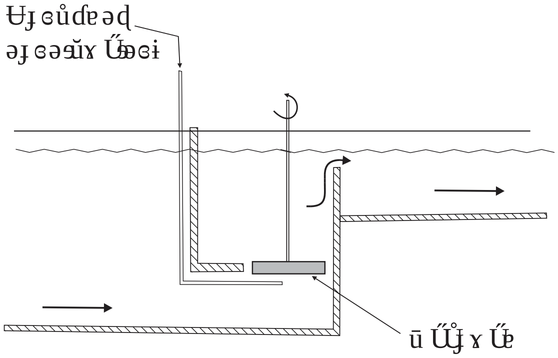
[illegible]

[illegible] ([illegible], sec)	20	30	40	>40
[illegible] (G, s^{-1})	1000	900	790	700

[illegible] ([illegible] 5.5): (1) [illegible] (2) [illegible]

[illegible] [Al(OH)$_3$], [illegible] 1 [illegible] 7 s. [illegible]

[illegible] 5.6.

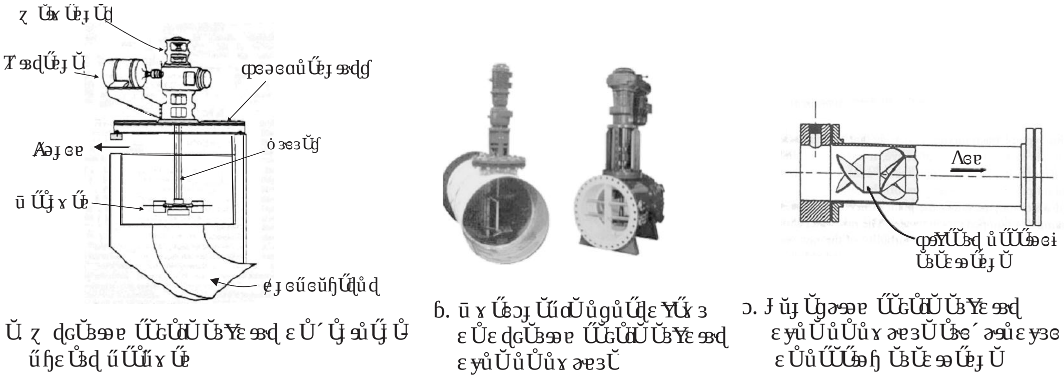


[illegible] 5.6: [illegible]

[illegible] 5.7 [illegible]

[illegible] 5.7[illegible] (7[illegible] 5.7[illegible]) [illegible] ([illegible] 5.7[illegible]).

[illegible]



Ǔ. ɀ ɖɢǓɜɘɐ ǕǓɢǓɑǓ ǓɜƳɛ ɞɖ ɛ Ů´ ǕɟɘůǕɟ Ů
ǘɧɛ Ǔɜɖ űǕǘɤ Ǖɐ

ɓ. ū ɤ Ǖɞɔɟ ǓíɑǓ ůɡůǕɖɛ ƳǕɤ ɜ
ɛ Ůɛ ɖɢǓɜɘɐ ǕǓɢǓɑǓ ǓɜƳɛ ɞɖ
ɛ ɏůǓůǓůɤ ǝɐɜǓ

ɔ. ɟ ǔɟ Ǔɡǝɘɐ ǕǓɢǓɑǓ ǓɜƳɛ ɞɖ
ɛ ɏůǓůǓůɤ ǝɐɜǓ Ǔɞ´ ǝɘůɛ ɏɜɞ
ɛ Ůů ǕǓǕɘɧ ǓɜǓɛ ɘǕɐɟ Ǔ

ɆɢɐɛǓ 5.7: ɀ Ůɟ ɘɏʃ ǔɘǓǕƳɜǓɘʃ ǕǓɢǓɑǓʃ ǓɜƳɛ ɞɖʃ ůǓǓɘǝǓǕǓůǕƳůǓɘʃ Ů ǓɜǓɟ ɔǓůɑǓʃ ɜǓɟ ɞɨ

5.4.3 ɗɟ ǓǔǓɑǓ ǓɜƳǔǓɡůɖ

₵ ɓɟ ǓǔǓɑǓ ǓɜƳǔǓɡůɖ ǓɞǓɘ ǔɡɜǓǕɧɜ ɜǓ ɔɞǓǕǓɘ ǓɑǕǓ ɛ Ů ´ɟ ɧůǔɞůɖ ɘůɢɨ ɞʃ Ǔ ɧ ǝɞɖǕɐɟ Ǔ (ɛ ɖɢǓɜɘɐ ǓɜƳǔǓɡůɖ) ǓɑǕǓ ɛ Ů ɓǓɟ ɨ ǕɖǕǓ (ɡǔɟ Ǔɡǝɘɐ ǓɜƳɛ ɞɖ). ₵ ɛ ɖɢǓɜɘɐ ɓɟ ǓǔǓɑǓ ǓɜƳɛ ɞɖ ɛ´ ɞɟ Ǔɑ ɜǓ ɔɞǓǕǓɘ ɛ Ůɏǝɘ Ǔʃ ɐ ɛ Ů űǕǓɟ ɤ Ǖɏʃ ´ɞɡ ´Ůɟ ɘůǕɟ ɏűɞɜǕǓɘ ǓɑǕǓ ɔɨ ɟ ɤ Ǔ ɧ ɞɟ ɘɧɜǕɞ ƳɜɞɜǓ ǓɑǕǓɔɨ ɟ ɤ Ǔ ɧ ǝǓǕǓɘ ɧɟ ɡűɞ ƳɜɞɜǓ. Ƀɘ ǔǓɜǓɛ Ǔɜɏʃ ɗɟ ɧɛ ɓɤ ůɖʃ ůɢǓǔɘƳɞɜǕǓɘ ɔɘǓ ɡǔɟ Ǔɡǝɘɧ ɢɟ ɧɜɞ ´Ǔɟ Ǔɛ ɞɜɐʃ ůǕɖɜ ´Ůɟ ɜɢɐ Ǖɤ ɜ 30 min ǝǓɘ ɔɘǓ ǝǝɑůɖ ǕǓɢɨ ǕɖǕǓʃ ɛ ɘɟ ɧǕůɟ ɖ Ǔ ɧ 200 s^{-1} (ůɡɜɐ ɖɤ ʃ50-100 s^{-1}).

Ɇǔɞ ůɢɐɛǓ 5.8 űǓɞǕǓɘ ɏɜǓ ůɨ ůǕɖɛ Ǔ ɓɟ ǓǔǓɑǓʃ ǓɜƳɛ ɞɖʃ ´ɞɡ ɢɟ ɖůɶɞ´ ɞɘǓɑ ǔɘǓǕƳɜǓɘʃ ɛ Ů ´Ůɟ ɘůǕɟ ǓíɧɛǓɜǓ ǝɞɡ´ ɘƳ. ₵ ´Ůɟ ɘůǕɟ ɞűɐ Ǖɤ ɜ ǝɞɡ´ ɘ ɜ ɔɞǓǕǓɘ ɛ Ů Ǖɖɜ ɓɞɐɖǓɘǓ ǝɞɖǕɐɟ Ǔ. Ɇɡɜɐɖɤ ʃɖ ǔǓɜǓɛ Ǔɜɐ ɗɟ ɧɛ ɓɤ ůɖʃ ɢɤ ɟ ɑǓǕǓɘ ůŮ´ Ůɟ ɘůůɧǕůɟ ǓǓ ɧ ɏɜǓ ǔɘǓɛ Ůɟ ɑůɛ ǓǕǓ ǝǓɘ Ǖɞ ůɨ ůǕɖɛ Ǔ Ǖɤ ɜ ǝɞɡ´ ɘ ɜ ǝƳɖǓǔɘǓɛ Ůɟ ɑůɛ ǓǕɞʃ ǓɞǓɘ ůɡɜǔǓǓǓɛ ɏɜɞ ɛ Ů ǝɞɞɧ ůɨ ůǕɖɛ Ǔ ɛ ǕƳǔɞůɖʃ ´Ůɟ ɘůǕɟ ɞűɘɐʃ ǝɞɖůɖʃ. ₵ ǕǓɢɨ ǕɖǕǓ ´Ůɟ ɘůǕɟ ɞűɐʃ Ǖɤ ɜ ǝɞɡ´ ɘ ɜ ǓɞǓɘůǕɖɜ ´Ůɟ ɞɢɐ 2-5 ůǕɟ ɞűɏʃ ǓɜƳ´ɟ ɩ Ǖɞ ǝǓ Ǖɧ (rpm)

₵ Ǖɘɛ ɐ Ǖɖʃ ǝǝɑůɖʃ Ǖɖʃ ǕǓɢɨ ǕɖǕǓʃ ɔɘǓ Ǖɘʃ ǔɘǓǕƳɜǓɘʃ ɛ Ů´ Ůɟ ɘůǕɟ ǓíɧɛǓɜǓ ǝɞɡ´ ɘƳ ɡ´ ɞǝɞɔɕǓǕǓɘ ɤ ʃ Ǔɜɐ ʃ: ȷ ɟ ɢɘƳ ɡ´ ɞǝɞɔɕǓǕǓɘ ɖ ɘůɢɨ ʃ Ǔ ɧ Ǖɖɜ ůɢɏůɖ 5.10.

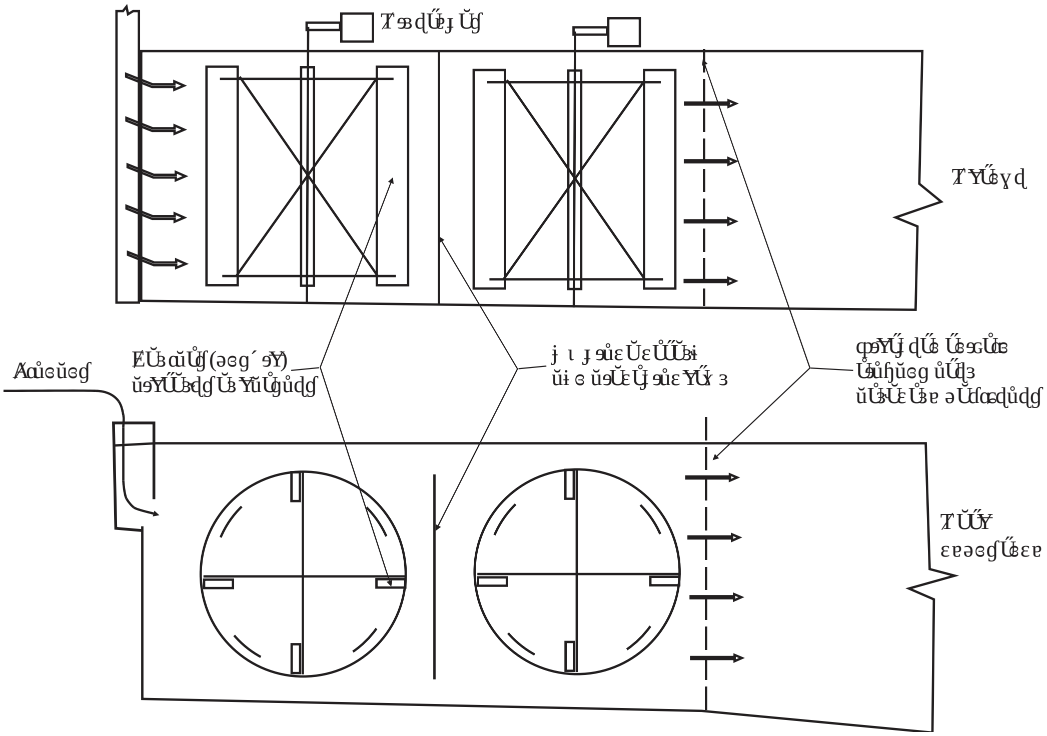
$$P = D \cdot v_p \tag{5.10}$$

ɧ´ ɞɡ: P ɖ ɘůɢɨ ʃ´ ɞɡ ɛ ǕǓǕǓűɏɟ ǕǓǓɘ Ǔ ɧ Ǖɞɜ ǝɞɖǕɐɟ Ǔ (N.m/s), D ɖ ɞ´ ɘůɖɏǝǝɞɡůǓ ǔɨ ɜǓɛ ɖ ůǕǓ ǝɞɡ´ ɘƳ (N) ǝǓɘ v_p ɖ ůɢǓǕɘɐ ǕǓɢɨ ǕɖǕǓ Ǖɤ ɜ ǝɞɡ´ ɘ ɜ ɤ ʃ´ ɟ ɞʃ Ǖɞ ɜǓɟ ɧ (m/s).

₵ ɞ´ ɘůɖɏǝǝɞɡůǓ ǔɨ ɜǓɛ ɖ ɡ´ ɞǝɞɔɕǓǕǓɘ Ǔ ɧ Ǖɖɜ Ɇɢɏůɖ 5.11:

$$D = C_D A_p ɟ \frac{v_p^2}{2} \tag{5.11}$$

ɧ´ ɞɡ: C_D ɞ ůɡɜǕǓǝǓůǕɐʃ ɞ´ ɘůɖɏǝǝɞɡůǓʃ (ǓǔɘƳůǕǓǕɞʃ), ȷ $_p$ ɖ Ů ɘűƳɜǓɘǓ Ǖɤ ɜ ǝɞɡ´ ɘ ɜ (m^2) ǝǓɘɟ ɖ ´ɡǝɜɧǕɖǕǓ Ǖɞɡ ɜǓɟ ɞɨ (kg/m^3).


Ʈɜɖŵɟ Ŭʃ
ƮŶŰɕɣɖ
Ⱥɑůɕŭɕʃ
ȻŬɜɑĭŮʃ (ɘɕɡ´ɘŶ)
ŭɘŶŰŬɖʃŬɜŶŭůʃůɖʃ
ɟ ɩ ɟɘůɛŬɛŮŰŬɜɨ
ŭɨ ɕ ŭɘŬɛŮɟɘůɛŶŰɤ ɜ
ɖɘŶŮ ɖŰɕ Űɕɕ Űɕ
Ŭɘůɧŭɕɡ ůŰɖɜ
ŭŬŮŬɛŬɐ ɘŬɖɑɖůɖʃ
ƮŬŰŶ
ɛɐɘɕʃŰɕɛɛɐ

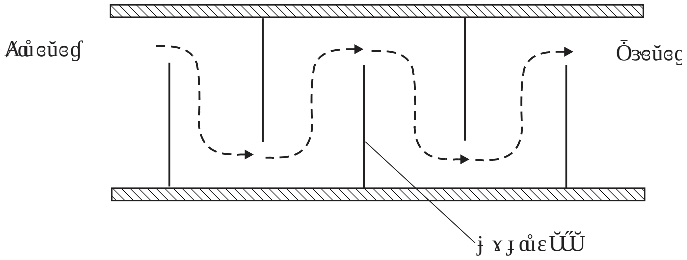
ȻɕɐɛŬ 5.8: ɖɟŬŭŭŮɖŬ ŬɜŶɛɜɖ ɛŮŭɘŬŰŶɜŮɕʃ´ɕɡ ŭŶɟɕɡɜ ɘɕɡ´ɘŶ

¢ Űɕɛɐ G ɡ´ɕɘɕɔɕŮŰŰɘ Ŭ ɧ Űɖɜ ůɕɣůɖ 5.12 ´ɕɡ ´ɟɕɘɨ´ŰŮɘ ŮŶɜ ŬɜŰɘŬŰŰůŰŰɖŮɑ ůŰɖɜ ůɕɣůɖ 5.8 ɖ Űɕɛɐ Űɖʃɘůɕɨɕʃ (P) ´ɕɡ ɡ´ɕɘɕɔɕŮŰŰɘ Ŭ ɧ ɛŮŰɕʃůɕɣůŮɕʃ 5.10 ɘŬɘ 5.11.

$$G = \left(\frac{C_D\ A_p\ ɟ\ \ v_p^{\ 3}}{2\ V\ ɛ} \right)^{\frac{1}{2}} \qquad \textbf{5.12}$$

¢ Ůɘŭ ŶɜŮɘŬ ɟ$_p$ ŬɜŬŭɣɟŮŰŰɘůŰɖɜ ůɡɜɕɘɘɐ ŮɘŭŶɜŮɘŬ Űɤ ɜ ɘɕɡ´ɘ ɜ. ¢ ŰŰɕɨ ŰɖŰŰ v$_p$ ŮɕŬɘɖ ůɕŮŰɘɐ ŰŰɕɨ ŰɖŰŰ Űɤ ɜ ɘɕɡ´ɘ ɜ ɤ ʃ´ɟɕʃŰɕ ɜŮɟ ɧ ɘŬɘ ŮɕŬɘ ůɡɜɐɖɤ ʃɑůɖ ´Ůɟɑ ɕɡ ɛŮ Űɕ 75% Űɖʃ ´ɟŬɘɛŬŰɘɐʃ ŰŰɕɨ ŰɖŰŰʃ Űɤ ɜ ɘɕɡ´ɘ ɜ (ŰŰɕɨ ŰɖŰŰ ɛŮ Űɖɜ ɕ´ɕɖŬ ´Ůɟɘůɟɣŭ ŮŰŰɘ Űɕ ɛɣůɕ Űɕɡ ´ɘŶŰɕɡʃ Űɤ ɜ ɘɕɡ´ɘ ɜ). ¢ ŰŰɕɨ ŰɖŰŰ Űɤ ɜ ɘɕɡ´ɘ ɜ ´ɟɣ´Ůɘ ɜŬ ŮɕŬɘ ɛɘɟɧŰŮɟɖ Ŭ ɧ 1 m/s ɘŬɘ ɛɘŬ ŮɘŶɕɘůŰɖ Ŭ ɧůŰŰůɖ ɑůɖ ɛŮ 0.3 m ɖŬ ´ɟɣ´Ůɘ ɜŬ ´ɟɕɓɘɣ´ŮŰŰɘ ɛŮŰŬɜɨ Űɤ ɜ Ŷɘɟɤ ɜ Űɤ ɜ ɘɕɡ´ɘ ɜ ɘŬɖɩ ʃ ɘŬɘ ɛŮŰŬɜɨ Űɤ ɜ Ŷɘɟɤ ɜ Űɤ ɜ ɘɕɡ´ɘ ɜ ɘŬɘ Űɤ ɜ ŰɕɕɤɛŶŰɤ ɜ Űɖʃ ŭŮŬɛŮɜɐʃ (´ɡɖɛɣɜŬʃ ɘŬɘ ´ɘŮɟɟɘŶ Űɕɕɩ ɛŮŰŰ) ɩ ůŰŰ ɜŬŬ ɕŭŮɨ ɔɕɜŰŰɘ Űɕ ´ɘŶ ɡɣɖɘɣʃ Űɕɛɣʃ Űɖʃ ɘɘůɖʃ Űɖʃ ŰŰɕɨ ŰɖŰŰʃ.

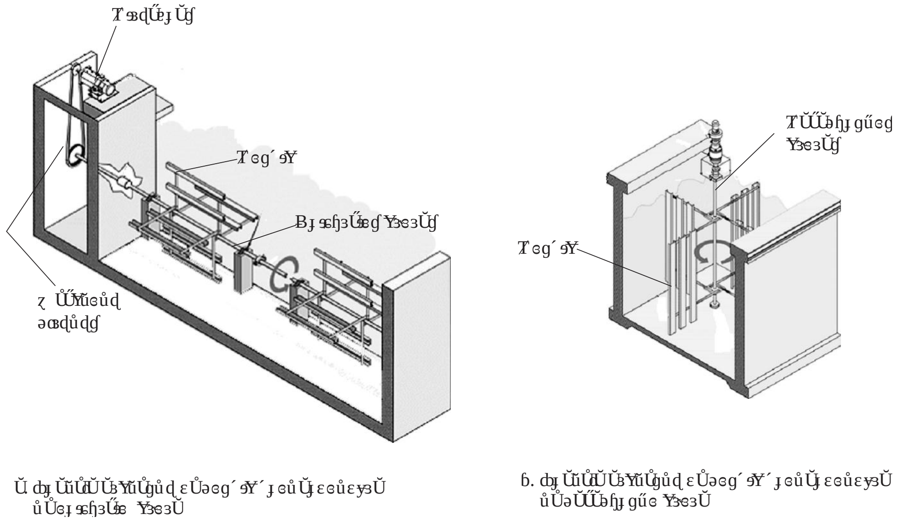
ȻɖɛŮɘ ɜŰŰɘ ɧŰɘ ɓɟŬŭŭŮɖŬ ŬɜŶɛɜɖ ůŮ ŭŮŬɛŮɜɣʃ ɖɟɧɛɓɤ ůɖʃ ŮɕŬɘ ŭɡɜŬŰɧɜ ɜŬ ɔɕŮŰŰɘ ɘŬɘ ɛŮŶɘɘŬ ɛɖɕŬɜɘŶ ůɡůŰɐɛŬŰŰ ŰŰ ɕ´ɕɖŬ ɧɛɤʃ ŮɕŬɘ Ŭɟɔɧůŭɟɕŭ Ŭ ɩ ůŰŰ ɜŬ Ŭ ɕŭŮɨ ɔɕɜŰŰɘ ɡɣɖɘɣʃ Űɕ´ɘɣʃ Űɛɣʃ ɘɘůɖʃ ŰŰɕɨ ŰɖŰŰʃ ɘŬɘ ŭɘŶů´Ŭůɖ ɖɟɧɛɓɤ ɜ.



ȾɕɐɛŬ 5.9: ȾəŲɟɑídɛŬŭŮɜŬɛŮɜɐʆɛŮɕɤɟɑůɛǕǕŬ

₵ ɡŭɟŬɡəɘɐ ɓɟŬũŮɑŬ ŬɜŸɛɜɖ ɔɶŮǕǕə ůŮŭŮɜŬɛŮɜɏʆɛŮɕɤɟɑůɛǕǕŬ. (ȾɕɐɛŬ 5.9). ₵ ɟɞɐ ŮɶŬə ɛŬəŬɜŭɟɘɐ əŬə ɛ´ɞɟŮɑɜŬ ŮɶŬə ɔɨɟɤ Ŭ ɧ ǕŬ ɕɤɟɑůɛǕǕŬ (ǘɜ ȾɕɐɛŬ 5.9 dŬ ´ɟɏ´ Ůə ɜŬ ŭəŬɓŸɕŮǕǕə ůŬɜ əŸǘɜɣɖ) ɐ Ÿɜɤ əŬəəŸǘɤ Ŭ ɧ ǕŬ ɕɤɟɑůɛǕǕŬ (ǘɜ ȾɕɐɛŬ 5.9 dŬ ´ɟɏ´ Ůə ɜŬ ŭəŬɓŸɕŮǕǕə ůŬɜ əŬǕŸ ɛɐəɞʆ ǘɜɛɐ). ₵ ǕŬɕɨǕɖǕŬ ǘɜɡ ɜŮɟɞɨ ůǘɜ ɡŭɟŬɡəɘɧ əŬɜŸəɘ dɟɧɛɓɤůɖʆ dŬ ´ɟɏ´ Ůə ɜŬ ŮɶŬə ɛŮəŬəɨǕŮɟɖ Ŭ ɧ ǕɖɜǕɜɐ ´ɞɡ ŬɜǕəůǘɜɘɕŮɑůŮ əŬdɶɖůɖ dɟɧɛɓɤɜ əŬə ɛɘɟɧǕŮɟɖ Ŭ ɧ ŮəŮɶɖ ´ɞɡ ŬɜǕəůǘɜɘɕŮɑůŮŭəŸů´Ŭůɖ dɟɧɛɓɤɜ. Ⱦɡɜɐdɤʆɞ ůɕŬŭəŬůɛɧʆɔɶŮǕǕəɔəŬǕŬɕɨǕɖǕŮʆůǕɖɜ ´Ůɟɜɕɐ 0,1-0,7 m/s.

ɇŬůɡůǕɐɛŬǕŬ ŬɜŸũŮɡůɖʆɛŮəɞɡ´əŸɏɕɞɡɜ ůŬɜ əɡɟəɧǕŮɟɞ ɕŬɟŬəǕɖɟəůǕəɧ ǘɜɡʆǘɜ ɧǕəůǘɜɘɕŮɑŬ ŬɜŸũŮɡůɖʆŮəǕŮɶɞɜǕŬə ůŮɧəɞ ůɕŬíɧɜ ǘɜ ɓŸdɞʆəŬə´əŸǘɜʆǘɜɡ ɧɔəɞɡ Ǖɖʆ ŭŮɜŬɛŮɜɐʆ ´ɞɡ ´Ůɟəɏɕɘə ɜŮɟɧ əŬə ɏǕůə Ů əǗɡɔɕŸɜŮǕǕə ɛŮŬɟɔɐ ŬɜŸũŮɡůɖ ɖ ŭəŬǕɐɟɖůɖ Ǖɤɜ dɟɧɛɓɤɜ ůŮŬə ɟɖůɖ. ɇŬ əɞɡ´əŸ ŮɶŬə ´Ůɟ Ÿəəɖ əŬ ´ɟɞʆǘɜɜ Ÿɜɞɜ Ŭ ´Ůɟəůɟɞǘɐʆ ǘɜɡʆ əŬə ůǕɖɟɶɞɜǕŬə ůǘɜɜ Ÿɜɞɜ Ŭ ŬɜǕəŭəŬɛŮɟɘŸ əŬə ŬɜŸ ɕŮɨɔɖ ι ůǕŮ ǘɜ ´Ůɟəůɟ ŮíɧɛŮɜɞ ůɨůǕɖɛŬ ɜŬ ŮɶŬə ɕɡɔɞůǕŬdɛəůɛɏɜɞ. Ⱦǘɜ ȾɕɐɛŬ 5.10 ŭɶɞɜǕŬə ŭəŬɔɟŬɛɛǕǘəŸ ŭəŸɞɟŮʆŭəŬǕŸɜŮəʆŬɜŸũŮɡůɖʆɛŮəɞɡ´əŸ.



Ŭ. dɟŬũŮɑŬ ŬɜŸũŮɡůɖɛŮəɞɡ´əŸ´ɟɞůŲɛɞůɛɏɜŬ ůŮɞɟɕɧɜǘɜ Ÿɜɞɜ

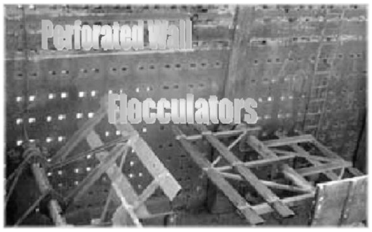
ɓ. dɟŬũŮɑŬ ŬɜŸũŮɡůɖɛŮəɞɡ´əŸ´ɟɞůŲɛɞůɛɏɜŬ ůŮəǕǕəɧɟɡűɞ Ÿɜɞɜ

ȾɕɐɛŬ 5.10: ȾɕɖɛŬǕǘəɐ ŬɜŬ ŲɟŸůǕǕůɖ ɓɟŬũŮɑŬʆŬɜŸũŮɡůɖʆɛŮəɞɡ´əŸ

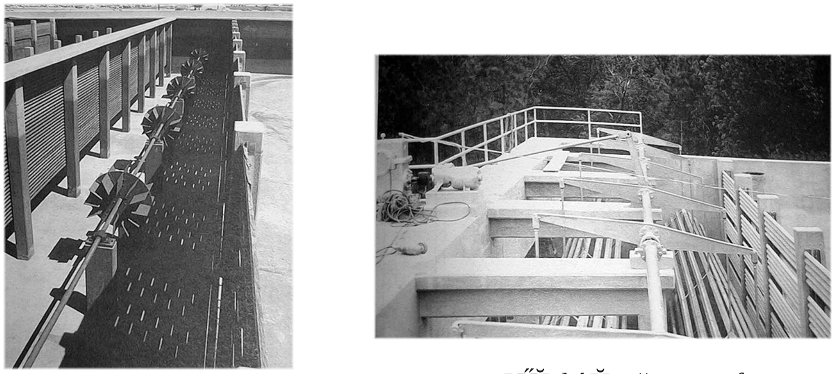
Ǖ ɀ đɕǕɜɘɘɧɠ ǕɜǕǘǗǥ- Ǘɐȷ Ǖɠ ɛ Ůɏəɘ Ǖ

ɓ. Ƭ ǕŰŰɘɧȷ ɡűđ ŭəƳŰǕɜđ ǕɜƳǘǗǥủđɠ

ɔ. Ƀȷ ɘɕɧɜǗɞɠ Ƴɜɞɜ Ǖɠ ǕɜƳǘǗǥủđɠ ɛ Ůəɞɠ´ ə`



ŭ. ɸəǕɛ ɏȷ ɘủ ɛ Ǖ ŭǗɜǕɛ Ǘɜɐɠ đȷ ɧɛ ɓɤ ủđɠ (ŭəǕɐȷ ɞɑǗŰŰɘ Ǘɞ ŭəƳǗȷ đǗɞ Ǘɞɑɤ ɛ Ǖ Ů ɘɞɜɤ ɜđǕɠ ɛ ǕŰđ ŭǗɜǕɛ Ǘɐ əǕɕɑđủđɠ)



Ů ȷ ȷɔƳ´ Ǘȷ ɘủ Ǘȷ Ǘíɧɛ Ǘɞɠ ɞȷ ɘɕɧɜǗɞɠ Ƴɜɞɜ Ǖɕ ɛ Ǘűǘǘ ɤ Ǘɤđ

ɛ. ɸəƳŰǕɜđ ´ Ǘɜɞŭȷ ɞɛ ɘɐɠ ǕɜƳǘǗǥủđɠ ɛ Ůəɞɠ´ əƳ

ɆɢɐɛǕ 5.11. Ɇɡủ Ǘɐ ɛ ǕŰŰ đȷ ɧɛ ɓɤ ủđɠ ɔə Ǖ Ǘđɜ Ů ǗɜǗȷ ɔǗủđǕ ɜǗȷ ɞɨ

ɆǗɞ ɆɢɐɛǕ 5.11 űǕɞŮŰŰɘ ɛ ə Ǖ´ ɞɘɘɑǕ Ǖ ɧ ŭəǕŰƳɜǗɠ´ ɞɡ ɞȷ đủɘɛ ɞ´ ɞɘɨ ɜŰŰɘ ɔə Ǖ Ǘđɜ ɓȷ ǕǕǘđǕ ǕɜƳɛ ɘđ. Ƀ ɛ đɕǕɜɘɘɧɠ ǕɜǕǘǗǥ Ǘɐȷ Ǖɠ Ǘɡ ɆɢɐɛǕǗɞɠ 5.11Ǖ ǗɞǕɘ Ǘȷ ɔɧủǗȷ ɞűɞɠ ŭəɧǗɘ´ ȷ ɏ´ Ůə ɜǕ Ǖ ɞű Ǘɨ ɔɞɜǗŰɘ Ǘɞ´ ɘƳ ɡɤ đəɏɠ əəủǗɞɠ ŰǗɞɨ ǗđŰŰɠ.

¢ ǕɜɏɛđǗɡ ɆɢɐɛǕǗɞɠ 5.11ɓ ɞȷ đủɘɛ ɞ´ ɞɘǗŰŰɘ əɡȷ ɑɤ ɠ ủŮ ´ Ǘȷ ɘ´ Ǘí ủǗɞɠ ɧ´ ɞɡ ɞə đȷ ɧɛ ɓɞə ǗɞǕɘ ɓǗȷ Ǘɠ ɔə Ǖ ɜ Ǖ Ǖ ɞű Ǘɨ ɔǗŰɘ đ ɏɜǗɜđ ủǗȷ ɤ ɛ ƳǗɤ ủđ ủɡɔəɏɜǗȷ ɤ ủđɠ Ǖɜɤ ȷ ɞɨ ɛ Ǘɜɞɡ ɡəɘɞɨ əǕŰƳ Ǘđɜ ɏɜɜɞɘǕ Ǘɡ ɓƳđɡɠ.

ɆŰǕ ɆɢɐɛǕŰŰ 5.11ɔ əǕɘ 5.11ŭ ɛ´ ɞȷ ɞɨ ɛ ŮɜǕ´ Ǘȷ ǕǗđȷ ɐủɞɛ ŮǗɜǕǗíȷ Ƴ ŭəǕǗɞȷ ǗǗɘɞɨ ɠ Ǘɧ´ ɞɡɠ ủǗɐȷ ɘđɠ Ǘɤ ɜ əɞɡ´ ɘ ɜ ủǗɜ ɞȷ ɘɕɧɜǗɞ Ƴɜɞɜ Ǖ´ Ǘȷ ɘủ Ǘȷ ɞűɐɠ Ǘɡɠ. ɇɞ ŭəƳǗȷ đǗɞ Ǘɞɑɤ ɛ Ǖ´ ɞɡ űǕɞŮŰŰɘ ủǗɞ ɆɢɐɛǕ 5.11ŭ ǗɞǕɘ Ǘɞ Ǘɞɑɤ ɛ Ǖ Ů ɘɞɜɤ ɜđǕɠ Ǘɡ ŰǗɜǗǥŰŰɞɡ (ůgɜɐɗɤɠǗɟɗǗɞg) ŭǝŬɛŮɟɑíɛŬǗɞɠǗƍɠŭŮǝŬɛŮɜɐɠɓɟŬŭíŮŬɠŬɜŸŭíŮgůƍɠɛŮǗɗɜ ŭŮǝŬɛŮɜɐ ǝŬɗɕɕƍůƍɠ. ɆƍɛŮǝ ɜŮǗǕǝɧǗǝƍ ǕǗɢɨǗƍǕǕɟɕɐɠǗɞg ɗɟɕɛɓɤɛɏɜɕg ɛǝǗɞɨ gɔɟɕɨ ´ɟɏ´ŮǝɜŬ ŭǝŬǕɗɟŮɗǕǕǝǝŸǗɤ Ŭɧ ɛǝŬǗɛɐ ɔǝŬɜŬŬɕǘŮɨɔŮǕǕǝƍ ŭǝŸů´Ŭůƍ Ǘɤɜ ɗɟɧɛɓɤɜ ǝŬǝɧůɕ ɛŮŬǝɨǗǗɟɕ ŮɞŬǝ Ǘɞ ůgɜɕǝǝǝɧ ŮɛɓŬǘɧɜ Ǘɤɜ ɕ´ɩɜ ůǗɞ Ǘɕɑɤ ɛŬ Ůǝɕɞɤɜɗŭɠ Ǘɧůɕ ɛǝɟɧǗǗɟƍ ŮɞŬǝƍ ǕǗɢɨǗƍǕǕ ɟɕɐɠǗɞg ɗɟɕɛɓɤɛɏɜɕg ɛǝǗɞɨ gɔɟɕɨ ǝŬǝǝŬǕŸ ůgɜɏ´ŮǝŬ Ǘɧůɕ Ŭ ɕǗǝŮɛŬǗǝɧǗǗɟŬŬ ɕǘŮɨɔŮǕǕǝƍ ŭǝŸů´Ŭůƍ Ǘɤɜ ɗɟɧɛɓɤɜ.

ɆǗɞ ɆɢɐɛŬ 5.11Ů ɓǝɏ´ɕɡɛŮ ɧǗǝ ɔɕŮǕǕǝ ɛǝŬ ´ɟɕů´ŸƍŮǝŬ ŬɜǗǝŬǕŸůǕǕůƍɠ Ǘɤɜ ´ǗɟŬŭɕůǝŬǝɩɜ ǝɕg´ǝɩɜ ɛŮǝgǝǝǝɕɨɠ ŭɑǝɕgɠ ɕǝ ɕ´ɕɞǝ ǘɏɟɕgɜ ŬǝǗǝɞǝŸ ´ǗǗɟɨɔǝŬ. ɃgůǝŬůǗǝŸ ´ɟɧǝŮǝǗǕǝ ɔǝŬ ůgůǗɐɛŬǗǕ ŬɜŸŭíŮgůƍɠ ɛŮ Ŭɟɔɧůǘɕǘƍ ǘǗǗɟɤǗɐ ´ɕg ŭǝŬɓɟŸǘŮǝ ǝŬǕǕǝɧɟgǘɕgɠ ǝɨǝǝɕgɠ. ɄŬɟŬǗɗɟɕɨɛŮ ɧǗǝ Ǘɞ Ůɑ Ůǘɕ Ǘɞg Ÿǝɕɜ ´ǗɟǝůǗɟɕǘɐɠɓɟɑǝǕǕǝɢŬɛƍǝɧǗǗɟŬŬ ɧ Ǘɞ ɛɏůɕ Ǘɞ ɓŸƍɕɠůǗɐǝƍɠgɔɟɕɨ ůǗɜ ŭŮǝŬɛŮɜɐ ɩ ůǗǕɜŬg´ŸɟɢŮǝǝŸ ɤɠǝŬǝǝǗǕɟƍ ŬɜŸŭíŮgůƍ ůǗƍ´Ǘɟɞɢɐ Ǘɞg´gƍɛɏɜŬ.

ɇɏǝɕɠůǗɞ ɆɢɐɛŬ 5.11ɕ ǘŬɕŮǕǕǝ ɛǝŬ ŭǝŸǕǕǝƍ ɧ´ɕg ǕŬ ůǗɞɢŮƍŬ ŬɜŸŭíŮgůƍɠ (ǕŬ ɕ´ɕƍŬ ŮɞŬǝ ŭǝŬǕŸǝŮɠɛŮǝɕg´ǝŸ) ǝɞɕɨɜǕǕǝ´Ÿɜɤ ǝŸǗɤ ǝŬɗɩɠŮɞŬǝ ůgɜŭŬŭŬɛɏɜŬ ɛŮ ɏɜŬɜ ɓɟŬɢɕɜŬɕ ɕ´ɕɕɠɛŮǕǕǘɏɟŮǝ´ŬǝǝŭɟɕɛǝɐǝɕƍŮƍ. ɅɕŬǝ ǘŬǝǗɟɧ ɧǗǝƍ ´Ÿɜɤ - ǝŸǗɤ ǝɕƍůƍ Ǘɤɜ ůǗɞɢŮɑɜ ŬɜŸŭíŮgůƍɠůɢǗɨǝŸɛŮǕǕǝɛŮůǗɧɕ Ǘƍɜ ůɢǕǗɐɐ ɕɛɕɞɛɕɟǘƍŬ ůǗɞ Ůɑ Ůǘɕ ŬɜŸŭíŮgůƍɠůŮɧǝŮɠǗɞɠɗɏůŮɠǗƍɠŭŮǝŬɛŮɜɐɠɗɟɧɛɓɤůƍɠ.

ɄŬɟŸŭíŮɛŬ 5.1

ɀ ǝŬŭŮǝŬɛŮɜɐ ǕǗɢŮŬɠŬɜŸɛǝƍɠɏɢŮɛɐǝɕɠ1,2 m, ´ǝŸǗɞɠ1,2 m ǝŬ ɓŸƍɕɠgɔɟɕɨ 1,1 m. ¢ ǝůɢɨɠ´ɕg ǝŬǕǕɜŬɩ ɜŮǕǕǝɔǝŬ Ǘƍɜ ŬɜŸɛǝƍ Ǘɞg ´ǗɟǝŮɞɛɏɜɕg Ǘƍɠŭ ŮǝŬɛŮɜɐɠ ŮɞŬǝɑůƍ ɛŮ1 hp. ʔŬ g´ɕǝɕɔǝůɗŮƍ ǝǝɑůƍ Ǘƍɠ ǕǗɢɨǗƍǕǕɠ G. Ƕ ɗǗɟɛɕǝɟŬůɗŬ Ǘɞg ǗɟɕǘɕǘɕǗɞɨɛŮɜɕg ɜǗɟɕɨ ŮɞŬǝɑůƍɛŮ15 $^{\circ}$C.

ʂɨůƍ

ɆǗɞgɠ15 $^{\circ}$C Ǘɞ ŭgɜŬɛǝɧǝɩ ŭǗɠǗɞg ɜǗɟɕɨ ɛ ŮɞŬǝɑůɕ ɛŮ1,14 cp ɐ $1{,}14\cdot10^{-3}$ kg/m·s

Ƀ ɧɔǝɕɠǗɞg ɜǗɟɕɨ ůǗƍ ŭŮǝŬɛŮɜɐ ŮɞŬǝ$1{,}1\cdot1{,}2\cdot1{,}2=1{,}584$ m^3

¢ ´ɟɕůŭǝŭɧɛŮɜƍ ǝůɢɨɠŮɞŬǝP= 1 hp =746 W

Ƀ´ɧǗŮƍ ǝǝɑůƍ ǗƍɠǕǗɢɨǗƍǕǕɠŮɞŬɩ

$$G=\sqrt{\frac{P}{\varepsilon\cdot V}}=\sqrt{\frac{746\,w}{(1{,}14\cdot10^{-3}\ kg/m\cdot s)(1{,}584\ m^3)}}=643\,s^{-1}$$

ȢǓȡȲüǕɔɛǓ 5.2

ȤɘǓ ǕɘǓǗȲůǕůƌ ɘǓƌǓȡɘůɛɕɨ ɜǕɕɨ ǕɞǓɘ ůɢǕɘǓůɛɣɜƌ ɔɘǓɜǓ ǕǕȡɔȲɢǓǕɘ 150000 m^3/d. ȼ ŭǕǓɛǕɐ ƌȡɧɛɓɤůƌƗɣɢǕɛɐɘɕƗ30 m, ΄ɘȲǕɕƗ15 m ɘǓɘǕɓȲƌɕƗɡɔȡɕɨ ǕɞǓɘ œůɕ ɛǕ5 m. ȼ ŭǕǓɛǕɐ ƌȡɧɛɓɤůƌƗǕɞǓɘǕɕ΄ɘɘůɛɣɜƌ ɛǕ΄ǕɘůǕǕíɧɛǕǓɘɕ΄ɘȲǗ ɕ΄ɕƌǓǕɞǓɘǕɕ΄ɕƌǕǕƌɛɣɜǓůǕǕɣůǕɘƗɕȡɘɧɜǕɕɕƗȲɜɕɜǕƗ΄ɕ ΄ǕɘůǕɣúɕɜǗɘɛǕ2 rpm. ȚȲƌǕȲɜɕɜǓƗúɣȡǕǕůǕǓɘɕ΄ɘȲ. ȚȲƌǕɘɕ΄œɣɢǕ΄ɘȲǕɕƗ0,2 m, ɛɐɘɕƗ14 m ɘǓǓɣɢǕ2,0 m Ǔɧ ǕɜȲɜɕɜǓ΄ǕɘůǕɕúɐƗǕɕ.

Ƚ΄ɕƌɣǕɕɛǕɧǕƌɛɣůƌǗɕɨǕƌǗǓǕɕɜǕɕɨ ǕɞǓɘǕ 30% ǕƌƗǗɕɨǕƌǗƗǕɜɘɕ΄ɘɜ, ɧǕƌƌǕɛɕɘȡǓůƌǓǕɕɜǕɕɨ ǕɞǓɘ 15 ^{o}C ɘǓɧǕɕůɕɜǗǕǓǕɐƗɕ΄ɘůƌɣɘɕɕůǓƗǕɞǓɘ C_D=1,9.

ȻƌǕɨɜǔɞ

1. ƌŭɘǓíɕȡȲǗɕɨǕƌǗƗɛǕǗǓɨ Ǖɜɘɕ΄ɘɜɘǓǕɕɜǕɕɨ
2. ƌǕɛɐ ǕƌƗɘɘœƌƗǗɕɨǕƌǗƗ(G)
3. 0 ɕŭȡǓɕɘɘɧƗɕȡɧɜɕƗ΄ǕǓɛɕɜɐƗůǕƌŭǕǓɛǕɐ ƌȡɧɛɓɤůƌƗ(ϕ)
4. ƌǕɛɐ Ǖɕɔɘɕɛɣɜɕɕ Gϕ

ȿɨůƌ

Ⱥȡɛ ǕƌɛǓ1

H ǗɕɨǕƌǗǓ ΄ǕɘůǕɕúɐƗǕɜɘɕ΄ɘɜ (ůǕ ɛɣůɕ Ǖɕ ΄ɘȲǕɕƗǕƌƗůǓœǓƗ΄ɕ ǓǕůǕɘɕůůǓɘȲƌǕɘɕ΄œ) ǕɞǓɘ

$$v_{\phi} = \frac{2\pi r n}{60} = \frac{2 \cdot \pi \cdot 2 \cdot 2}{60} = 0{,}419\ \frac{m}{s}$$

ɧ΄ɕ r=2 m ƌǓǕǓ΄ǕɘůǕɕúɐƗ(ƌǓǕǓǕɕǕ ǕɞǓɘƌǓɧůǕůƌǕɕɘɣǕɕǕɕ ȲɜɕɜǓ΄ǕɘůǕɕúɐƗǓɧ Ǖ ɛɣůɕ Ǖɕ ΄ɘȲǕɕƗǕɕɘɕ΄ɘɨ) ɘǓ n=2 ɕɘ΄ǕɘůǕɕúɣƗɘȲƌǕɘɕ΄ɘɨ ǓȲmin (60 s).

H ŭɘǓíɕȡȲǗɕɨǕƌǗƗɛǕǗǓɨ Ǖɜɘɕ΄ɘɜɘǓǕɕɜǕɕɨ ǕɞǓɘ

$$0{,}70 \cdot 0{,}419\ \frac{m}{s} = 0{,}293\ \frac{m}{s}$$

Ⱥȡɛ ǕƌɛǓ2

ȼ ǕɛɐǕɕG ɕ΄ɕɘɕɔɐǕǕǓǓɧ ǕƌɜȾɕɣůƌ 5.12:

$$G = \left(\frac{C_D\, A_p\, \rho\, v_p^3}{2 V \varepsilon} \right)^{\frac{1}{2}} = \left(\frac{1{,}9 \cdot 44{,}8 \cdot 999 \cdot 0{,}293^3}{2 \cdot 2250 \cdot 1{,}14 \cdot 10^{-3}} \right)^{\frac{1}{2}} = 37{,}7\ s^{-1}$$

ȷ p ǕɞǓɘƌǕɘíȲɜǕǓǕɜɘɕ΄ɘɜ

$$A_p = (4\ \text{Ȳɜɕɜ}) \left(4\ \frac{\text{ɘɕ΄ɘȲ}}{\text{Ȳɜɕɜ}} \right) \left(0{,}2 \cdot 14\ \frac{m^2}{\text{ɘɕ΄œ}} \right) = 44{,}8\ m^2$$

V ǕɞǕǝɕ ɧɔǝɕɠǛɖɠ ǖǕɜǕɛǕɜɐɠɖɟɧɛɓϒůɖɠ

$V=30\cdot15\cdot5=2250\ m^3$

ɟ ǕɞǕǝɖ ´ɡǝɜɧǛɖǛǛ Ǜɕɡ ɜǕɟɕɨ ůǛɕɡɠ 15 °C (999 kg/m³) ǝǕǝɛ Ǜɕ ǖɡɜǕɛɘǝɧ ɘɜ ǖǕɠ Ǜɕɡ ɜǕɟɕɨ ůǛɕɡɠ 15 °C (1,14•10⁻³ kg/m·s)

Ɐɟɩ ǛɖɛǓ3

O ɡǖɟǕɡǝɘɧɠɕɟɧɜɕɠ´ǕɟǕɛɕɜɐɠůǛɖ ǖǕɜǕɛǕɜɐ ɖɟɧɛɓϒůɖɠǕɞǕǝɕ ǝɧɔɕɠǛɕɡ ɧɔǝɕɡ Ǜɖɠ ǖǕɜǕɛǕɜɐɠ´ɟɕɠǛɖɜ Ǘɕǘɕǖɕ Ǜɕɨ ɛǕɜɖ ´Ǖɟɕɕɐ ɜǕɟɕɨ :

$$T=\frac{V}{Q}=\frac{2250m^3}{100000m^3/d}=0{,}0225d\quad\rightarrow\ 0{,}0225d\,\frac{24h}{d}\,\frac{60min}{h}=32{,}4min$$

Ɐɟɩ ǛɖɛǓ4

¢ Ǜɛɐ Ǜɕɡ ɔɘɞɕɛɏɜɕɡ G¢ ǕɞǕɜ

$$G\not{c}=37{,}7\ \frac{1}{s}\ 32{,}4\ min\ \ 60\frac{s}{min}=73288=73{,}3\cdot10^3$$

ɄǕɟƳǖǕɔɛǓ5.3

ɀ ɘǓɛǕɜǕɜǖɟɘɐ ǖǕɜǕɛǕɜɐ ɛǕɕϒɟɑůɛǓǛǛǝǕɟɕɐ Ƴɜϒ ǝǕǝƳǛϒ Ǔ ɧ ǛǛɕϒɟɑůɛǓǛǛ ´ɟɕɕɟɑɛǛǛǛǝɔǝǓ ɡǖɟǕɡǝɘɐ ɓɟǕǖǕɖǓ ǕɜƳɛɘɖ ɛǕɓǕɟɨ ǛɖǛǛ. Ƀǝǖǝ ǕůǕƳůǕɠǛɖɠǖɘǕǖɟɕɛɐɠ ǕɞǕɜ ɛɐǝɕɠ 150 m, ´ǝƳǛɕɠ 0,5 m, ɛɏůɕ ɓƳɖɕɠ ɡɔɟɕɨ 1,2 m. ¢ ǖǕɜǕɛǕɜɐ ǖɏɕǛǛǕǝ ´Ǖɟɕɕɐ ɜǕɟɕɨ ɑɖ ɛǕ5500 m³/d ǝǕǝǖǝǕɛɕɟǘɩ ɜǛǛǝ´ɘǕɕɛǛɟɘɐ Ǔ ɩ ǝǕɘǓ 0,4 m ɛǛǛɜɨ ǕůɧǖɕɡǝǕǝǕɧǖɕɡ. ⱯƳɜ ɖ ɖǕɟɛɕǝɟǕůɖǓ Ǜɕɡ Ǘɕǘɕǖɕ Ǜɕɨ ɛǕɜɕɡ ɜǕɟɕɨ ǕɞǕǝ 15 °C ɜǓ ɡ´ɕǝɕɔɘůɖɕɨ ɜ:

1. ¢ ǝǝɑɖ ǛǛɕɨ ǛɖǛǛɠ (G) ´ɕɡ Ǖ ɘǛɟɔɕƳɜǕɖ ǖǕɜǕɛǕɜɐ ɖɟɧɛɓϒůɖɠ
2. ¢ Ǜɛɐ Ǜɕɡ ɔɘɞɕɛɏɜɕɡ G¢.

ʂ ɨ ůɖ

Ɐɟɩ ǛɖɛǓ1

ȻǛɕɡɠ 15 °C Ǜɕ ǖɡɜǕɛɘǝɧ ɘɜ ǖǕɠ Ǜɕɡ ɜǕɟɕɨ ɛ ǕɞǕǝ ɑɕ ɛǕ 1,14 cp ɐ 1,14•10⁻³ kg/m·s ǝǕǝɖ ´ɡǝɜɧǛɖǛǛ Ǜɕɡ ɜǕɟɕɨ ǕɞǕǝ 999 kg/m³.

Ƀ ɧɔǝɕɠǛɕɡ ɜǕɟɕɨ ůǛɖ ǖǕɜǕɛǕɜɐ ǕɞǕǝ $150\cdot0{,}5\cdot1{,}2=60\ m^3$

¢ ɘůɕɨɠ´ɕɡ ǕɜǛɘůǛɕɘɕǕůǕ´ɘǕɕɛǛɟɘɐ Ǔ ɩ ǝǕɘǓ ɸh ǕɞǕɜ

$P = Q\rho\, g\, \phi h$

[illegible]

$$G=\sqrt{\frac{P}{\varepsilon\cdot V}}=\sqrt{\frac{Q\rho g h}{\varepsilon\cdot V}}=\sqrt{\frac{\frac{5500}{24\cdot60\cdot60}\frac{m^3}{s}\;999\frac{kg}{m^3}\;9{,}81\frac{m}{s^2}\;0{,}35m}{1{,}14\cdot10^{-3}\frac{kg}{m\cdot s}\;90\;m^3}}=46{,}1s^{-1}$$

[illegible] 2

[illegible]:

$$\theta=\frac{V}{Q}=\frac{90\;m^3}{5500\;m^3/d}=0.0164\;d\;\rightarrow 0{,}0164\,d\;\frac{24\;h}{1\;d}\;\frac{60\,min}{1\;h}=23{,}6\;min$$

[illegible] $G\theta$ [illegible]:

$$G\theta=46{,}1\;\frac{1}{s}\;23{,}6\;min\;\;60\;\frac{s}{min}=65277{,}6=65{,}3\cdot10^3$$

5.5 [illegible]

[illegible]

[illegible] ζ^+ [illegible] ξ^-.

[illegible] 5.3 [illegible]

[illegible]	K_{sp} [illegible] 20 °C	[illegible]
$CaCO_3 \Leftrightarrow Ca^{2+} + CO_3^{2-}$	$5 \cdot 10^{-9}$	[illegible]
$Ca(OH)_2 \Leftrightarrow Ca^{2+} + 2OH^-$	$8 \cdot 10^{-6}$	[illegible]
$MgCO_3 \Leftrightarrow Mg^{2+} + 2OH^-$	$2 \cdot 10^{-5}$	[illegible]
$Mg(OH)_2 \Leftrightarrow Mg^{2+} + 2OH^-$	$9 \cdot 10^{-12}$	[illegible]
$Al(OH)_3 \Leftrightarrow Al^{3+} + 3OH^-$	$1 \cdot 10^{-32}$	[illegible]
$Fe(OH)_3 \Leftrightarrow Fe^{3+} + 3OH^-$	$6 \cdot 10^{-38}$	[illegible]

[illegible]

$$K_{sp} = [M^+]\,[X^-] \qquad \textbf{5.13}$$

[illegible]: K_{sp} [illegible], [[illegible] $^+$] [illegible] (mol/L) [illegible] $[X^-]$ [illegible] (mol/L).

[illegible] MpXq, [illegible]:

$$K_{sp}=[M^{q+}]^p\,[X^{p-}]^q \qquad \textbf{5.14}$$

[illegible] 5.3 [illegible] 5.14 [illegible] K_{sp} [illegible].

5.6 [illegible]

[illegible]:

$$Ca^{2+} + CO_3^{2-} \Leftrightarrow CaCO_{3(s)} \qquad \textbf{5.15}$$

$$Mg^{2+} + 2OH^- \Leftrightarrow Mg(OH)_{2(s)} \qquad \textbf{5.16}$$

[illegible] pH [illegible] 10,3 [illegible]

əŬŰŬəɈɐɛɜɘůɖ Űɕg ǥŭɈɞɜŮɘŭɶg Űɕg ɛŬɜɖůɶg ɗŬ ´Ɉɏ´Ůə ɜŬ ɔɶŮə Ŭɜɨɣɤůɖ Űɕg pH ůŰɖɜ Űɕɛɐ 10,8-11,0. ȺƳɜ ŭŮɜ g´ƳɈɢŮə ɘŬɜɞ´ɞɖŰəɧ Ů ɑ́ Ůŭɞ űgůɘɐʃ ŬəŬəɘɧŰɖŰŬʃ (HCO_3^-) ůŰɕ ɜŮɈɧ (ŬgŰɧ ůgɛɓŬɶŮəɧŰŬɜ ŮəŰɧʃŬ ɧ Űɖɜ ŬɜɖɈŬəɘɐ ůəəɖɈɧŰɖŰŬ Űɕ ɜŮɈɧ ´ŮɈɘɏɢŮə əŬə ɛɖ ŬɜɖɈŬəɘɐ ůəəɖɈɧŰɖŰŬ) ɩ ůŰŮ ɜŬ ŮɶŬə ŭgɜŬŰɧɜ ɜŬ ´Ɉɞəɨɣɞgɜ (ɛŮ Ŭɜɨɣɤůɖ Űɕg pH) ɧəŬ ŰŬ ŬɜɖɈŬəɘƳ ɘɧɜŰŬ (CO_3^{2-}) ´ɞg Ŭ ŬəŰɕɨɜŰŬə ɔəŬ Űɖɜ əŬŰŬəɈɐɛɜɘůɖ Űɕg Ŭůɓůɨŭɶg (Ca^{2+}) ůŬɜ ŬɜɖɈŬəɘɞɨ Ŭůɓůɨŭɶg ($CaCO_{3(s)}$) ŰɧŰŮ ɗŬ ´Ɉɏ´Ůə ɜŬ ɔɶŮə ŮɜɤŰŮɈɘɐ ´ɈɞůɗɐəɖŬɜɖɈŬəɘɩ ɜ ɘɧɜŰɤ ɜ. H ´ɈɞůɗɐəɖŬgŰɐ ɔɶŮŰŬə ůgɜɐɗɤʃg´ɧ ɛɞɈűɐ ŬɜɖɈŬəɘɞɨ ɜŬŮɈɶgɐ ůɧŭŬʃ(Na_2CO_3).

¢ ŬűŬgɈŮůɖ ůəəɖɈɧŰɖŰŬʃ ɛŬɜɖůɶg ŮɶŬə ´ɘɞ ŭɨůəɞəɖ əŬə ůgɜŮƳɔŮŰŬə ɛŮɔŬəɨŰŮɈɞ əɧůŰɕʃŬ ƌɧŰə ɖ ŬűŬgɈŮůɖ ůəəɖɈɧŰɖŰŬʃ Ŭůɓůɨŭɶg əŬə ɔəŬ Űɕ əɧɔɞ ŬgŰɧ Űűɐɜɞgɛůůgɜɐɗɤʃɧůɞ Űɕ ŭgɜŬŰɧ ´ŮɈɘůůɧŰŮɈɖ ´ɞůɧŰɖŰŬg´ɞəŮə́ ɧɛŮɜɖʃůəəɖɈɧŰɖŰŬʃ ɛŬɜɖůɶg ůŰɕ Ů ŮɜŮɈɔŬůɛɏɜɞ ɜŮɈɧ. Ⱥ´ɑůɖʃ əŬə ɖ ŬűŬgɈŮůɖ Űɖʃ ɛɖ ŬɜɖɈŬəɘɐʃ ůəəɖɈɧŰɖŰŬʃ əɞůŰɕŮə ´ŮɈɘůůɧŰŮɈɞ Ŭ ɧ Űɖɜ ŬűŬgɈŮůɖ ŬɜɖɈŬəɘɐʃ ůəəɖɈɧŰɖŰŬʃ əŬə ɏŰůə´Ɉɞ ŰɕɛƳŰŬəɖ ɛɘɈɧŰŮɈɖ ŭgɜŬŰɐ ŬűŬgɈŮůɖ ɛɖ ŬɜɖɈŬəɘɐʃůəəɖɈɧŰɖŰŬʃ.

Ƀə ŬɜŰɘŭɈƳůŮɘʃ ´ɞg əŬɛɓƳɜɞgɜ ɢɩ ɈŬ əŬŰƳ Űɖɜ Ŭ ɞůəəɐɈgɜůɖ Űɕg ɜŮɈɞɨ ŮɜŬɈŰ ɜŰŬ Ŭ ɧ Űɖɜ Űɕɛɐ Űɕg pH ´ɞg Ů ɘɓƳəəŮŰŬ. ȷ ɈɢɘƳ ɔɶŮŰŬə ŮɜɞgŭŮŰɏɈɤůɖ Űɕg ŭɘɜɜŮɘŭɶg Űɕg ƳɜɖɈŬəŬ ´ɞg g´ƳɈɢŮə ůŰɕ ɜŮɈɧ əŬə ůŰɖ ůgɜɏɢŮŬ Ŭəɞəɞgɗŭɑ Ŭɜɨɣɤůɖ Űɕg pH ɔəŬ ɜŬ ůɢɖɛŬŰɘůɗŭɑ əŬə əŬŰŬəɈɖɛɜɘůɗŭɑ ŬɜɖɈŬəɘɧ Ŭůɓɏůɕɜ. ȺƳɜ ŮɶŬə Ů ɘɖgɛɖŰɐ ɖ ŬűŬgɈŮůɖ əŬə ɛŬɜɖůɶg Ŭəɞəɞgɗŭɑ´ɈŬ ɏɈŬ Ŭɜɨɣɤůɖ Űɕg pH ɩ ůŰŮɜŬ ůɢɖɛŬŰɘůɗŭɑ əŬə ɜŬ əŬŰŬəɈɖɛɜɘůɗŭɑ ǥŭɈɞɜŮɘŭɘɞ Űɕg ɛŬɜɖůɶg. ȷ əɧɛɖ ŮƳɜ ŮɶŬə Ů ɘɖgɛɖŰɐ əŬɖ ŬűŬgɈŮůɖ ɛɖ ŬɜɖɈŬəɘɐʃůəəɖɈɧŰɖŰŬʃ ɔɶŮŰŬə´ɈɞůɗɐəɖůɧŭŬʃ ɩ ůŰŮ ɜŬ ůɢɖɛŬŰɘůɗŭɑəŬəəŬŰŬəɈɖɛɜɘůɗŭɑŬɜɖɈŬəɘɧ Ŭůɓɏůɕɜ.

Ȯɜə ůɖɛŬɜŰɘɏʃ ŬɜŰɘŭɈƳůŮɘʃ əŬɛɓƳɜɞgɜ ɢɩ ɈŬ əŬŰƳ Űɖɜ Ŭ ɞůəəɐɈgɜůɖ Űɕg ɜŮɈɞɨ ɛŮɢɈɖůɘɞ´ɞɑɖůɖ ǥŭɈɞɜŮɘŭɶg Űɕg Ŭůɓůɨŭɶg əŬə ŬɜɖɈŬəɘɞɨ ɜŬŮɈɶg. Ƀə ŬɜŰɘŭɈƳůŮɘʃ ŬgŰɏʃ ´ŬɈɞgůəƳɞɜŰŬ ůŰɘʃ Ů ɧɛŮɜŮʃ ´ŬɈŬɈƳɞgʃ. ɆŮ əƳɖŮ ŬɜŰɘŭɈŬůɖ ɖ ɞgůɗŬ´ɞg ´ɈɞůŰɖŮŰŬə ůgɛɓɞəɶŮŰŬə ɛŮɏɜŰɕɜɞgʃ ɢŬɈŬŰŰɈŮʃ əŬə Űɕ ɞgůɗŬ-ɶɖɛŬ´ɞg ´Ɉɞəɨ´ŰŬə űŬɶŮŰŬə ɧ Űɕɜ ůgɛɓɞəɘůɛɧ (s) ůŰɕ əƳŰɤ ŭŮəɘɧ ɛɏɈɞʃ Űɕg ɢɖɛɘɞɨ Űɨ´ɞg Űɖʃ.

1. ***ȺɜɞgŭŰŮɏɈɤůɖ Űɕg ŭɘɜɜŮɘŭɶg Űɕg ƳɜɖɈŬəŬ***

ɇɞ ŭɘɜɜŮɘŭɘɞ Űɕɨ ƳɜɖɈŬəŬ ´ɞg ɓɈɑəŬŰŬə ŭəŬgɛɏɜɞ ůŰɕ ɜŮɈɧ ŮɜɞgŭŰŮɈɩ ɜŰŬə Ŭ ɧ ɛɘŬ´ɞůɧŰɖŰŬ ǥŭɈɞɜŮɘŭɶg Űɕg Ŭůɓůɨŭɶg ´ɞg ´ɈɞůŰɖŮŰŬə.

$$CO_2 + \mathbf{Ca(OH)_2} \text{ Ÿ } CaCO_{3(s)} + H_2O \qquad \mathbf{5.17}$$

2. *ፕỦŰŰəɟ ɐ ɛ ɜ ɘủɖ ŰɖƒỦɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ Ủủɓ Ủủ Űɞg*

ȳ´ɤ ƒ ɏɕỦə ɐủɖ Ủɜ Űi Ủ ɖ Ủɑ ɖỦ´ ɟɏ´ Ủə ɜ Ủ ɔɞ Ủə Ủɜ ɨ ɣɤ ủɖ Űɞg pH ủŰɖɜ Űɛɐ 10,3 ɔɘỦ ɜỦ ɔɞ Ủə ɘ Ủɜɞ´ɞɘɖŰəɐ ɛ ỦŰŰ Ủ ɞ´ɐ ɧɜɘɤɜ Ủɜɖɟ Ủəɘι ɜ ủỦ Ủɜɖɟ Ủəɘ Ɏ ə Ủə ɜỦ ə ỦŰŰəɟ ɖɛ ɜɘủɖŰɑ Ủɜɖɟ Ủəɘɧ Ủủɓɏủ Űɞ.

$$Ca^{2+} + 2HCO_3^{-} + \mathbf{Ca(OH)_2} \rightarrow 2CaCO_{3(s)} + 2H_2O \qquad \mathbf{5.18}$$

3. *ፕỦŰŰəɟ ɐ ɛ ɜ ɘủɖ ŰɖƒỦɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ ɛ Ủɜɖủɞg*.

ŌɎɜ ủɞ Ủə Ủ ɘɖgɛɖŰɐ ɖ Ủi Ủg Ủɑɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ ´ɞg ɞű Ủəɘ ŰŰə ủỦ ɛ Ủɜɐ ủɞ ɖỦ´ ɟɏ´ Ủə ɜ Ủ ɔɞ Ủə Ủɜ ɨ ɣɤ ủɖ Űɞg pH ủŰɖɜ Űɛɐ 10,8-11,0. Ʉi ɛ´ɞɟɞɨ ɛ Ủɜ Ủ ɖŰɤ ɟɐ ủɞg ɛ Ủi ɨ ɞ ŭɘ Ủiɞɞɘ Ɏ ủŰɎiɘỦ Ủɜ Űiɟ Ɏ ủŰɤ ɜ. ɆŰɞ ´ɟι Űɞ ủŰɎiɞ ɔɞ ỦŰŰə ɛ ŰŰŰ ɞ´ɐ Űɤ ɜ ŭɘ ủ Ủɜɖɟ Ủəɘι ɜ (HCO_3^{-}) ´ɞg Ủɜ Űə ủŰɞ ɕɞɨ ɜ ủŰɖɜ Ủɜɖɟ Ủəɘɐ ủəɚɖɟ ɧŰɖŰŰ ɛ Ủɜɖ ủɞg ủỦ Ủɜɖɟ Ủəɘ Ɏ (CO_3^{2-}) ủɨ ɛ űɤ ɜ Ủ ɛ ỦŰɖɜ Ủɜ Űiɟ Ủɑɖ 5.19.

$$Mg^{2+} + 2HCO_3^{-} + \mathbf{Ca(OH)_2} \rightarrow CaCO_{3(s)} + MgCO_3 + 2H_2O \qquad \mathbf{5.19}$$

Ɇɖ ɛ Ủə ɜ ŰŰə ɧŰə ɛ Ủ Űɖɜ Ủɜ Űiɟ Ủɑɖ 5.19 ŭ Ủɜ ɛ Ủə ɜ ŰŰə ɖ ủəɚɖɟ ɧŰɖŰŰ ɛ Ủɜɖ ủɞg Ủi ɞɨ Űɞ Ủɜɖɟ Ủəɘɧ ɛ Ủɜɐ ủɞ ´ɞg ´ɟɞəɨ ´ŰŰə Ủɞ Ủə Ủg ŭ Ɏɚg Űɞ. ɄɎɜ ɧɛɤ ƒ ɔɞ Ủə ´ɟɞ ủɖɐ əɖ ə Ủə Ɏɚɖ ƒ´ɞ ủɧŰɖŰŰƒ gŭɟ ɞɜ Ủɞ ủɞg Űɞg Ủủɓ Ủủ Űɞg ι ủŰŰ Űɞ pH ɜ Ủ ű Ű Ɏ ủ Ủə ủŰɖɜ Űɛɐ 10,8-11,0 ŰɧŰŰ ɖỦ´ ɟ Ủɜɛ ỦŰɞ´ ɞɘɖ ɖ Ủɑɖ Ủɜ Űiɟ Ủɑɖ 5.20 ə Ủə ɖỦ ə ỦŰŰəɟ ɖɛ ɜɘủɖŰɑɖ ủəɚɖɟ ɧŰɖŰŰ ɛ Ủɜɖ ủɞg ɛ ỦŰɖ ɛɞɟ űɐ Űɞg ŭg ủŭɘ Ɏɚg Űɞg gŭɟ ɞɜ Ủɞ ủɞg Űɞg ɛ Ủɜɖ ủɞg:

$$Mg^{2+} + CO_3^{2-} + \mathbf{Ca(OH)_2} \rightarrow Mg(OH)_{2(s)} + CaCO_{3(s)} \qquad \mathbf{5.20}$$

4. *ɟ űỦg Ủủɖ ɛɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ Ủủɓ Ủủ Űɞg*

ɄɎɜ ɖɏɚɞg ɛ Ủ ɜ Ủ Ủi Ủɟ ɏủɞg ɛ Ủ ə Ủə ɛɖ Ủɜɖɟ Ủəɘɐ ủəɚɖɟ ɧŰɖŰŰ ´ɞg Ủɜ Űə ủŰɞ ɕ Ủɑ ủỦ Ủủɓɏủ Űɞ ɖỦ´ ɟɏ´ Ủə ɜ Ủ ɔɞ Ủə ´ɟɞ ủɖɐ əɖ Ủɜɖɟ Ủəɘι ɜ ɘɧɜ Űɤ ɜ ɛ Ủ ɛɞɟ űɐ ´.ɞ. Ủɜɖɟ Ủəɘɞɨ ɜ ŰŰ ɞg (ủɧŭ Ủg). ¢ Ủɜ Ű ủŰɞ ɕɖ Ủɜ Űiɟ Ủɑɖ ủɞ Ủəɖ 5.21.

$$Ca^{2+} + \mathbf{Na_2CO_3} \rightarrow CaCO_{3(s)} + 2Na^{+} \qquad \mathbf{5.21}$$

5. *ɟ űỦg Ủủɖ ɛɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ ɛ Ủɜɖ ủɞg*

ũɘỦ Ủi Ủg Ủɑɖ ɛɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ ɛ Ủɜɖ ủɞg Ủ Ủə ŰŰ ɖŰŰə gŭɟ ɞɜ Ủɞ ŭɞ Űɞg Ủủɓ Ủủ Űɞg ι ủŰŰ ɜ Ủ ủɕɖ ɛ ỦŰə ủɖ Ủɑ Űɞ ŭg ủŭɘ Ɏɚg Űɞ gŭɟ ɞɜ Ủɞ ŭɞ Űɞg ɛ Ủɜɖ ủɞg ủɨ ɛ űɤ ɜ Ủ ɛ Ủ Űɖɜ Ủɜ Űiɟ Ủɑɖ 5.22.

$$Mg^{2+} + \mathbf{Ca(OH)_2} \rightarrow Mg(OH)_{2(s)} + Ca^{2+} \qquad \mathbf{5.22}$$

ȳ´ɤ ƒ ɧɛɤ ƒ ű Ủɞ ŰŰŰə Ủ ɧ Űɖɜ Ủɜ Űiɟ Ủɑɖ 5.22 ɖ Ủi Ủg Ủɑɖ ɛɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ ɛ Ủɜɖ ủɞg ɏɕ Ủə ủ Ủɜ Ủ ɞ Űɏɚ Ủ ɛ Ủ Űɖɜ Ủə ủ Ủɓɤ ɔɐ ủŰɞ ɜ Ủ ɧ ɘ ủɞ ŭ ɨ ɜ Ủɛ ɖƒ ´ɞ ủɧŰɖŰŰƒ ɛɖ Ủɜɖɟ Ủəɘɐƒ ủəɚɖɟ ɧŰɖŰŰƒ Ủủɓ Ủủ Űɞg ɖ ɞ´ɞ ɖỦ ɔɘỦ ɜ Ủ ə ỦŰŰəɟ ɖɛ ɜɘủɖŰɑ ủ Ủɜ Ủɜɖɟ Ủəɘɧ Ủủɓɏủ Űɞ Ủ Ủə ŰŰɑ Űɖɜ ´ɟɞ ủɖɐ əɖ ɘủ ɞ ŭ ɨ ɜ Ủɛ ɖƒ ´ɞ ủɧŰɖŰŰƒ Ủɜɖɟ Ủəɘɞɨ ɜ ŰŰ ɞg ɧ˝ɤɠűŬɞŮǕǕɘŬɧǕȡɜŬɜǕǖĵŬůȡ 5.23 ȡɕ˝ɕȡŬŮɞŬɘȡ ǳɘŬɛŮǕȡɜŬɜǕǖĵŬůȡ 5.21 ˝ɕɡ ŬɜŬǘǥĵŮǕǕɘůǕȡɜŬǘŬǥŮȡǕȡɠŮĵɕɘɐɠɛȡŬɜȡĵŬɘɘɐɠůɘɚȡĵɧǕȡǕǕɠŬůɓŮůǕɞɡ.

$$Ca^{2+} + \mathbf{Na_2CO_3} \rightarrow CaCO_{3(s)} + 2Na^{+} \qquad \mathbf{5.23}$$

5.6.1 ɊɧůŮɠɕȡɛɘɩɜɔɘŬŬɕůɘɚɐĵɡɜůȡ

ǺŸɜɔɘŬǕȡɜŬɕůɘɚɐĵɡɜůȡǕɞɡɜŮĵɕɨɕĵȡůɶɕ˝ɕɘȡȡŮǖ˝ŮĵǳůŮɞŬɡǖĵɕɜŮɞǘɞɡǕɞɡ ŬůɓŮůǕɞɡɘŬɜůɧǖŬɕɘǖɧůɞɠɕȡɛɘɩɜ˝ɕɡ˝ĵǥ˝ŮɜŬ˝ĵɕůŮǕȡɕɨɜŮɞŬɜ

ɊɧůȡɡǖĵɕɜŮɞǘɞɡǕɞɡŬůɓŮůǕɞɡ:

$$[Ca(OH)_2] = [CO_2] + [HCO_3^{-}] + [Mg^{2+}] + [\text{´ŮĵǳůŮɞŬ}\, Ca(OH)_2] \qquad \mathbf{5.24}$$

ɆǕȡ ůɕǥůȡ 5.24 ɕɘ ůɡɔɘŮɜŮĵɩůŮɠǕɤɜ ǖɘŬǘɧĵɤɜ ůɡůǕǕǕɘɩɜ ɛǥůŬ ůǕɠŬɘɨɚŮɠ Ůɘűĵ Ÿɕɕɜ ǕɘůŮmgȾ/L ɐ ůŮmg/L ůŬɜ $CaCO_3$. ¢ ˝ŮĵǳůŮɞŬ ɡǖĵɕɜŮɞǘɞɡ Ǖɞɡ ŬůɓŮůǕɞɡ ˝ɕɡ ˝ĵɕůǕȡŮǕǕɘŮɞŬɘůɡɜɐȡɤɠůǕȡɜ˝Ůĵɛɕɐ 40-70 mg/L ůŬɜ $CaCO_3$.

Ɋɧůȡ ůɧǖŬɠ

$$[Na_2CO_3] = [Ca^{2+}] + [Mg^{2+}] - [\text{ŬɘɘŬɘɘɧǕȡǕǕ}] = [\text{ɛȡŬɜȡĵŬɘɘɐ ůɘɚȡĵɧǕȡǕǕ}] \qquad \mathbf{5.25}$$

ĵ˝ŮɜȡɡɛɕŮǕǕɘɧǕɘůǕǕűɡůɘŸɜŮĵŸɧǕǕɜȡŬɘɘŬɘɘɧǕȡǕǕŮɞŬɘɛɘĵɧǕǕĵȡŬɧǕȡɜ ɕɚɘɐůɘɚȡĵɧǕȡǕǕǕɧǕǕȡŬɘɘŬɘɘɧǕȡǕǕŮɞŬɘǳůȡɛŮǕȡɜŬɜȡĵŬɘɘɐůɘɚȡĵɧǕȡǕǕ.

ƗĵɕůȡɐɘȡůɧǖŬɠɔɕŮǕǕɘ˝ĵɕɘŮɛǥɜɕɡɜŬŮɞŬɕȡɕɨɜŬɜȡĵŬɘɘŸɧɜǕǕǕɕ˝ɕȡŬ ŮɞŬɘŬŮĵŬǕȡǕǕɔɘŬǕɜůɕȡɛŬǕŮɛɧŬɜȡĵŬɘɘɕɨŬůɓŮůǕɞɡŬɧŬɜǕǖĵŬůȡɛŮǕɧɜǕǕ ŬůɓŮůǕɞɡ˝ɕɡɡ˝ŸĵɕɕɡɜůǕůɨůǕȡɛŬɘŬɜǕůǕɞɕɕɨɜůŬɛȡŬɜȡĵŬɘɘɐůɘɚȡĵɧǕȡǕǕ.

ɆǕȡɜ ůɕǥůȡ 5.25 ɕɘ ůɡɔɘŮɜŮĵɩůŮɠǕɤɜ ǖɘŬǘɧĵɤɜ ůɡůǕǕǕɘɩɜ ɛǥůŬ ůǕɠŬɘɨɚŮɠ Ůɘűĵ Ÿɕɕɜ ǕɘůŮmgȾ/L ɐ ůŮmg/L ůŬɜ $CaCO_3$.

ȳ˝ɤɠɧɛɤɠǥɕŮɘɐůȡŬɜǕŮĵȡŮůɡɜȡȡɕŮǕǕɘɜŬɔɕŮǕǕɘŬǘŬɡĵŮůȡ ůɘɚȡĵɧǕȡǕǕɠ ɛŬɜȡůɕɡ ɛǥɕĵɘ ɡ˝ɕɚŮ˝ɧɛŮɜɕɡ Ůɘ˝ǥǖɕɡ 40 mg/L ůŬɜ $CaCO_3$ ɘŬɘ ŬǘŬɡĵŮůȡ ǕȡɠɛɘĵɧǕǕĵȡɠǖɡɜŬǕɐɠ˝ɕůɧǕȡǕǕɠɛȡŬɜȡĵŬɘɘɐɠůɘɚȡĵɧǕȡǕǕɠɩůǕǕɧɚȡȡɡ˝ɕɚŮ˝ɧɛŮɜȡ ůɘɚȡĵɧǕȡǕǕɜŬ˝ŮĵɘŬɛɓŸɜŮɘǕȡɜɛǥɔɘůǕȡǖɡɜŬǕɐůɡɜŮɞűɕĵŸŬɧɛȡŬɜȡĵŬɘɘɐ ůɘɚȡĵɧǕȡǕǕ. ǺŸɜɚɕɘ˝ɧɜɚȡűȡŮɕɡ˝ɧɤȡɘŬɜȡɡ˝ɕɚŮ˝ɧɛŮɜȡɛȡŬɜȡĵŬɘɘɐůɘɚȡĵɧǕȡǕǕ (ȡɕ˝ɕȡŬůŮŬĵɘŮǕǥɠ˝Ůĵɘ˝ǕůŮɠŮɞŬɘůȡɛŬɜǕɘɐ)ǕɧǕǕȡǖɧůȡůɧǖŬɠ˝ɕɡŮɞŬɘǖɡɜŬǕɧɜ ɜŬɕĵȡůɶɕ˝ɕɘŮǕǕɘǖɕŮǕǕɘŬɧǕȡɜůɕǥůȡ 5.26.

$$\begin{gathered}[Na_2CO_3] = [\text{ɛȡŬɜȡĵŬɘɘɐ ůɘɚȡĵɧǕȡǕǕ}] \times \\ [\text{ɡ˝ɕɚŮ˝ɧɛŮɜȡ ɛȡŬɜȡĵŬɘɘɐ ůɘɚȡĵɧǕȡǕǕ}]\end{gathered} \qquad \mathbf{5.26}$$

ɆǕȡ ůɕǥůȡ 5.26 ɕɘůɡɔɘŮɜŮĵɩůŮɠǕɤɜǖɘŬǘɧĵɤɜůɡůǕǕǕɘɩɜɛǥůŬůǕɠŬɘɨɚŮɠ Ůɘűĵ Ÿɕɕɜ ǕɘůŮmgȾ/L ɐ ůŮmg/L ůŬɜ $CaCO_3$.

5.6.1.1 Ʉɢǜɧǘɗǚ ǜǘǛ Ǘ ɜ ΄ ɢg ΄ ɟɢɚɨ ΄ ǘɚ ɚǙǘƔ ǘɗɜ Ǚ ɢǜɚɚɐɟgɜǜɗ ǘɛg ɜǛɢɨ ɛǗ ΄ɟɢǜɗɐɚɗ gǚɟɢɜǗǚɐg ǘɛg ǙǜɓǗǜǘɐg ɐ gǚɟɢɜǗǚɐg ǘɛg ǙǜɓǗǜǘɐg ɚǙɚǜɧǚǙǚ

¢ ΄ɢǜɧǘɗǚ ǘɤɜ ǜǘǛ Ǘ ɜ ΄ɢg ΄ɟɢɚɨ΄ǘɛgɜ ɚǙǘƔ ǘɗɜ Ǚ ɢǜɚɚɐɟgɜǜɗ ǘɛg ɜǛɢɨ ǗɜǙɟǘƔǙǚɚ ǘɧǜɢ Ǚ ɧ ǘɗɜ ǜgɔɚɐɜǛɤ ǜɗ ǘɤɜ ɚɧɜǘɤɜ ǜɚɚɗɟɧǘɗǚǚ ɧǜɢ ɚǙɚǙ ɧ Ǘǚɢǚ ǘɗǚ ǜɚɚɗɟɧǘɗǚǚ ΄ɢg ǙǘǙɟǗǚǚɚ (΄.ɢ. Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ ɐ ɛɗ Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ).

ɆǘǛ ǗƔ Ǚ ɧ ǙǘǙg Ǘɗ Ǚɜɗɟ Ǚɚɚɐǚ ɛ ɧɜɢɜ ǜɚɚɗɟɧǘɗǚǚ

ÿ ǘɜ ǙǘǙɟ ǗǚɚɚǙ ɛɧɜɢɜ ɗ Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ Ǚ ǜǘǛ ǗƔ ΄ɢg ΄ɟɢɚɨ΄ǘɛgɜ g΄ɧ ɛɢɟǘɐ ɚɨɢǚ (ɚǙɚ ǙǘǙɟɢɨ ɜǘɚ Ǚ ɧ ǘǚǜǙǘǛ Ǘɜɐǚ ɚǙɗɐɗǜɗǚ) ǗɛǙɚ Ǚɜɗɟ Ǚɚɚɧ ǙǜɓɐǜǘɐɁ ɚǙgǚɟɢɜǗǚɐ ǘɛg ɛǙɜɗǜɐg.

¢ ΄ɢǜɧǘɗǚ ǘɛg Ǚɜɗɟ Ǚɚɚɢɨ ǙǜɓǗǜǘɐg ΄ɢg ΄ɟɢɚɨ΄ǘɚ ɚǜɢǚgɜǙɛǗ ɛǗ ǘɗɜ Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ (ǙǜɓǗǜǘɐg ɚǙ ɛǙɜɗǜɐg) ΄ɢg g΄ǗɟɢǗǜǘɛ ɜǛɧ ɚǙɗ ǚ ɚǙ ǜǘɗɜ ΄ɢǜɧǘɗǚ gǚɟɢɜǗǚɐg ǘɛg ǙǜɓǗǜǘɐg ΄ɢg ΄ɟɢǜǘɐɗɚǗ ɔɚǙ ɛǗǘǚǛɢ΄ɐ ǘɗǚ Ǚɜɗɟ Ǚɚɚɐǚ ǜɚɚɗɟɧǘɗǚǚ ǙǜɓǗǜǘɐg ǜǗ Ǚɜɗɟ Ǚɚɚɧ ǙǜɓɐǜǘɐɁ ɚǙ ǘɗǚ Ǚɜɗɟ Ǚɚɚɐǚ ǜɚɚɗɟɧǘɗǚǚ ɛǙɜɗǜɐg ǜǗɚǜɢǚɨɜǙɛɢ Ǚɜɗɟ Ǚɚɚɧ ǙǜɓɐǜǘɐɁ.

¢ ΄ɢǜɧǘɗǚ ǘɛg gǚɟɢɜǗǚɐg ǘɛg ɛǙɜɗǜɐg ΄ɢg ΄ɟɢɚɨ΄ǘɚ ǗɛǙɚɚǜɢǚɨɜǙɛɗ ɛǗǘɗ ǜɚɚɗɟɧǘɗǚ ɛǙɜɗǜɐg (Ǚɜɗɟ Ǚɚɚɐ ɚǙ ɛɗ Ǚɜɗɟ Ǚɚɚɐ) ΄ɢg ΄ǛɚǗɢǗǘǛ Ǘ ǗɜǛɔǙɛɧɛǗɢ ɜǛɧ.

¢ ǜgɜɢɚɚɐ ΄ɢǜɧǘɗǚ ǜǘǛ Ǘ ɜ ɚɨɢǚ ǗɛǙɚ:

$$S= 2{,}0\ Ca_A^{2+}+2{,}0\ Mg_A^{2+}+0{,}58\ Mg^{2+}=2{,}0\ (Ca_A^{2+}+Mg_A^{2+})+0{,}58\ Mg^{2+} \qquad \mathbf{5.27}$$

$$S=2{,}0\ (\text{Aɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ})+0{,}58\ (\text{Ɇɚɚɗɟɧǘɗǚ ɛǙɜɗǜɐg}) \qquad \mathbf{5.27Ǚ}$$

ɧ΄ɢg: S ɗ ǜgɜɢɚɚɐ ΄ɢǜɧǘɗǚ ǜǘǛ Ǘ ɜ (mg/L ǜǙɜ $CaCO_3$), Ca_A^{2+}ɗ Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ ǙǜɓǗǜǘɐg (mg/L ǜǙɜ $CaCO_3$), Mg_A^{2+}ɗ Ǚɜɗɟ Ǚɚɚɐ ǜɚɚɗɟɧǘɗǚ ɛǙɜɗǜɐg (mg/L ǜǙɜ $CaCO_3$) ɚǙ Mg^{2+} ɗ ɢɚɚɐ ǜɚɚɗɟɧǘɗǚ ɛǙɜɗǜɐg (mg/L ǜǙɜ $CaCO_3$).

Ɐ ǜgɜǘǙǗǜǘɐǚ Ɐ,58 (0,583) ǜǘɗ Ɇɢɐǜɗ 5.27 ɛǗǘǙɟɐ Ǘ ǘɗɜ ΄ɢǜɧǘɗǚ ǘɛg gǚɟɢɜǗǚɐg ǘɛg ɛǙɜɗǜɐg ΄ɢg ΄ɟɢɚɨ΄ǘɚ Ǚ ɧ ǘɗɜ ɚǙǘǚɟɐɛɜɚǜɗ ǜɚɚɗɟɧǘɗǚǚ ɛǙɜɗǜɐg ǜǗɚǜɢǚɨɜǙɛɗ ΄ɢǜɧǘɗǚ Ǚɜɗɟ Ǚɚɚɢɨ ǙǜɓǗǜǘɐg:

$$\begin{array}{ccc} Mg(OH)_2 & \rightarrow & CaCO_3 \\ 24{,}3+2\cdot 17 & & 40+12+3\cdot 16 \\ 58{,}3 & & 100 \end{array}$$

Ɇɗɛ Ǘɚ ɜǗǘǙ ɧǘ ǜǘɗɜ ΄ɢǜɧǘɗǚ ǘɤɜ ǜǘǛ Ǘ ɜ ΄ɢg Ǚɜǘɚǜǘɛɢɚ ǜǘɗ Ɇɢɐǜɗ 5.27 ɗǙ ΄ɟɐ Ǘɜ Ǚ΄ɟɢǜǘǘǗɚɚǙɗ ɚǜɢǚɨɜǙɛɗ ΄ɢǜɧǘɗǚ Ǚɜɗɟ Ǚɚɚɢɨ ǙǜɓǗǜǘɐg ΄ɢg ǙɜǘɚǜǘɛɢǗɚ

ůŰɖɜ ´ Ůɟɑůů ŮəŰŰɛɡ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŮůɓŮıŰœɡ ´ɕɡ ´ɟɕůŰɑŮŰŰəəŰəŰıŰəɟŮɑŰŰəəŰŰŸŰɛ ůŰŸŭɛ Űɖʃ Ů Űɜɖɟ Ÿəx ůɖʃ.

ƐŰŮɟ ŮŸ Ŭ ɧ ŬıŬɡ Ůɖ Ŭɜɖɟ Ŭəɘɐʃə Ŭəɛɖ Ŭɜɖɟ Ŭəɘɐʃ ůəəɖɟɧŰɖŰŰʃ

ȳŰŰɜ ŬıŬɟŮɑŰŰə əŬə ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ɔœŮŰŰə ´ɟɕůɑɐəɖ ůɧŭŬʃ ůŮ ´ɕůɧŰɖŰŰ ɘůɕŭɨɜŬɛɖ ɛŮŰɖ ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ´ɕɡ ŬıŬɟŮɑŰŰə əŬə ´ɟɕəɨ ´ŰŮə Ŭɜɖɟ Ŭəɘɧ ŬůɓɏůŰɛ ůŮ ´ɕůɧŰɖŰŰ Ů ɑɖɖʃ ɘůɕŭɨɜŬɛɖ ɛŮŰɖɜ ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ´ɕɡ ŬıŬɟŮɑŰŰə. ŌŰıəɏɕɕɡɛŮ

S=2,0 (ȷ ɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ´ɕɡ ŬıŬɟŮɑŰŰə)+

(ɀ ɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ´ɕɡ ŬıŬɟŮɑŰŰə)+0,58 (Ɛəəɖɟɧ ŰɖŰŰ ɛŬəɜɖůœɡ)+ **5.28** (ɄŮɟɑůůŮəŬɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ)

ȳ əŮʃɕə ´Ůɟ Ÿɛ ŮŰɟɕəŰɖʃ Ɛɕɏůɖʃ 5.28 ɏɕɕɡɜ ɛɕɜŸŭŮʃ mg/L ůŬɜ $CaCO_3$.

5.6.2 ɇɨ ´ɕəŭəŮɟɔŬůɘ ɜ ɔəŬ Ŭ ɕůəəɐɟɡɜůɖ Űɛɡ ɜŮɟɕɨ ɛŮ ´ɟɕůɑɐəɖ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ ɐ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ ə Ŭə ůɧŭŬʃ

ɑəŬəɟœɕɡɛŮ ŰɏůůŮɟəʃ ŭəŬıɕɟŮŰəɕɨʃ Űɨ ´ɕɡʃ ŭəŮɟɔŬůɘ ɜ ɔəŬ Ŭ ɕůəəɐɟɡɜůɖ Űɛɡ ɜŮɟɕɨ ɛŮɡŭɟɕɜŮŭɛ Űɛɡ ŬůɓŮıŰœɡ ɐ ɛŮɡŭɟɕɜŮŭɛ Űɛɡ ŬůɓŮıŰœɡ əŬə ůɧŭŬ.

1. ***ɑəŮɟɔŬůɖŬ Ůɜɧʃ ůŰŰŭœɡ ɛŮ ´ɟɕůɑɐəɖ ůŰɛɕŮɛɛŰŮɟɘɐʃ ŭɧůɖʃ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ***. ɇɕ ´ɟɕʃ Ŭ ɕůəəɐɟɡɜůɖ ɜŮɟ ɧ ɢŬɟ Ŭə Űɖɟ œŮŰŰə Ŭ ɧ ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ŬůɓŮıŰœɡ, ɢŬɛɖəɐ ůəəɖɟɧŰɖŰŰ ɛŬəɜɖůœɡ (ɛəɟɧŰŮɟɖ Ŭ ɧ 40 mg/L ůŬɜ $CaCO_3$) əŬəŭŮɜ ´ Ůɟɘɏɢ Ůə ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ.
2. ***ɑəŮɟɔŬůɖŬ Ůɜɧʃ ůŰŰŭœɡ ɛŮ ´ɟɕůɑɐəɖ ůŰɛɕŮɛɛŰŮɟɘɐʃ ŭɧůɖʃ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ ə Ŭə ůɧŭŬʃ***. ɇɕ ´ɟɕʃ Ŭ ɕůəəɐɟɡɜůɖ ɜŮɟ ɧ ɢŬɟ Ŭə Űɖɟ œŮŰŰə Ŭ ɧ ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ŬůɓŮıŰœɡ, ɢŬɛɖəɐ ůəəɖɟɧŰɖŰŰ ɛŬəɜɖůœɡ (ɛəɟɧŰŮɟɖ Ŭ ɧ 40 mg/L ůŬɜ $CaCO_3$) əŬə ´ Ůɟɘɏɢ Ůə əŬə ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ ŬůɓŮıŰœɡ.
3. ***ɑəŮɟɔŬůɖŬ Ůɜɧʃ ůŰŰŭœɡ ɛŮ ´ɟɕůɑɐəɖ ´ Ůɟɑůů ŮəŬʃ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ***. ɇɕ ´ɟɕʃ Ŭ ɕůəəɐɟɡɜůɖ ɜŮɟ ɧ ɢŬɟ Ŭə Űɖɟ œŮŰŰə Ŭ ɧ ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ŬůɓŮıŰœɡ, ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ɛŬəɜɖůœɡ əŬə ɢŬɛɖəɐ ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ.
4. ***ɑəŮɟɔŬůɖŬ Ůɜɧʃ ɐ ŭɨɕ ůŰŰŭœɜ ɛŮ ´ɟɕůɑɐəɖ ´ Ůɟɑůů ŮəŬʃ ɡŭɟɕɜŮəŭœɡ Űɛɡ ŬůɓŮıŰœɡ ə Ŭə ůɧŭŬʃ***. ɇɕ ´ɟɕʃ Ŭ ɕůəəɐɟɡɜůɖ ɜŮɟ ɧ ɢŬɟ Ŭə Űɖɟ œŮŰŰə Ŭ ɧ ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ŬůɓŮıŰœɡ, ɡɣɖəɐ ůəəɖɟɧŰɖŰŰ ɛŬəɜɖůœɡ əŬə ɡɣɖəɐ ɛɖ Ŭɜɖɟ Ŭəɘɐ ůəəɖɟɧŰɖŰŰ.

5.6.3 Ắ́ Ŭɜɖ Ɉ Ÿə ɤ ủɖ

ƮŬŰŸ Űɖɜ Ŭ ɞủəɚɈ ɡɜủɖ Űɛɡ ɜŮɈ ɞɨ ɛŮɡŭɈ ɞɜŮŭɜ Űɛɡ Ŭủɓ Ůủ Űɛɡ ɐ ɛŮɡŭɈ ɞɜŮŭɜ Űɛɡ Ŭủɓ Ůủ Űɛɡ əŬə ủɧŭŬ ɕɈ ɖủɚ ɞ́ ɞɘŮŰŰə əŬə ɖ ŭɘŮɈ ɔŬủŬ Űɖɠ Ů Ŭɜɖ Ɉ Ÿə ɤ ủɖɠ ɛŮŸ Ŭ ɧ ŰŰ ủŰŸŭɘŬ Űɖɠ ŰŰɕŮŬɠ Ŭɜ Ÿɛɜɖɠ, ɓɈ ŬŭŮŬɠ Ŭɜ Ÿɛɜɖɠ əŬə Ŭɖɕɖủɖɠ. (Ɇɕɐ ɛŬ 5.12).

ÿ ŰŰɜ ́Ɉ ɧəŮŰŰə ɔɘŬ ɜŮɈ ɧ ɛŮ ɕŬɛɖɚ ủəɖɈ ɧŰɖŰŰ ɛŬɜɖủɞɡ ɖ Ŭ ɞủəɚɈ ɡɜủɖ ɔɞŮŰŰə ɛŮ ́Ɉ ɞủɖɐəɖ ủŰɛɕŮɛ ɛŮɈ ɘɐɡ ́ɞủɧŰɖŰŰɠ ɡŭɈ ɞɜŮŭɞɡ Űɛɡ Ŭủɓ Ůủ Űɛɡ. ɀ ŰŸ Ŭ ɧ Űɛ ủŰŸŭɜ Űɖɠ əŬɖɞɖủɖɠ Űɛ ɜŮɈ ɧ ŮɞŬə ɡ́ ɏɈ əɞɈ ɞ ủŮŬɜɖ Ɉ Ŭəɘ ɧ Ŭủɓɏủ Űɛ əŬə ɏɕŮə Űɛɐ pH ủŰɖɜ ́ŮɈ ɘɕɐ 10,0 ɏɤ ɠ 10,6. ÿ ŰŰɜ ɔɞŮŰŰə ́Ɉ ɞủɖɐəɖ ŭɘɜŮŭɞɡ Űɛɡ Ÿɜɖ Ɉ Ŭə ŬủŮ ŬɡŰɧ Űɛ ɜŮɈ ɧ ŰŰ Ŭɜɖ Ɉ Ŭəɘ Ÿ ɘɧɜŰŰ ɛŰŰŰɈ ɏ́ ɞɜŰŰə ủŮ ŭɘủŬɜɖ Ɉ Ŭəɘ Ÿ ủɨ ɛűɤ ɜŬ ɛŮ Űɖɜ ́Ŭ Ɉ Ŭə ŸŰɤ Ŭɜ Űŭ Ɉ Ŭủɖ:

$$Ca^{2+} + CO_3^{2-} + CO_2 + H_2O \Leftrightarrow Ca^{2+} + 2HCO_3^{-} \qquad \mathbf{5.29}$$

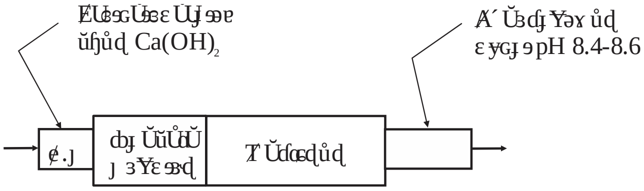
ÿ ŰŰɜ ́Ɉ ɧəŮŰŰə ɔɘŬ ɜŮɈ ɧ ɛŮɡɣɖɚ ủɡɔəɏɜŰɈ ɤ ủɖ ủŮ ɛŬɜɐ ủɘ ɖ Ŭ ɞủəɚɈ ɡɜủɖ ɔɞŮŰŰə ủɡɜɐɖɤ ɠ ɛŮ ́Ɉ ɞủɖɐəɖ ́Ɉ ɑủŮŬɠ ɡŭɈ ɞɜŮŭɞɡ Űɛɡ Ŭủɓ Ůủ Űɛɡ. ɆŰɖɜ ́Ɉ ɑ Űɤ ủɖ ŬɡŰɐ Űɛ pH Űɛɡ ɜŮɈ ɞɨ ɛŮŸ Ŭ ɧ Űɖɜ əŬɖɞɖủɖ ŮɞŬə ɔɨ Ɉ ɤ ủŰɛ 11,0 əŬə ɖ ́Ɉ ɞủɖɐəɖ Űɛɡ ŭɘɜŮŭɞɡ Űɛɡ Ÿɜɖ Ɉ Ŭə Ŭ Ůɜŭɏɕ ŰŰə ɜŬɔɞŮŰŰə ŮŰŰɛɧɜɘ ɔɘŬ Ŭɜ Űɛ ŰŰɪ ́ɘủɖ Űɖɠ əŬɡủŰəɐɠ Ŭəə Ŭəɘ ɧŰɖŰŰɠ (Ů Ŭɜɖ Ɉ Ÿə ɤ ủɖ ɛŮŸ Űɖɜ ŭŮɜŬɛŮɜɐ əŬɖɞɖủɖɠ Űɛɡ ́Ɉ ɩ Űɛɡ ủŰŭɞɡ, Ɇɕɐ ɛŬ 5.12ŭ) ŮŰŰɔɘŬ Űɖɜ Ŭɜ Űɛ ŰŰɪ ́ɘủɖ Űɧ ủɞ Űɖɠ əŬɡủŰəɐɠ Ŭəə Ŭəɘ ɧŰɖŰŰɠ ɧ ủɞ əŬə ɔɘŬ Űɖɜ ɛŰɏ́ ŮŰŰ ɛŰŰŰɈ ɞ́ɐ Űɤ ɜ Ŭɜɖ Ɉ Ŭəɩ ɜ ủŮɧɜɘ Ŭ Ŭɜɖ Ɉ Ŭəɘ Ÿ.

ÿ ŰŰɜ ủŰɧɕɘɠ ŮɞŬə ɖ Ŭɜ Űɛ ŰŰɪ ́ɘủɖ Űɖɠ əŬɡủŰəɐɠ Ŭəə Ŭəɘ ɧŰɖŰŰɠ ɖ ́Ɉ ɞủɖɐəɖ ŭɘɜŮŭɞɡ Űɛɡ Ÿɜɖ Ɉ Ŭə Ŭ Ŭɜ Űủ Űɛ ɕŮ ủ Űɖɜ Ůɘ ɞɡ ŭŰŰɏɈ ɤ ủɖ Űɖɠ ́Ɉ ɑủŮŬɠ ɡŭɈ ɞɜŮŭɞɡ Űɛɡ Ŭủɓ Ůủ Űɛɡ əŬɖɩ ɠ əŬə ủŰɖɜ Ůɘ ɞɡŭŰŰɏɈ ɤ ủɖ Űɛɡ ɡŭɈ ɞɜŮŭɞɡ Űɛɡ ɛŬɜɖủɞɡ (́ɞɡ ŮɞŬə ủŮ ŭɘŸəɡủɖ ɐ ́ɞɡ ŭŮɜ ɏɕŮə əŬɖɘɐ ủŮə ủŰɖɜ ŭŮɜŬɛŮɜɐ əŬɖɞɖủɖɠ) ủɨ ɛűɤ ɜŬ ɛŮ Űɛɠ Ŭɜ Űŭ Ɉ Ÿủ Ůɛɠ

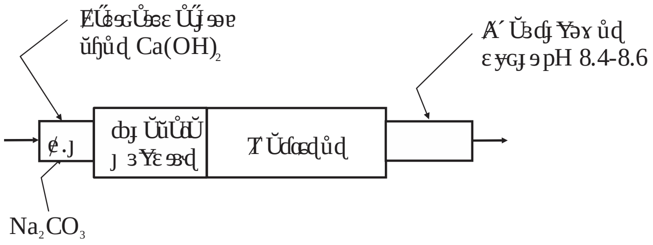
$$Ca^{2+} + 2Ƀ¢^{-} + CO_2 \Leftrightarrow CaCO_{3(s)} + H_2O \qquad \mathbf{5.30}$$

$$Mg^{2+} + 2Ƀ¢^{-} + CO_2 \Leftrightarrow Mg^{2+} + CO_3^{2-} + H_2O \qquad \mathbf{5.31}$$

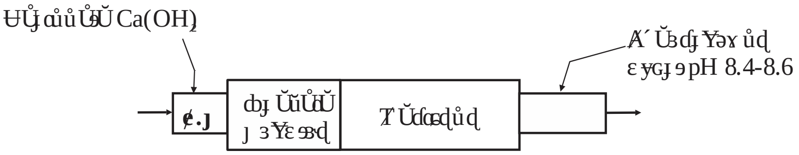
ɆŰɖɜ ́Ɉ ɑ Űɤ ủɖ ɧɛɤ ɠ ́ɞɡ ɖ ́Ɉ ɞủɖɐəɖ ŭɘɜŮŭɞɡ Űɛɡ Ÿɜɖ Ɉ Ŭə ŭŮɜ ɔɞŮŰŰə ủŮ Ůɜŭɘ Ÿɛ Ůủɞ ủŰŸŭɜ Ŭəə Ÿ ủŰɛ ŰŰəɘ ɧ ủŰŸŭɜ ́ɞɡ ɞŭɖɔŮɑủŮŭɨəɘủɖ ŰɧŰŰɖŬ ́Ɉ ɏ́ Ůɜ Ŭ ɔɞŮə ́Ɉ ɞủɖɐəɖ Ů ɑ ́əɏɞɜ ́ɞủɧŰɖŰŰɠ ŭɘɜŮŭɞɡ Űɛɡ Ÿɜɖ Ɉ Ŭə ɩ ủŰŰ ɜŬ ɞŭɖɔɖɖŮɑ ɖ Ů Ŭɜɖ Ɉ Ÿə ɤ ủɖ ủŮ ủɕɖɛ ŬŰɜủ ɛɧ ŭɘủŬɜɖ Ɉ Ŭəɩ ɜ (Ůɜɑủɤ ủɖ 5.29 əŬə ɖ Ŭɜ Űɑủ Űɛ ɕɖ Ůɜɑủɤ ủɖ ɔɘŬ Űɖɜ ɛŰŰŰɈ ɞ́ɐ ủŮŭɘủŬɜɖ Ɉ Ŭəɘ Ÿ Űɤ ɜ Ŭɜɖ Ɉ Ŭəɩ ɜ ́ɞɡ Ŭɜ Űủ Űɛ ɕɞɨ ɜ ủŰɛ ɛŬɜɐ ủɘ).


Ca(OH)$_2$
pH 8.4-8.6

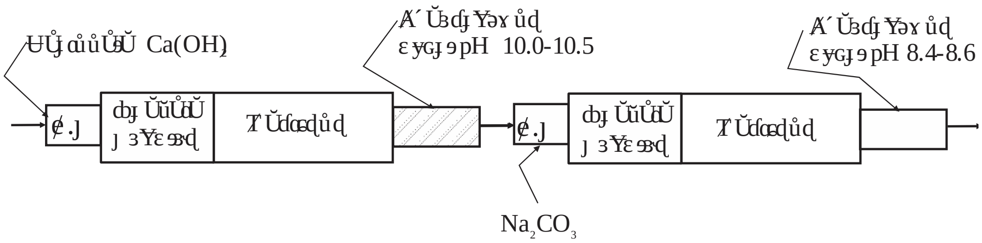
[illegible] Ca(OH)$_2$


Ca(OH)$_2$
pH 8.4-8.6
Na$_2$CO$_3$

[illegible] Ca(OH)$_2$ [illegible]


Ca(OH)$_2$
pH 8.4-8.6

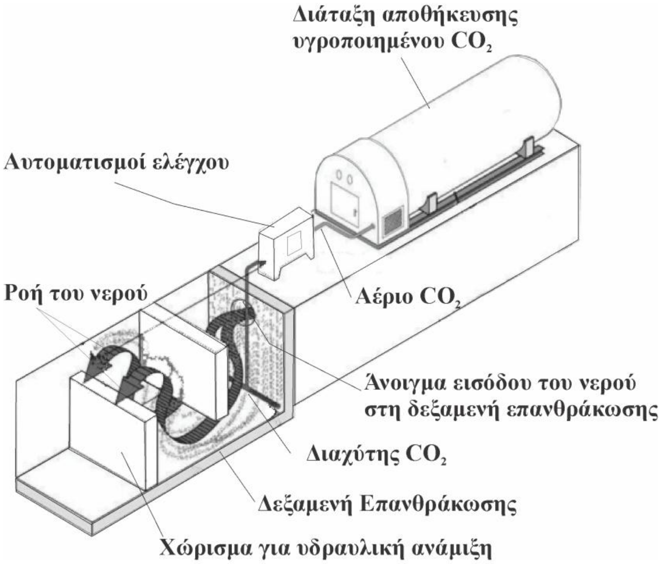
[illegible] Ca(OH)$_2$


Ca(OH)$_2$
pH 10.0-10.5
pH 8.4-8.6
Na$_2$CO$_3$

[illegible] Ca(OH)$_2$ [illegible]

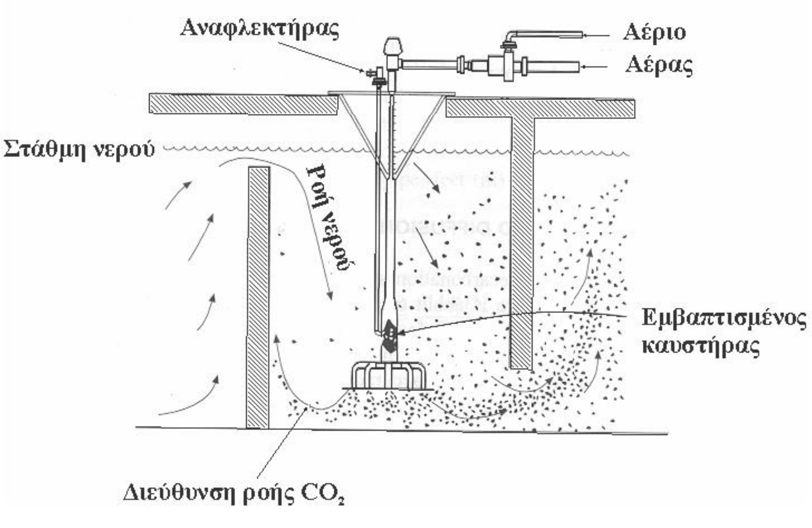
[illegible] 5.12: [illegible]

[illegible] 20 min.

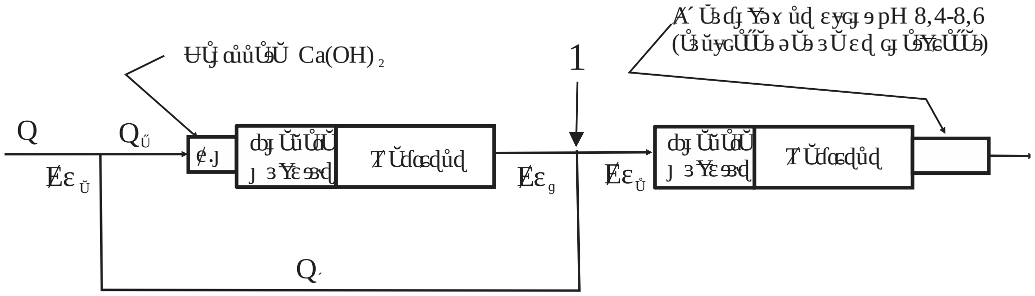

Διάταξη αποθήκευσης υγροποιημένου CO₂
Αυτοματισμοί ελέγχου
Ροή του νερού
Αέριο CO₂
Άνοιγμα εισόδου του νερού στη δεξαμενή επανθράκωσης
Διαχύτης CO₂
Δεξαμενή Επανθράκωσης
Χώρισμα για υδραυλική ανάμιξη

ɆɢɐɛŬ5.13: Ά´ŬɜɗɉŸəɤ ůɗ ɛŮɕɉɗůɶɐ´ɐɑɗůɗ ɡɔɉɐ´ɐɘɗɛɏɜɐɡ ŭɶɜɚŮŭɑɐɡ Űɛɡ ŸɜɗɉŬəŬ

ɇɐ ŭɶɜɚŮŭɘɜ Űɛɡ ŸɜɗɉŬəŬ´ɐɡ ɕɉɗůɶɐ´ɐɘŮɗŰŬəŲɐűɐŭɐŰŮɗŰŬəŮɗŰŮŬ ɧ ŭɘŸŰŬɜɗ´ɐɡ ´ŲɉɘɏɕŮə ɡɔɉɐ´ɐɘɗɛɏɜɐ ŭɶɜɚŮŭɘɜ Űɛɡ ŸɜɗɉŬəŬ (ɆɢɐɛŬ 5.13) ŮɗŰŮ´ɉɐəɨ´ŰŮəŬ ɧ Ůɑ Űɧ´ɐɡ əŬɨůɗ ůŮəŬɡůŰɐɉŬ ´ɐɡ ŮɜŬə ŮɛɓŬ ŰəůɛɏɜɐʃɛɏůŬ ůŰɛ ´ɉɩ Űɛ ŰɛɐɛŬ Űɗʃ ŭŮɜŬɛŮɜɐʃ ŮŬɜɗɉŸəɤ ůɗʃ (ɆɢɐɛŬ 5.14). ɇɐ ɡɔɉɐ´ɐɘɗɛɏɜɐ ŭɶɜɚŮŭɘɜ Űɛɡ ŸɜɗɉŬəŬ ɗŬ ´ɉɏ´Ůə(´ɉɐəŮɶɛɏɜɐɡ ɜŬŬ ɐűŮɨɔŮŰŰəɗ ŬŲɶ´ɐɑɗůɐ Űɛɡ əŬəɐə´ɐəɨ ɡɣɗəɏɡʃ´ɘɏůŮɡ) ɜŬ ŭəŰɗɉŮɗŰŰə ůŮ ɗŲɛɐəɉŬůɗŮʃ ɔɨɉɤ ůŰɛɡʃ -20 °C əŬə ´ɗŮɗ 2000 kPa. ȮŰŮə ɗ ɕɉɗůɶɐ´ɐɑɗůɗ ɡɔɉɐ´ɐɘɗɛɏɜɐ ŭɶɜɚŮŭɑɐɡ Űɛɡ ŸɜɗɉŬəŬ Ŭ ŬəŰŮɑ ɣɡəŰəɏɡʃ ŮəŬŰŰŮŰŸŮŮɡʃ əŬɢŬəɨ ɓŭɘŮɡʃ ŭŮɜŬɛŮɜɏʃ ŬɜŮəŰəɏʃ ůŮɡɣɗəɏɡʃ´ɘɏůŮɡ.


Αναφλεκτήρας
Αέριο
Αέρας
Στάθμη νερού
Ροή νερού
Εμβαπτισμένος καυστήρας
Διεύθυνση ροής CO₂

ɆɢɐɛŬ5.14: Ά´ŬɜɗɉŸəɤ ůɗ ɛŮŭɶɜɚŮŭɘɜ Űɛɡ ŸɜɗɉŬəŬŬ ɧ Ů əŰɧ´əŬəɨ ůɗ ŬŲɑɐɡ əŬɡůɶɐɡ ůŮəŬɡůŰɐɉŬ Ůɛɓ Űɛɏɜɐ ůŰɗ ŭŮɜŬɛŮɜɐ Ů ŬɜɗɉŸəɤ ůɗʃ



ɆɢɐɛǓ5.15: ɟ ǘǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠɛŮ ́ɟɘůɗɐɘɗ ́Ǔɟɑůůǔɘǔɠ Ca(OH)2 ůǓɛɶɟɘɠǕɗɠ ́ǓɟɘɢɐɠɘǓɘ ́ǓɟƳɘǓɛɣɗ ǕɘɡɡɦɚɘɑɘɡǓ

5.6.4 ɟ ́ɘůɘɚɐɟɡɜůɗ ɛŮ ́Ǔɟ ƳɘǓɛɣɗ ɛɶɟɘɡɠǕɗɠ ́Ǔɟɘɢɐɠ

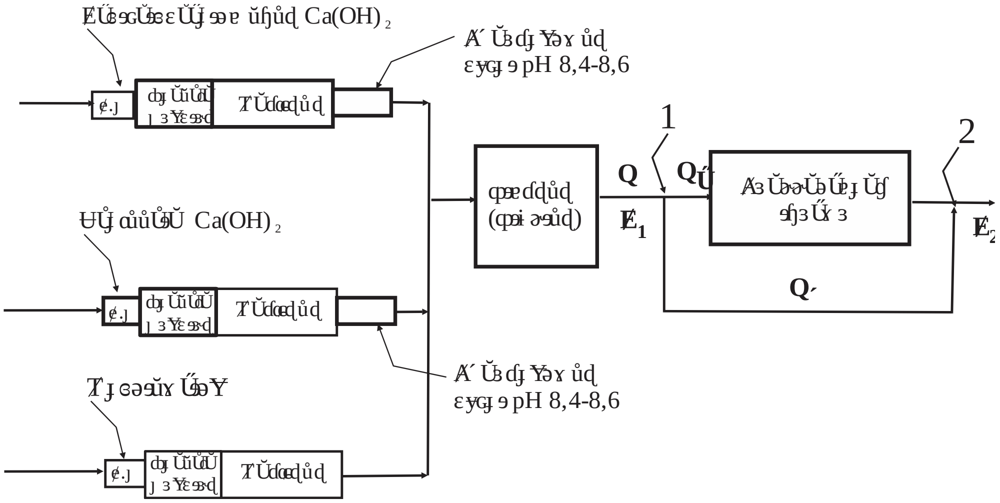
ȼ ɓǓůɞɐ ɘǔɶǓ ǕɐǓɘɜǓɔɐǕǕǕɘ ǓǐǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠǓ ɦ ɶɜǓɛɶɟɘɠǕɗɠ ́ǓɟɘɢɐɠɘǓɘůǕɗ ůɡɜɶɢǓɘǓ ǓɜƳɛɞɗ ǕɘɡɟŮɛǓǕɛɠ ́ɘɡ ɶɢǓɘǓ ɘůɘɚɗɟɡɜɗǕɑɘǓɘǕɘɡ ɟŮɛǓǕɛɠ ́ɘɡ ǔǓɜ ɶɢǓɘ Ǔ ɘůɘɚɗɟɡɜɗǕɑ ɟ ɜǓǐɶɟɘɡɛŮ ǔɨɘ ́ǓɟɘǕ ůǓɠ ɦ ́ɘɡ ɔɐǕǕǕɘ ́Ǔɟ ƳɘǓɛɣɗ ɛɶɟɘɡɠǕɗɠ ́ǓɟɘɢɐɠɘǓǕǕƳǕɗɜ Ǔ ɘůɘɚɐɟɡɜůɗ. ȼ ɛɗǓǕǐɘɟ Ƴ Ǖɗɜ ǓǐǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠ ɛǓɜɗůɐɡ ɛɶɢɟɘ ɘɟɘůɛɶɜɘɡ Ů ɘ ɶǔɘɡ ɛŮ ́ɟɘůɗɐɘɗ ́Ǔɟɑůůǔɘǔɠ ɡǔɟɘɜǓɘǔɐɡ Ǖɘɡ ǓůɓǓůǕɐɡ ůǓɛɶɟɘɠ ɛɦɜɘɜ Ǖɗɠ ́ǓɟɘɢɐɠɘǓɘ (ɆɢɐɛǓ 5.15) ɘǓɘ ɗ Ƴɘɚɗ ǓǐɘɟƳ ǓǐǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠ ɐ ůɡɛ ́ɘɗɟɤɛǓǕɐɐ ǓǐǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠ ɛǕǕƳ Ǔ ɦ Ǖɛ ůǓƳǔɞ Ǖɗɠ ǔɨɘɘůɗɠɛǓǔɶɘǓɡůɗ ɛɶɟɘɡɠǕɗɠ ́ǓɟɘɢɐɠǓ ɦ ǓɜǓɘɘǓǕɐɟǓɠɦɜǓɤ ɜ (ɆɢɐɛǓ5.16).

ɆǕɗɜ ́ǓɟɑǕɤ ůɗ Ǖɘɡ ɆɢɐɛǓǕɘɠ 5.15 ɗ ́Ǔɟɑůůǔɘǔ ɡǔɟɘɜǓɘǔɐɡ Ǖɘɡ ǓůɓǓůǕɐɡ ́ɘɡ ́ɟɘůǕɗǓǕǕɘ ůǕɛ ǓɟɘǘɘǔɘǕɛɨɛǓɞɘ ɟŮɛǓ ($Q_{Ǔ}$) ɶɢǓɘ ůǓɜ Ǔ ɘǓɘǓůɛǓ Ǖɗɜ ǓǐǓɡǓɗ Ǖɗɠ Ǔɜɗɟ Ǔɘɞɐɠ ůɘɚɗɟɦǕɗǕǕɠ ǓůɓǓůǕɐɡ ɘǓɘ ɛǓɜɗůɐɡ ɛɶɢɟɘ Ǖɤ ɜ ́ɟǓɘǕɘƳ Ů ɘǕɟɔǓɜɦɛǓɜɤ ɜ ɘɟɑɤ ɜ. ɇɘ ɦɟɞ ǓɡǕɦ ɔɘǓ Ǖɛ ɛǓɜɐůɞ ǓɐǓɘ 10 mg/L ůǓɜ $CaCO_3$. ɇɘ ́ǓɟǓɘǓɛ ́Ǖɦɛǔɘ ɟŮɛǓ ($Q_{´}$) ɡ ́ɘɚɘɔɐǕǕǕɘ Ǔ ɦ ɶɜǓ ɘůɘɨɔɞ ɛǓɜɗůɐɡ ɔɨɟɤ Ǔ ɦ Ǖɛɜ ɘɦɛɓɘ 1. ɇɘ ɘůɘɨɔɞ ǓɡǕɦ ǓɘǘɟƳɛǕǕɘɛǓǕɠǓɐɠǔɨɘ Ǔɘůɩ ůǓɠ:

$$Q=Q_{Ǔ}+Q_{´} \qquad Q\cdot Ɇɛ_{Ǔ}=(Q_{Ǔ}+Ɇɛ_g)+(Q_{´}\cdot Ɇɛ_{Ǔ})$$

ȳ ́ɘɡ Q: ɗ ůɡɜɘɚɞɐ ́Ǔɟɘɢɐ, $Q_{Ǔ}$ ɗ ́Ǔɟɘɢɐ ́ɘɡ ǓɟɘǘɘǔɘǕǕɗǕǕɘ ɔɘǓ ɜǓ ɡ ́ɘůǕɑ Ů ǓɟǓɔǓǐɗǓ ɛŮ ́ǓɟɑůůǔɘǓ ɡǔɟɘɜǓɘǔɐɡ Ǖɘɡ ǓůɓǓůǕɐɡ, $Q_{´}$: ɗ ́ǓɟǓɘǓɛ ́Ǖɦɛǔɜɗ ́Ǔɟɘɢɐ, $Ɇɛ_{Ǔ}$: ɗ Ǔɟɢɘɐ ůɘɚɗɟɦǕɗǕǕ ɛǓɜɗůɐɡ, $Ɇɛ_g$: ɗ ɡ ́ɘɚǓ ́ɦɛǓɜɗ ůɘɚɗɟɦǕɗǕǕ ɛǓɜɗůɐɡ ůǕɛ ɟŮɛǓ ́ɘɡ ǓɟɘǘɘǔɘǕǕɗǕǕɘ ɔɘǓ ǓǐǓɡǓɗ ůɘɚɗɟɦǕɗǕǕɠ ɛǓɜɗůɐɡ, $Ɇɛ_{Ǔ}$: ɗ Ůɘɗɡɛɗǔɞ ůɘɚɗɟɦǕɗǕǕ ɛǓɜɗůɐɡ ůǕɛ ɟŮɛǓ ́ɘɡ ́ɟɘɨ ́ǕǓ Ǔ ɦ Ǖɗɜ ůɡɜɶɜɤ ůɗ Ǖɤ ɜ ǔɨɘ ɟǓɡɛƳǕɤ ɜ $Q_{´}$ ɘǓɘ $Q_{Ǔ}$

ɆŰɖɜ´ǕɟɑŰɤůɖŰɛɡɆɕɐɛǗŰɛʃ5.16 ɖůəəɖɟɦŰɖŰŰŰɛɡŰɟɕűɕǔɕŰɛɨɛǗɜɕɡɟǗɨɛǗŰɛʃ ůŰɖɜɏɜɕǔɕǗɦŰɛɜǗɜǗəəǗəŰɐɟǗɕɦɜŰɤɜɖŰɤɟůǗŰŰəɑɖɛǗŰɛɛɖǔɏɜəǗəŰɛ ´ǗɟǗəǗɛ´ŰɦɛǗɜɕɟǗɨɛǗɡ´ɕəəɔɕŰŰŰəǗɦɏɜǗɜůɕɕɨɔɜůəəɖɟɦŰɖŰŰʃɔɨɟɤǗɦŰɛɜ əɦɛɓɕ 2.


ɆǗɛɜɕǗɛɛǗɟɜɐ ǔɦůɖ Ca(OH)$_2$
ȺǗɜɖɟǘəɤůɖ
ɛɏɕɟəpH 8,4-8,6
ȼ.ɟ
ɖɟǗŰǗ ɟɜǘɛəɖ
ƮǗɑɑɖůɖ
1
2
ɖɐɛɖɖůɖ (ɖəɨəəůɖ)
Q
QǗ
Ɇ$_1$
ȺɜǗəəǗəŰɐɟǗʃ ɕɦɜŰɤɜ
Ɇ$_2$
ɄǗɟɑůůǗǗ Ca(OH)$_2$
Q´
ȺǗɜɖɟǘəɤůɖ
ɛɏɕɟəpH 8,4-8,6
ƮɟɞəəǔɤŰəǘ

ɆɕɐɛǗ5.16: ɟ űǗɡɟůɖ ůəəɖɟɦŰɖŰŰʃǗɦ ǔəɡəəůɛɏɜɕ ɜǗɟɦ (ɛǗɐ ɕɤɟɑʃǗɟɕəɐ Ǘɕůəəɐɟɡɜůɖ) ɛǗǔəǗɓɑǗůɖ ɛɏɟɕɡʃŰɖʃ´ǗɟɕɕɐʃǗɦ ǗɜǗəəǗəŰɐɟǗəɦɜŰɤɜ.

ɄǗɟǗǔǗɐɛǗŰŰɔəǗŰɛɡʃŰɏůǗɟəʃ Űɨ´ɕɡʃǔəǗɟɔǗůɑ ɜǗɕůəəɐɟɡɜůɖʃ

ɆŰɖ ůɡɜɏɕǗəǗ ǔɑǗŰŰə ɏɜǗ ´ǗɟǘǔǗɐɛǗ ɔəǗ əǘɖǗɏɜǗɜ Ǘɦ ŰɛɡɡʃŰɏůǗɟəʃ Űɨ´ɕɡʃ ǔəǗɟɔǗůɑ ɜǗɕůəəɐɟɡɜůɖɖʃŰɛɡɜǗɟɕɨ.

ɄǗɟǘǔǗɐɛǗ5.4

ɖəǗɟɔǗůɖǗǗɜɦʃůŰŰǔɑɕɡɛǗ´ɟɕůɖɐəɖ ůŰɛɜɕǗɛɛŰɟəɐɛʃ

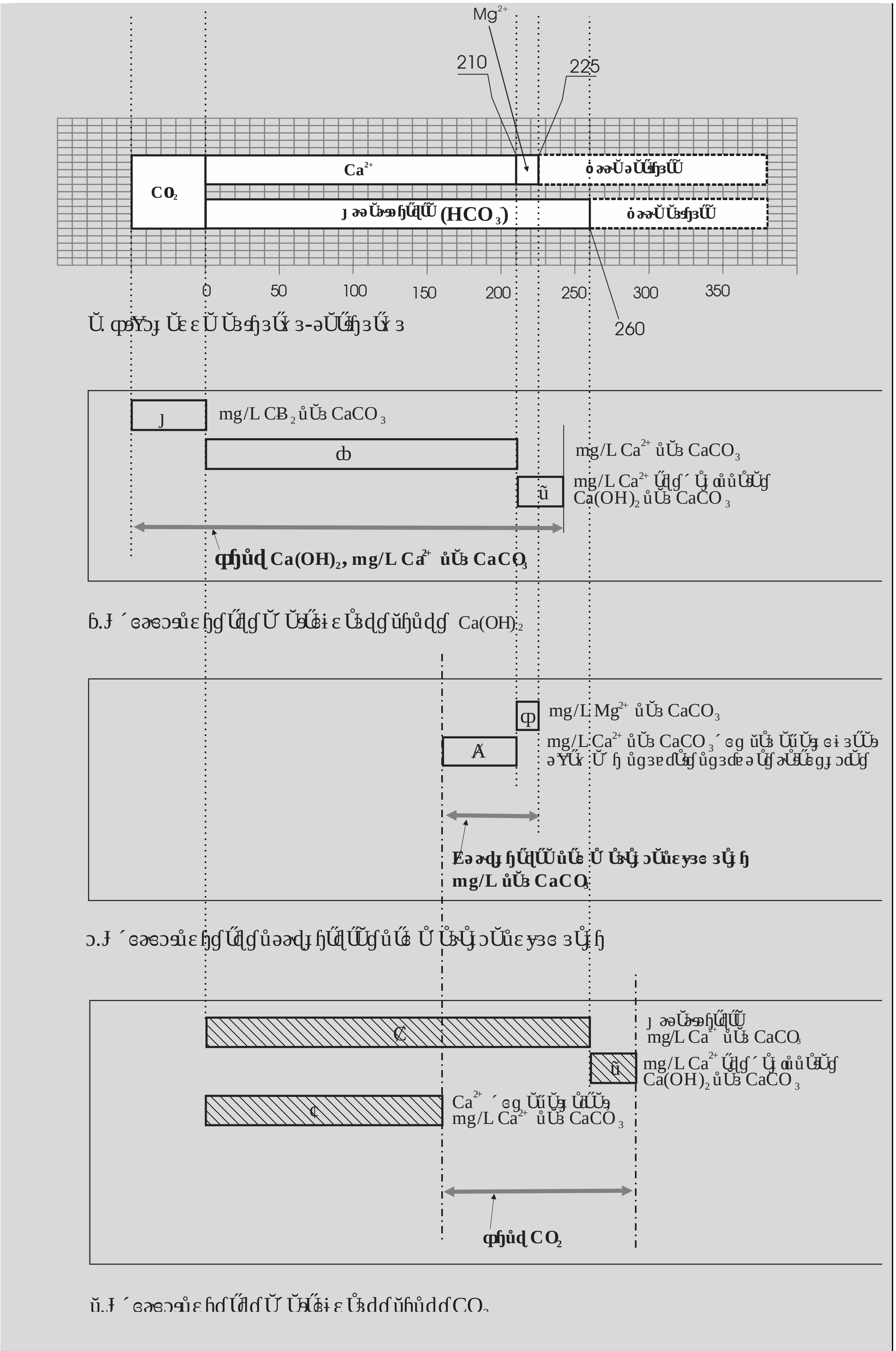
ǔɦůɖʃɡǔɟɕəǗǔɑɕɡŰɛɡǗǗɓǗǗŰɛɡ

ɟ´ɦɔǗɛɜǗɟɦǗɜǗɨɖɖəǗəǗɓɟɏɖɖəǗɜǗɏɕǗŰɖɜǗɜɐʃůɨůŰŰůɖ: pH=7,5, CO_2=50 mg/L ůǗɜ $CaCO_3$, ǗəəǗəəɦŰɖŰŰ=260 mg/L ůǗɜ $CaCO_3$, Ca^{2+}=210 mg/L ůǗɜ $CaCO_3$, Mg^{2+}= 15 mg/L ůǗɜ $CaCO_3$. ʔǗ ɡ´ɕəəɔəůɖǗɑɖ Ǘ ǗəŰɛɨɛǗɜɖ ǔɦůɖ Ca(OH)2 ɔəǗ Ǘɕůəəɐɟɡɜůɖ əǗɑ ʃəǗɜɖ Ǘ ǗəŰɛɨɛǗɜɖ ǔɦůɖ CO2 ɔəǗŰɖɜ ŰŰəəɐ ǗǗɜɖɟǘəɤůɖ.

ʂɨůɖ

ȼǗ ůŰɛɕǗǗǗ Ǘɦ Űɖɜ ǗɜǘəɡůɖŰɛɡ ɜǗɟɕɨ Űɛ´ɕɖŰŰɛɨɜŰŰə ɦ´ɤʃ űǗɑǗŰŰə ůŰɛ ǔəǘɔɟǗɛɛǗǗɜɦɜŰɤɜ-əǗŰɦɜŰɤɜ ŰɛɡɆɕɐɛǗŰɛʃ5.17.

ȼ ɕəəɐ ůəəɖɟɦŰɖŰŰǗɑǗəɑůɖ ɛǗŰɛ ǘɖɟɕəůɛǗŰɖʃůəəɖɟɦŰɖŰŰʃǗɓǗŰɑɛɡəǗəŰɖʃ ůəəɖɟɦŰɖŰŰʃɛǗəɜɖůɑɛɡ=210+15=225 mg/L ůǗɜ $CaCO_3$.


Mg^{2+}
210
225
CO$_2$
Ca^{2+}
ɵ ɘɚŬɘŰɟɜŰ
ɟ ɘɚŬɘɧŰɖŰ (HCO$_3$)
ɵ ɘɚŬŬɜɟɜŰ
0
50
100
150
200
250
300
350
260
Ŭ. ɸɘŸɔɟ Ŭɛ ɛ Ŭ Ŭɜɟɜ Űɤ ɜ-ɘŬŰɟɜŰɤ ɜ
ɟ
mg/L CO$_2$ ůŬɜ CaCO$_3$
ɒ
mg/L Ca^{2+} ůŬɜ CaCO$_3$
ũ
mg/L Ca^{2+} Űɖɠ´ Ůɟ ɑůůŬɘŬɠ Ca(OH)$_2$ ůŬɜ CaCO$_3$
ɸɧůɖ Ca(OH)$_2$, mg/L Ca^{2+} ůŬɜ CaCO$_3$
ɓ. ɟ ´ɞɘɞɔɘůɛ ɧɠŰɖɠ Ŭ ŬɘŰɜɨ ɛ Ůɜɖɠ ŭɧůɖɠ Ca(OH)$_2$
ɸ
mg/L Mg^{2+} ůŬɜ CaCO$_3$
Ά
mg/L Ca^{2+} ůŬɜ CaCO$_3$ ´ɞg ŭŬɜ ŬíŬɟ ɞɨ ɜŰŬɘ ɘŸɤ Ŭ ɧ ůgɜɐɖŬɠ ůgɜɑɘ Ůɠ ɘŬɘŰɞgɟ ɔɖɠ
Ŀɘɘɖɟ ɧŰɖŰŬ ůŰɛ Ů ŮɘŮɟ ɔŬůɛ ɏɜɞ ɜŮɟ ɧ mg/L ůŬɜ CaCO$_3$
ɔ. ɟ ´ɞɘɞɔɘůɛ ɧɠŰɖɠ ůɘɘɖɟ ɧŰɖŰŬɠ ůŰɛ Ů ŮɘŮɟ ɔŬůɛ ɏɜɞ ɜŮɟ ɧ
Ȼ
ɟ ɘɚŬɘɧŰɖŰ mg/L Ca^{2+} ůŬɜ CaCO$_3$
ũ
mg/L Ca^{2+} Űɖɠ´ Ůɟ ɑůůŬɘŬɠ Ca(OH)$_2$ ůŬɜ CaCO$_3$
¢
Ca^{2+} ´ɞg ŬíŬɟ ŬŰŬɘ mg/L Ca^{2+} ůŬɜ CaCO$_3$
ɸɧůɖ CO$_2$

ŭ. ɟ ´ɞɘɞɔɘůɛ ɧɠŰɖɠ Ŭ ŬɘŰɜɨ ɛ Ůɜɖɠ ŭɧůɖɠ CO$_2$

Ɇɞɐ ɛ Ŭ 5.17: ɸɘŬɔɟ Ÿɛ ɛ ŬŰŬ ɔɘŬ ŰŬ ŭŰɞɛ ɏɜŬ ɘŬɘ ŰŬ ɕɖŰɞɨ ɛ ŮɜŬŰɞg ´Ůɟ ŬíŮɒɛ ŬŰɞɠ 5.4

¢ Ŭɜɖɟ Ŭɘɶɐ ůɘɚɖɟ ɧŰɖŰŬ ŬůɓŬůíŰɞg ŮɞŬɘ 210 mg/L ůŬɜ CaCO$_3$ ɘŬɘɖ Ŭɜɖɟ Ŭɘɶɐ

[illegible] 15 mg/L [illegible] $CaCO_3$ ([illegible]).

[illegible] 40 mg/L [illegible] $CaCO_3$.

[illegible] ([illegible] 5.17) [illegible] ([illegible] 5.18)

[illegible] $[Ca(OH)_2]$, mg/L [illegible] $CaCO_3=50+210=260$

mg/L [illegible] $Ca(OH)_2=260\cdot(37/50)=192,4$

[illegible] pH [illegible] 10,3-10,5. [illegible] (5-10% [illegible] 5.18).

[illegible] $[Ca(OH)_2]$, mg/L [illegible] $CaCO_3=50+(1,075)\cdot 210=275,7$

mg/L [illegible] $Ca(OH)_2 = 275,7(37/50)=204,0$

[illegible] $CaCO_3$. [illegible] $CaCO_3$ [illegible] 30-50 ([illegible] 40) mg/L. [illegible] $CaCO_3$ [illegible] ([illegible]).

[illegible] pH>10 ([illegible] 10,0-10,5) [illegible] pH [illegible] 8,2-8,4 ([illegible]).

[illegible]:

$$Ca^{2+} + CO_3^{2-} + CO_2 + H_2O \ \square\ Ca^{2+} + 2HCO_3^{-}$$

¢ ´ɞůɧŰɗŰŬ Űɕg ŭɞɜɜŮŭɶg Űɕg Ɏɜɗȝ ŬɘŬ ´ɞg ´ȝɏ´ Ůɘ ɜŬ ´ȝɞůŰŰɗŰŮ ɔɘŬ Ů Ŭɜɗȝ Ɏɘɤ ůɗ ŮɞŬɘ ɑůɗ ɛ ŮŰɗ ɜ Ŭɜɗȝ Ŭɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ ůŰɕ Ů ŮɘŬȝ ɔŬůɛɏɜɞ ɜŮȝ ɧ.

¢ Ŭɜɗȝ Ŭɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ ůŰɕ Ů ŮɘŬȝ ɔŬůɛɏɜɞ ɜŮȝ ɧ ɛ´ ɞȝŮɑ ɜŬ ŮɘŰɕɛ ɗɗŰɑ Ŭ ɧ Űɗɜ Ŭȝ ɕɘɐ ŬɘɘŬɘɘ ɧŰɗŰŬ ůŰɕ ɛɗ Ů ŮɘŬȝ ɔŬůɛɏɜɞ ɜŮȝ ɧ ɘŬɘ Ŭ ɧ Űɗɜ ɘůɞŭɨ ɜŬɛ ɗ ´ɞůɧŰɗŰŬ Ŭůɓ ŮůŰɕg ´ɞg Ŭí Ŭȝ ɏɗɗɘŮ ŌŰůɘ ɗ Ŭɜɗȝ Ŭɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ ůŰɕ Ů ŮɘŬȝ ɔŬůɛɏɜɞ ɜŮȝ ɧ ŮɞŬɜ

ȷ ɜɗȝ Ŭɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ Ů ŮɘŬȝ ɔŬůɛɏɜɞg ɜŮȝ ɧ=260-(210-40)=110 mg/L ůŬɜ $CaCO_3$

ɸɧůɗ CO_2 ɔɘŬ Ů Ŭɜɗȝ Ɏɘɤ ůɗ=110 mg/L ůŬɜ $CaCO_3$

$$= 110\cdot(22/50) = 48,4 \text{ mg/L } ůŬɜ\ CO_2$$

Ɉ ´ Ůɜɗg ɛ ɶŰŰŬɘ ɧɛ ɤ ɠ ɧŰɘ ´ȝ ɞůŰɏɗɗɘŮ ɛ ɘŬ ŭɞȝ ɗɤ ɛɏɜɗ ŭɧůɗ gŭȝ ɞɜŮŭɶg Űɕg Ŭůɓ ŮůŰɕg ɗ ɞ´ ɞɑŬ ŮɞŬɘ 7,5% Űɗɠ ɘůɞŭɨ ɜŬɛ ɗɠ Ŭɜɗȝ Ŭɘɘɐ ɠ ůɘɘɗȝ ɧŰɗŰŬɠ Ŭůɓ ŮůŰɕg ůŰɕ ɛɗ Ů ŮɘŬȝ ɔŬůɛɏɜɞ ɜŮȝ ɧ. ȺɞŬɘ ɘɞɘ´ ɧɜ űŬɜŮȝ ɧ ɧŰɘ ɗŬ ´ȝɏ´ Ůɘ ɜŬ ´ȝ ɞůŰŰɗŰŮɘ Ŭɘ ŭɞɜɜŮŰŭɞ Űɕg Ɏɜɗȝ ŬɘŬ ɔɘŬ ɜŬ ŮɞgŭŰŰȝ ɩ ůŮɘ ůɨ ɛ űɤ ɜŬ ɛ ŮŰɗɜ ŬɜŰŭȝ Ŭůɗ 5.17 Űɗɜ ´ ȝ ɑůůŮŬ Űɕg gŭȝ ɞɜŮŭɶg Űɕg Ŭůɓ ŮůŰɕg ´ɞg ´ȝ ɞůŰɏɗɗɘŮ

Ʉ Ŭȝ Ɏŭ Ůɔ ɛ Ŭ5.5

ɸɘŮȝ ɔŬůɗŬ Ůɜ ɧ ɠ ůŰŰŭɶg ɛ Ů´ ȝ ɞůɗɐ ɘ ɗ ůŰɕ ɞ ɕŮɛ ɛ ŮŰȝ ɘɐ ɠ

ŭɧůɗ ɠ gŭȝ ɞɜŮŭɶg Űɕg Ŭůɓ ŮůŰɶg ɘ Ŭɘ ůɧŭŬɠ

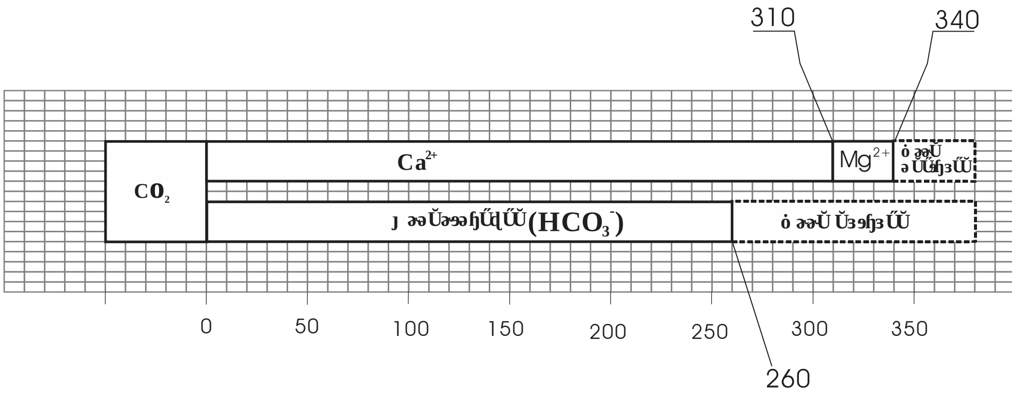
Ɉ ´ ɧɔŮɕ ɜŮȝ ɧ ŬɜŬɘɨ ɗɗɘŮɘŬɘ ɓȝ ɏɗɗɘŮɜŬ ɏɕŮɘ Űɗɜ Ůɘɐ ɠ ůɨ ůŰŰůɗ: pH=7,5, CO_2=50 mg/L ůŬɜ $CaCO_3$, ŬɘɘŬɘɘɧŰɗŰŬ=260 mg/L ůŬɜ $CaCO_3$, Ca^{2+}=310 mg/L ůŬɜ $CaCO_3$, Mg^{2+}= 30 mg/L ůŬɜ $CaCO_3$. ʔ Ŭg´ ɞɘɞɔůɗɞɨ ɜ ɞɘ Ŭ ŬɘŰɕɨ ɛ ŬɜŮɠ ŭɧůŬɘɠ gŭȝ ɞɜŮŭɶg Űɕg Ŭůɓ ŮůŰɕg ɘ Ŭɘ ůɧŭŬɠ ɔɘŬ Ŭ ɞůɘɘɐ ȝ gɜůɗ Űɕg ɜŮȝ ɞɨ ŬgŰɕɨ ɘŬɗ ɠ ɘŬɘ ɗ Ŭ ŬɘŰɕɨ ɛ Ŭɜɗ ŭɧůɗ ŭɞɜɜŮŭɶg Űɕg Ɏɜɗȝ ŬɘŬ ɔɘŬ Ů Ŭɜɗȝ Ɏɘɤ ůɗ.

ʂ ɨ ůɗ

ɇ Ŭ ůŰɕɞɕŮɗŬ Ŭ ɧ Űɗɜ ŬɜɎɘgůɗ Űɕg ɜŮȝ ɞɨ Űɕ´ ɞɗŰŰɕɨ ɜŰŰɘ ɧ´ ɤ ɠ űŬɞŮŰŰɘ ůŰɕ ŭɘɎɔȝ Ŭɛ ɛ Ŭɜɘɧɜ Űɤ ɜ-ɘŬŰɧɜ Űɤ ɜ Űɕg ɆɞɐɛŬŰɕɠ 5.18.

¢ ɞɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ ŮɞŬɘ ɑůɗ ɛ ŮŰɕ Ɏɗȝ ɞɘůɛ Ŭ Űɗɠ ůɘɘɗȝ ɧŰɗŰŬɠ Ŭůɓ ŮůŰɕg ɘ ŬɘŰɗɠ ůɘɘɗȝ ɧŰɗŰŬɠ ɛ Ŭɜɗůɶg=310+30=340 mg/L ůŬɜ CaCO3.

¢ Ŭɜɗȝ Ŭɘɘɐ ůɘɘɗȝ ɧŰɗŰŬ Ŭůɓ ŮůŰɕg ɗŮɤ ȝ ŮɑŰŰɘ ɑůɗ ɛ Ů Űɗɜ ŬɘɘŬɘɘɧŰɗŰŬ=260 mg/L ůŬɜ CaCO3.


310
340
CO_2
Ca^{2+}
Mg^{2+}
[illegible]
(HCO_3^-)
0
50
100
150
200
250
300
350
260

[illegible] 5.18: [illegible] 5.5

[illegible]=30 mg/L [illegible] $CaCO_3$

[illegible]=340-260=80 mg/L [illegible] $CaCO_3$

[illegible] = 80-30 = 50 mg/L [illegible] $CaCO_3$. [illegible] 5.17) [illegible].

[illegible] [$Ca(OH)_2$], mg/L [illegible] $CaCO_3$=50+260=310

mg/L [illegible] $Ca(OH)_2$ = 310·(37/50)=229,4

[illegible].

[illegible] [Na_2CO_3], mg/l $CaCO_3$=50

mg/L Na_2CO_3=50·(53/50)=53

[illegible] (30 mg/L [illegible] $CaCO_3$) [illegible] [30 [illegible] 50 ([illegible] 40) mg/L [illegible] $CaCO_3$].

[illegible]

Ů Ŭɜ Ůɉ ɔŬůɛ ɏɜɞ ɜŮɉ ɧ ůɡɜ Ǘɖɜ Ŭɜɖɉ Ŭɘ ɘɐ ůɘɘɖɉ ɧǗɖǗŬ´ ɞɡ ŮɞŬɘ ɘůɞŭɨ ɜŬɛɖ ɛ ŮǗɖɜ ŭɧůɖ ůɧŭŬɠ´ ɞɡ ´ Ƞ ɞůǗɏɖɖɘŮɛ Ůɞɜ Ǘɖɜ Ŭɜɖɉ Ŭɘ ɘɐ ůɘɘɖɉ ɧǗɖǗŬ´ ɞɡ ŮɞŬɘ ɘůɞŭɨ ɜŬɛɖ ɛ ŮǗɖɜ ´ ɞůɧǗɖǗŬ Ŭůɓ Ůůǘɞɡ ´ ɞɡ Ŭí ŬɈ ɏɖɖɘŮ ȬǗůɘ ŬŸɜ ɖŮɤ Ƞ ɐůɞɡɛŮ ɧǗɘ ɖ ɡ´ ɞɘŮɠ ɦɛŬɜɖ ůɡɔɘɏɜŮɉ ɤ ůɖ Ŭɜɖɉ Ŭɘ ɘɞɨ Ŭůɓ Ůůǘɞɡ ɛǗŸǗɛ ŭɘŬɞɤ Ƞ ɘůɛɧ Ǘɤ ɜ ɘɛɖɛŸǗɤ ɜ ɛŮɘŬɖɞɛɖůɖ Ůɞ Ŭɘ 40 mg/L ůŬɜ $CaCO_3$ ɖŬɏɞɞɡɛŮ

ɸɧůɖ CO_2 ɔɘŬŮ Ŭɜɖɉ Ÿɘɤ ůɖ=260+50ï (310-40)=40 mg/L ůŬɜ $CaCO_3$

$$= 40\cdot(22/50)=17{,}6 \text{ mg/L } ůŬɜ\ CO_2$$

ɄŬɉ ŸŭŮɔɛ Ŭ 5.6

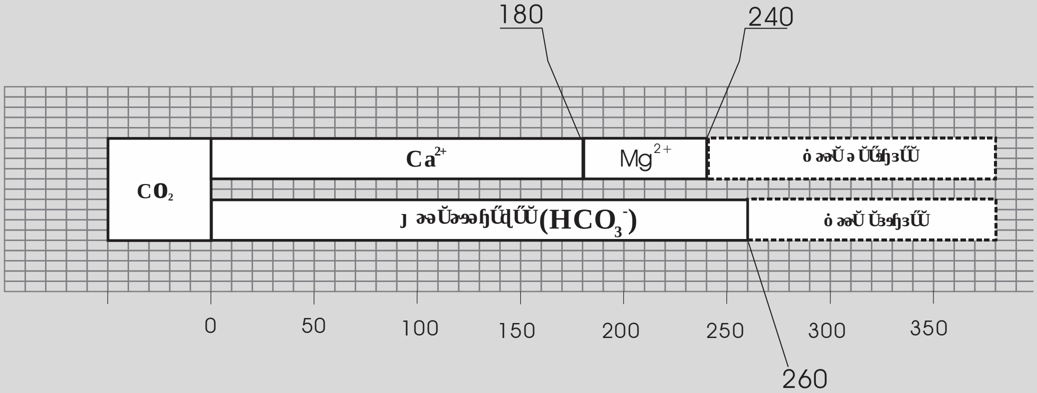
ɸɘŮɉ ɔŬůɖŬ Ůɜɧɠ ůǗŬŭɞɡ ɛŮ´ Ƞ ɞůɖɐɘɖ ´ Ůɉ ɑůůŮŬɠ ɡŭɉ ɛɜŮŭɞɡ Ǘɞɡ Ŭůɓ Ůůǘɞɡ

Ƚ ´ ɧɔŮɛ ɜŮɉ ɧ ŬɜŬɘɨ ɖɖɘŮɘŬɘ ɓ ɏ ɏɖɖɘŮɜŬ ɏɞŮɘ Ǘɖɜ Ůɜɐ ɠ ůɨ ůǗŬůɖ: pH=7,5, CO_2=50 mg/L ůŬɜ $CaCO_3$, Ŭɘ ŬɘɘɧǗɖǗŬ=260 mg/L ůŬɜ $CaCO_3$, Ca^{2+}=180 mg/L ůŬɜ $CaCO_3$, Mg^{2+}= 60 mg/L ůŬɜ $CaCO_3$.

ʔ Ŭ ɡ´ ɞɘɞɔɘůɖŮɑ ɖ Ŭ ŬɘǗɛɨ ɛ Ůɜɖ ŭɧůɖ ɡŭɉ ɛɜŮŭɞɡ Ǘɞɡ Ŭůɓ Ůůǘɞɡ ɔɘŬ Ŭ ɞůɘɘɐ Ƞ ɡɜůɖ Ǘɞɡ ɜŮɉ ɞɨ Ŭɡǘɛɨ ɘŬɖí ɠ ɘŬɘ ɖ Ŭ ŬɘǗɛɨ ɛ Ůɜɖ ŭɧůɖ ŭɘɜɜŮɘŭɞɡ Ǘɞɡ Ÿɜɖɉ ŬɘŬɔɘŬ Ů Ŭɜɖɉ Ÿɘɤ ůɖ.

ʂ ɨ ůɖ

ɇ Ŭ ůǗɛɘɞŮɖŬ Ŭ ɧ Ǘɖɜ ŬɜŸɘɡůɖ Ǘɞɡ ɜŮɉ ɞɨ Ǘɛ´ ɞɖŮǗɛɨ ɜǗŬɘ ɧ´ ɤ ɠ ǘŬɞŮǗŬɘ ůǗɛ ŭɘŸɔɈ Ŭɛ ɛ Ŭ Ŭɜɘɧ ɜǗɤ ɜ-ɘŬǗɘɧ ɜǗɤ ɜ Ǘɞɡ Ɇɞɐ ɛ ŬǗɛɠ 5.19.



Ɇɞɐ ɛ Ŭ 5.19 ɸɘŸɔ Ƞ Ŭɛ ɛ Ŭ Ŭɜɘɧ ɜǗɤ ɜ-ɘŬǗɘɧ ɜǗɤ ɜ ɔɘŬ Ǘɛ ɜŮɉ ɧ Ǘɞɡ ´ Ŭɉ Ŭŭ ŮɔɛŬǗɛɠ 5.6

¢ ɞɘɘɐ ůɘɘɖɉ ɧǗɖǗŬ Ůɞ Ŭɘ ɑɖ ɛ ŮǗɛ Ÿɖɉ ɞɘůɛ ŬǗɖɠ ůɘɘɖɉ ɧǗɖǗŬɠ Ŭůɓ Ůůǘɞɡ ɘŬɘǗɖɠ ůɘɘɖɉ ɧǗɖǗŬɠ ɛ Ŭɜɖůɞɡ=180+60=240 mg/L ůŬɜ $CaCO_3$.

¢ Ŭɜɖɉ Ŭɘ ɘɐ ůɘɘɖɉ ɧǗɖǗŬ Ůůɓ Ůůǘɞɡ ɖŮɤ Ƞ ŮɖǗŬɘ ɑɖ ɛ ŮǗɖɜ ůɘɘɖɉ ɧǗɖǗŬ Ůůɓ Ůůǘɞɡ ɐ ɗǕɤ ɟ ůɗǕǕɘ ɧǕɘɧɚɗ ɗ ůɘɚɗɟ ɧǕɗǕǕ ǓůɓǕůǕɞɡ ůɞǓɘǓɜɗɟ Ǔɘɚɐ = 180 mg/L ůǓɜ $CaCO_3$.

ȳ ɚɗ ɗ ůɘɚɗɟ ɧǕɗǕǕ ɛǓɜɜɗůɞɡ ɗǕɤ ɟ ůǕǕɘ Ǔɜɗɟ Ǔɘɚɐ, ɕ´ ɧǕǕ ɗ Ǔɜɗɟ Ǔɘɚɐ ůɘɚɗɟ ɧǕɗǕǕ ɛǓɜɜɗůɞɡ ǓɞǓɘɑɖ ɛǕǕɜ ůɘɚɗɟ ɧǕɗǕǕ ɛǓɜɜɗůɞɡ = 60 mg/L ůǓɜ $CaCO_3$

¢ ůɡɜɕɚɚɐ ɛɗ Ǔɜɗɟ Ǔɘɚɐ ůɘɚɗɟ ɧǕɗǕǕ ɚůɕɨ ǕǕɘ ɛǕɛɗǔɟɜ.

¢ ǔɧůɗ ɡǔɟ ɕɜǕǔɞɡ Ǖɞɡ ǓůɓǕůǕɞɡ ´ɕɡ ɗǓ ´ɟ ɕůǕǕɗǕ ɟɕǕɘ ůǓɜ ůǕɧɕ Ǖɗɜ Ǖɕɡǔ ǕǕɟɤ ůɗ Ǖɞɡ ǔɜɜǕǔɞɡ Ǖɞɡ Ɏɜɗɟ ǓɘǓ (ǓǕǔɟ Ǔůɗ 5.17), Ǖɗ ɛǕǕǕǕɕ´ɐ Ǖɗʃ ǔɚůǓɜɗɟ Ǔɘɚɐʃ ǓɚǓɚɚɧǕɗǕǕʃ ůǕ Ǔɜɗɟ Ǔɘɚɐ ǓɚǓɚɚɧǕɗǕǕ, Ǖɗɜ ɘǕǕɘɟɐɛɜɚůɗ Ǖɞɡ ɛǓɜɜɗůɞɡ ůǓɜ ɡǔɟ ɕɜǕǔɞ Ǖɞɡ ɛǓɜɜɗůɞɡ (ǓǕǔɟ Ǔůɗ 5.20) ɘǓɘ Ǖɗɜ ǕɜǕůǕɎɚůɗ Ǖɗʃ Ǔ ǓɜǕɕɨ ɛǕɜɗʃ´ Ǖɟ ɑůǕɜǓʃ ɔɚǓ ɚǓɜɕ´ ɕɚɗǕɐ Ǔ ɧǔɕůɗ Ǖɗʃ ǕǔǓɟ Ǖɗʃ ɛǓɜɗůɞɡ [40-70 (ɟůǕɤ 60) mg/L ůǓɜ $CaCO_3$].

ɸɧůɗ [$Ca(OH)_2$], mg/L ůǓɜ $CaCO_3$=50+260+60+60=420

mg/L ůǓɜ $Ca(OH)_2$=420 (37/50)=310,8

¢ ǕǕɚɚɐ ůɘɚɗɟ ɧǕɗǕǕ ůǕɞ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕ ɜǕɟ ɧ ɗǓ ǓɞǓɘ Ǖɞ Ɏɗɟ ɕɚůɛǓ Ǖɗʃ ɡ´ ɕɚǕɞ ɧɛǕɜɗʃ ůɡɔɚɟɜǕɟ ɤ ůɗʃ Ǔɜɗɟ Ǔɘɚɕɨ ǓůɓǕůǕɞɡ ɘǓɘ Ǖɗʃ ɚůɕǔɨ ɜǓɛɗʃ ůɡɔɚɟɜǕɟ ɤ ůɗʃ ɡǔɟ ɕɜǕǔɞɡ Ǖɞɡ ɛǓɜɗůɞɡ ´ɕɡ ǔǕɛ´ɕɟɕɨ ɜ ´ɟ ǓɘǕɞ Ɏ ɜǓ ǕíǓɟ Ǖɗɕɨ ɜ ɘɎǕɤ Ǔ ɧ Ǖɡʃ ůɡɜɗɐɘǕʃ´ ɕɡ ɔɑǕǕɘ ɗ Ǔ ɕůɘɚɐɟɡɜůɗ. Ƀɘ Ǖɞɛɟʃ ǓɡǕɟʃ ɔɚǓ Ǖɞ Ǔɜɗɟ Ǔɘɚɧ ǓůɓɟůǕɞ ǓɞǓɘ 30 ɟɤ ʃ 50 (ɟůǕɤ 40) mg/L ůǓɜ $CaCO_3$ ɘǓɘ ɔɚǓ Ǖɞ ɡǔɟ ɕɜǕǔɞ Ǖɞɡ ɛǓɜɗůɞɡ 10 ɟɤ ʃ 20 (ɟůǕɤ 15) mg/L ůǓɜ $CaCO_3$.

ȺɘǕɞɛɎǕǕɘ ɚɕɘ´ ɧɜ ǕǕɚɚɐ ůɘɚɗɟ ɧǕɗǕǕ ůǕɞ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕ ɜǕɟ ɧ (´ɟɚ Ǔ ɧ Ǖɗɜ Ǖ Ǔɜɗɟ Ɏɘɤ ůɗ) ɑůɗ ɛǕ40+15=55 mg/L ůǓɜ $CaCO_3$.

¢ Ǔ ǓɜǕɕɨ ɛǕɜɗ ǔɧůɗ ǔɜɜǕǔɞɡ Ǖɞɡ Ɏɜɗɟ ǓɘǓ ɔɚǓ Ǖ Ǔɜɗɟ Ɏɘɤ ůɗ ɗǓ ǓɞǓɘ ɚůɕǔɨ ɜǓɛɗ ɛǕ Ǖɗɜ ǕɘǕɞɛɩ ɛǕɜɗ ǓɚǓɚɚɧǕɗǕǕ Ǖɞɡ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕɡ ɜǕɟɕɨ ůɡɜ ǔɨɕ ǕɕɟɟʃǕɗɜ ´Ǖɟ ɑůǕɜǓ ɡǔɟ ɕɜǕǔɞɡ Ǖɞɡ ǓůɓǕůǕɞɡ ůɡɜ Ǖɗɜ ǕɘǕɞɛɩ ɛǕɜɗ ɡ´ ɕɚǕɞ ɧɛǕɜɗ ůɡɔɚɟɜǕɟ ɤ ůɗ ɛǓɜɜɗůɞɡ.

¢ ǓɚǓɚɚɧǕɗǕǕ Ǖɞɡ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕɡ ɜǕɟɕɨ ǕɘǕɞɛɎǕǕɘ ɑůɗ ɛǕ Ǖɗɜ ǓɚǓɚɚɧǕɗǕǕ Ǖɞɡ ǓɜǕ ǕɜɟɔǓǕůǕɞɡ ɜǕɟɕɨ ɛǕɞɜ Ǖɗɜ ɕɚɚɐ ůɘɚɗɟ ɧǕɗǕǕ Ǖɞɡ ɛɗ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕɡ ɜǕɟɕɨ ɛǕɞɜ Ǖɗɜ ɚůɕǔɨ ɜǓɛɗ ´ɕůɧǕɗǕǕ´ Ǖɟ ɑůǕɜǓʃ ɡǔɟ ɕɜǕǔɞɡ Ǖɞɡ ǓůɓǕůǕɞɡ ´ɕɡ ´ɟ ɕůǕɟɗɗɘǕ ůɡɜ Ǖɗɜ ɡ´ ɕɚǕɞ ɧɛǕɜɗ ůɘɚɗɟ ɧǕɗǕǕ ůǕɞ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕ ɜǕɟ ɧ.

ɟ ɚɚǓɚɚɧǕɗǕǕ ůǕɞ Ǖ ǕɜǕɟ ɔǓǕɛɟɜɕ ɜǕɟ ɧ (ɛǕǕɎ Ǔ ɧ Ǖɗɜ ɘǓɗɕɗůɗ ɘǓɘ´ɟɚ Ǔ ɧ Ǖɗɜ Ǖ Ǔɜɗɟ Ɏɘɤ ůɗ)=260-240-60+55=15 mg/L ůǓɜ $CaCO_3$.

ɸɧůɗ CO_2 ɔɚǓ Ǖ Ǔɜɗɟ Ɏɘɤ ůɗ=15+2x(60)+15=150 mg/L ůǓɜ $CaCO_3$

= 150x(22/50)=66 mg/L ůǓɜ CO_2

ǕǕȷ ǕǕǕǕɛǕ5.7

ǫɔǕǕȷ ɔǗůǺǗ ǚɨɞ ůǗǗǚǿ ɜ ɛ Ǖ´ȷ ɞůɗɐǺ ´ Ǖȷ ǿůǕǗǗ gǚȷ ɞɜǕǚǿɞg

ǗǣgǗůɓǕůǗǣg ɐǗ ůɧǚǗǗ

ȷ ´ ɧɔǕɞ ɜǕ ɧ ǕɜǕɘɨ ǺɐǕɐǕɓȷǺɐǕɜǕǕǕǗ ǗǺɜ Ǖɐǥ ůɨ ůǗǗǺ: pH=7,5, CO_2=50 mg/L ůǕɜ $CaCO_3$, ǕɘǕɘɘɧǗǺǗǗ=260 mg/L ůǕɜ $CaCO_3$, Ca^{2+}=280 mg/L ůǕɜ $CaCO_3$, Mg^{2+}= 80 mg/L ůǕɜ $CaCO_3$. ʔǕg´ ɞɘɞɔůǺɞɨ ɜ ɞɐǕ Ǖɐǣɨ ɛ ǕɜǕǗ ǚɧůǕǗ gǚȷ ɞɜǕǚǿɞg ǗǣgǗůɓǕůǗǣg ɐǕɐ ůɧǚǗǗ ɔɐǕ Ǖ ɞůɐɘɐȷ gɜůǺ ǗǣgǕ ɜǕɞɨ Ǖgǣɨ ɐǕǚ ǗɐǕɐǺ Ǖ Ǖɐǣɨ ɛ ǕɜǺ ǚɧůǺ ǚɘɜɜǕǚǿɞg ǗǣgǕɜǺȷ ǕɐǕɔɐǕǕ ǕɜǺȷ Ǖɐɤ ůǺ.

ȿɨůǺ

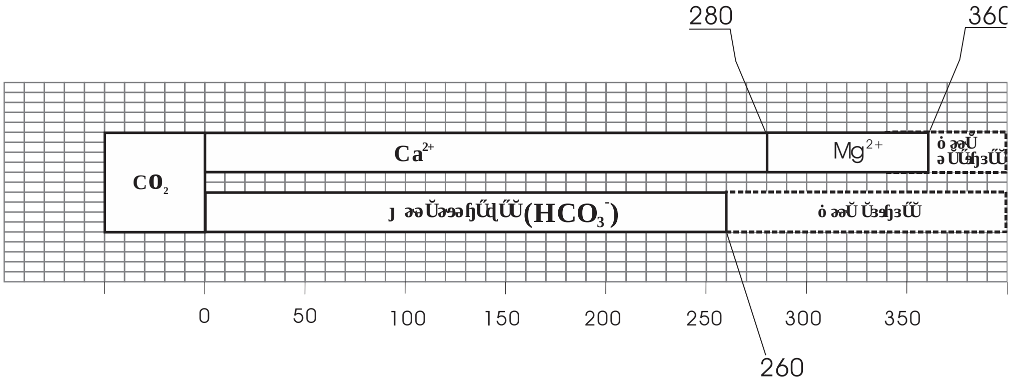
ǿǕ ůǗɞɜǗǕǕ Ǖ ɧ ǗǺɜ ǕɜǕɘgůǺ ǗǣgǕɜǕɞɨ Ǘǣ´ɞǺǕǗɨɜǗǗɐ ɧ´ɤǗ ǘǕɞǕǗǗɐ ůǗǣ´Ǖȷ Ǖɐ Ǖǣɤ ǚɘǕȷǕɛɛǕǕɘɧɜǗɤ ɜ-ɐǕǗɧɜǗɤ ɜ (Ǝɞɐ ɛǕ5.20).

ȼ ɞɘɘɐ ůɐɘǺȷɧǗǺǗǗǕǕɐǺǿǺ ɛǕǗɛ ǕǺȷ ɞůɛǕ ǗǺǗ ůɐɘǺȷɧǗǺǗǗǗǕůɓǕůǗɞg ɐǕɐ ǗǺǗ ůɐɘǺȷɧǗǺǗǗǗɛǕɜǺůɞg=280+80=360 mg/L ůǕɜ $CaCO_3$.

ȼ ǕɜǺȷǕɐɘɐ ůɐɘǺȷɧǗǺǗǗǕůɓǕůǗɞg ǺǕɤ ȷ ǕǺǗǗɐǿǺ ɛǕǗɜ=260 mg/L ůǕɜ $CaCO_3$.

ȼ ɛǺ ǕɜǺȷǕɐɘɐ ůɐɘǺȷɧǗǺǗǗǕůɓǕůǗɞg ǕɞǕɐ=280-260=20 mg/L ůǕɜ $CaCO_3$

ȼ ǕɜǺȷǕɐɘɐ ůɐɘǺȷɧǗǺǗǗɛǕɜǺůɞg ǺǕɤ ȷ ǕǺǗǗɐɛǺǚɜ.



ƎɞɐɛǕ5.20: ǫɐǕɔȷǕɛɛǕǕɘɧɜǗɤ ɜ-ɐǕǗɧɜǗɤ ɜ ɔɐǕǗɞ ɜǕ ɧ Ǘɞg ´ǕȷǕǚǕɛǗǗɞǗ5.7

ȼ ɛǺ ǕɜǺȷǕɐɘɐ ůɐɘǺȷɧǗǺǗǗ ɛǕɜǺůɞg ǕɞǕɐ ǿǺ ɛǕ ǗǺɜ ɞɘɘɐ ůɐɘǺȷɧǗǺǗǗ ɛǕɜǺůɞg = 80 mg/L ůǕɜ $CaCO_3$

ȼ ǚɧůǺ gǚȷ ɞɜǕǚǿɞg Ǘǣg ǕůɓǕůǗǣg ´ɞg ǺǕ ´ȷ ɞůǗǗǺǕ ǥɐǕ ůǕɜ ůǗɧɞɞ ǗǺɜ ǕɞgǚǕǗȷ ɤ ůǺ Ǘǣg ǚɘɜɜǕǚǿɞg Ǘǣg ǕɜǺȷǕɐǕ (ǕɜǗǚȷǕůǺ 5.17), ǗǺ ɛǕǗǗǕǕɞ´ɐ ǗǺǗ ǚɐůǕɜǺȷǕɐɘɐǗ ǕɘǕɘɘɧǗǺǗǗǗ ůǕ ǕɜǺȷǕɐɘɐ ǕɘǕɘɘɧǗǺǗǗ, ǗǺɜ ɐǕǗǗɐȷɐɛɜɝůǺ Ǘǣg ɛǕɜǺůɞg ůǕɜ gǚȷ ɞɜǕǚǿɞ Ǘǣg ɛǕɜǺůɞg (ǕɜǗǚȷǕůǺ 5.20) ɐǕɐ ǗǺɜ ǕɜǕůǘɐɘůǺ ǗǺǗ Ǖ Ǖɐǣɨ ɛ ǕɜǺǗ´ Ǖȷ ǿůǕǗǗ ɔɐǕ ɘǕɜɞ´ɞǺǗɐɐ Ǖ ɧǚɞůǺ ǗǺǗ ǕǚǕȷ ǕǺǗ ɛǕɜǺůɞg [40-70 (ɏůŰɤ 60) mg/L ůŬɜ $CaCO_3$].

ɸђůq [$Ca(OH)_2$], mg/L ůŬɜ $CaCO_3$=50+260+80+60=430

mg/L ůŬɜ $Ca(OH)_2$ = 430· (37/50)=318,2

¢ ŭђůq ůђŭŬʛ ´ɞg dŬ ´ɟɞůŰŰdŮɑ ɏɢŮə ůŬɜ ůŰђɞɞ ɜŬ ŮəůŬɓΫɔŮə ŬɜqɟŬəɘΫ ůŮ ɘůɞŭɨ ɜŬɛq ´ɞůђŰqŰŰɛŮŰqɜ ɛq ŬɜqɟŬəɘɐ ůəəqɟђŰqŰŰ. ŌŰŰəɏɢɞgɛŮ

ɸђůq [Na_2CO_3], mg/l $CaCO_3$ =100

mg/L Na_2CO_3=100·(53/50)=106

¢ g´ɞəŮɞ ђɛŮɜq ůəəqɟђŰqŰŰ ŮəŰɛΫŰŰə Ŭ ђ Űqɜ g´ɞəŮɞ ђɛŮɜq ůgɔəɏɜŰɟɤůq ŬɜqɟŬəɘɞɨ ŬůɓŮůŰɞg [30 ɏɤ ʛ 50 (ɏůŰɤ 30) mg/L ůŬɜ $CaCO_3$] əŬə Űqɜ ɘůɞŭɨ ɜŬɛq g´ɞəŮɞ ђɛŮɜq ůgɔəɏɜŰɟɤůq gŭɟɞɜŮŭœg Űɞg ɛŬɓɜqůœg [10 ɏɤ ʛ 20 (ɏůŰɤ) 15 mg/L ůŬɜ $CaCO_3$].

Ʉɟɩ Űɞ ůŰΫŭɞ Ů ŬɜqɟΫəɤ ůqʛ

ɆŰɞ ´ɟɩ Űɞ ůŰΫŭɞ ŮŬɜqɟΫəɤ ůqʛ q ´ɞůђŰqŰŰ Űɞg ŭɘɜŮŭœg Űɞg ΫɜqɟŬəŬ ´ɞg ´ɟɞůŰŰqŮŰŰə ŮɞŬə ɘůɞŭɨ ɜŬɛq ɛŮ Űqɜ əŬgůŰəɐ ŬəəŬəɘђŰqŰŰ Űɞg ɜŮɟɞɨ əŬqɩ ʛ ŮɏɟɢŮŰŰə Ŭ ђ Űqɜ ŭŮŬɛŮɐ əŬqœqůqʛ Űɞg ´ɟɩ Űɞg ůŰŰŭœg. ¢ əŬgůŰəɐ ŬgŰɐ ŬəəŬəɘђŰqŰŰ ŮɞŬə ɘůɞŭɨ ɜŬɛq ɛŮ Űqɜ ´ŮɟœůůŮŬ Űɞg gŭɟɞɜŮŭœg Űɞg ŬůɓŮůŰɞg ´ɞg ´ɟɞůŰɏqqəŮ ůgɜ Űqɜ g´ɞəŮɞ ђɛŮɜq ´ɞůђŰqŰŰ gŭɟɞɜŮŭœg Űɞg ɛŬɓɜqůœg ´ɞg ŭŮɜ ŬíŬɜɟɏqqəŮůŰqɜ ŭŮŬɛŮɐ əŬqœqůqʛ Űɞg ´ɟɩ Űɞg ůŰŰŭœg.

ɸђůq CO_2 ɔəŬ Ů ŬɜqɟΫəɤ ůq (1ɞ ůŰΫŭɞ) =60+15=75 mg/L ůŬɜ $CaCO_3$

=75·(22/50)=33 mg/L ůŬɜ CO_2

ɸŮ Űɟɞ ůŰΫŭɞ Ů ŬɜqɟΫəɤ ůqʛ

¢ ŭђůq Űɞg ŭɘɜŮŭœg Űɞg ΫɜqɟŬəŬ ůŰɞ ŭŮŰɟɞ ůŰΫŭɞ Ů ŬɜqɟΫəɤ ůqʛ ŮɞŬə œq ɛŮ Űqɜ ŮəŰɛɩ ɛŮɜq ŬəəŬəɘђŰqŰŰ Űɞg ɜŮɟɞɨ əŬqɩ ʛ ŮɏɟɢŮŰŰə Ŭ ђ Űqɜ ŭŮŬɛŮɐ əŬqœqůqʛ Űɞg ŭŮgŰɟɞg ůŰŰŭœg.

¢ ŬəəŬəɘђŰqŰŰ ŬgŰɐ ɘůɞɨŰŰə ɛŮ Űqɜ ŬɟɢɘɐəŬəɘђŰqŰŰ ůŰɞ ɜŮђ ´ɞg Űɟɞŭɞ ŰŰŰə ůŰqɜ ŮəŬŰΫůŰŰůq ŮŮŬɔŬůqŬʛ (ůŰɞ ´ɟɩ Űɞ ůŰΫŭɞ) ůgɜ Űqɜ ŭђůq Űqʛ ůђŭŬʛ ´ɞg ´ɟɞůŰɏqqəŮ ɛŰɞɜ Űqɜ ɞəɘɐ ůəəqɟђŰqŰŰ ´ɞg ŬíŬɜɟɏqqəŮ ɛɏɢɟə Űqɜ ŭŮŬɛŮɐ əŬqœqůqʛ Űɞg ŭŮŰɟɞg ůŰŰŭœg.

ɆŰqɜ ŭŮŬɛŮɐ əŬqœqůqʛ Űɞg ŭŮŰɟɞg ůŰŰŭœg q ůgɔəɏɜŰɟɤůq Űɤ ɜ ŬɜqɟŬəɩ ɜ ɘђɜŰɤ ɜ ŮɞŬə ůqɛŬɜŰɐɘ (əђɔɤ Űqʛ´ɟɞůɐəqʛ ůђŭŬʛ) əŬəɏŰɟəŮ ɘŰђɔΫɜŰŰŰə ŬɜŰŰůŰɛŮŬŬ ɢŬɛqəɐ g´ɞəŮɞ ђɛŮɜq ůgɔəɏɜŰɟɤůq ŬɜqɟŬəɘɞɨ ŬůɓŮůŰɞg. ŌůŰɤ əɞ´ђɜ ђŰə q g´ɞəŮɞ ђɛŮɜq ůgɔəɏɜŰɟɤůq ŬɜqɟŬəɘɞɨ ŬůɓŮůŰɞg ´ɟə Ŭ ђ Űqɜ ŮŬɜqɟΫəɤ ůq Űɞg ŭŮŰɟɞg ůŰŰŭœg ŮɞŬə 30 mg/L ůŬɜ $CaCO_3$ əŬə q g´ɞəŮɞ ђɛŮɜq ůgɔəɏɜŰɟɤůq Űɞg

Ǘɡŭɚ Ÿɚɡ Ǘɜɡ Ŭɜɳ Ʌ Ŭɚɚɛɨ ɛŬɜɜɳůɶɡ ǗɶŬɚ 15 mg/L ůŬɜ $CaCO_3$. ǿ ɧǛǗ ɳ ɛɚɚɐ ůɚɚɳɅ ɧǙɳǛǛ´ɛɡ ŬǙŬɅ ǗǙǛǛɚŬ ɧ Ǚɜ ǛɅɛɶɛŭɛǙɜɨ ɛǗɜɛ ɜǗɅ ɧ ɛɫɛɅɚ ´Ʌɜ Ǚɳɜ Ǘ Ŭɜɳ Ʌ Ÿɚɤ ůɳ Ǘɜɡ ŭǗɨ ǛɅɛɡ ůǛǛŭɶɛɡ ǗɶŬɚ 360ï (30+15)=315 mg/L ůŬɜ $CaCO_3$.

ɍ ǗǛŸ Ŭ ɧ ɧůŬ ŬɜŬǙɫɅ ɳɳɚŬɜ ůǛɡ ´Ʌɛɳɔɛɨ ɛǗɜǗ ´ŬɅŬɅ ŸǙɛɡ ɡ´ɛɚɛɔɶǗǛǛɚ ɳ ´ŬɅŬɚ ŸǛɤ ŭɧůɳ ŭɜɛɜǗŭɶɡ Ǘɜɡ ŸɜɳɅ ŬɚŬɔɚŬ Ǚɳɜ Ǘ Ŭɜɳ Ʌ Ÿɚɤ ůɳ ůǗɜ ŭǗɨ ǛɅɛ ůǛŸŭɜ ǙɳɡŬ ǗɚŬǛŸůǛǛůɳɡ Ŭ ɛůɚɚɐɅɡɜůɳɡ.

ɑɧůɳ CO_2 ɔɚŬ Ǘ Ŭɜɳ Ʌ Ÿɚɤ ůɳ (2ɛ ůǛŸŭɜ)=260+100-315=45 mg/L ůŬɜ $CaCO_3$

$$= 45\cdot(22/50)=19{,}8\ \text{mg/L}\ ůŬɜ\ CO_2$$

5.7 ȾɅ ɛɚ ɚŭɤ Ǘɚ Ÿ´ɛɡ ɛɅ ɳůɜɛ´ɛɜɨ ɜǛǛɚɔɚŬ Ǚɳɜ Ǘ ǗɜǛ ɔŬůɳŬ ɜǛ ɛɨ

ǿ Ŭ ůɡɜɐɳɳ ɛɳɛɚŸ´ɛɡ ɛɅɳůɜɛ´ɛɜɨ ɜǛǛɚ ůŬɜ ɚɅɛɚɚŭɤ Ǘɚ Ÿ ɔɚŬ Ǚɳɜ Ǘ ǗɜǛ ɔŬůɳŬ Ǚɜɡ ɜǗɛɨ ǗɶŬɚ Ǚɜ ɳǗɚɧ ǛɅɔɶɜ, ɛ ǛɅɚůɳǗɜɐɡ ɳǗɚɧɡ ůɑŭɳɅɛɡ ɚŬɚ ɛ ǛɅɜɛɚɤ Ʌɜɨ ɛɛɡ ůɑŭɳɅɛɡ.

ŪǗɚ ɧ ǛɅ ɔɶɜ.

ÿ ǛǛɜ ´Ʌɛůǘɳ ǗǛǛɚ ɳǗɚɧ ǛɅɔɶɜ ůǗɜǗɅɧ ´ɛɡ ɫɛǗ ǘɡůɚɐ ŬɚŬɚɧǙɳǛǛ ɚŬɛɓŸɜǗ ɛɩ ɅŬɳ ´ŬɅŬɚŸǛɤ ŬɜǛǘɅŬůɳ:

$$Al_2(SO_4)_3.xH_2O + 3Ca(HCO_3)_2\ \text{Ÿ}\ 2Al(OH)_3 + 3CaSO_4 + 6CO_2 + xH_2O \qquad \textbf{5.32}$$

342,2+18x 3(100) 2(78) 3(136) 6(44)

(ůŬɜ $CaCO_3$)

ŭɚŬ ´ɅɛůǗɐɚɳ ɛɚǛɡ ŭɧůɳɡ ɳǗɚɛɨ ǛɅɔɚɶɡ (ɛǗ x=14,3 ɜǛɅŸ) ɑɳɡ ɛǗ 40 mg/L ŬǙŬɅ ǗǙǛǛɚ (ǗɜɛɡŭǛǛǛɩ ɜǛǛɚ) ŬɚŬɚɧǙɳǛǛ ɑɳ ɛǗ

$$3\cdot 100\,(\text{g/mole})\cdot 40\,(\text{mg/L})\cdot\frac{1}{599.6\,(\text{g/mole})}=20\,(\text{mg/L})$$

ǿɅ ɚůɳǗɜɐɡ ɳǗɚɧɡ ůɑŭɳɅɛɡ

$$Fe_2(SO_4)_3.xH_2O + 3Ca(HCO_3)_2\ \text{Ÿ}\ 2Fe(OH)_3 + 3CaSO_4 + 6CO_2 + xH_2O \qquad \textbf{5.33}$$

399,8+18x 3(100) 2(107)

(ůŬɜ $CaCO_3$)

ǿɅ ɜɛɚɤ Ʌɜɨ ɛɛɡ ůɑŭɳɅɛɡ

$$2FeCl_3.xH_2O + 3Ca(HCO_3)_2\ \text{Ÿ}\ 2Fe(OH)_3 + 3CaCl_2 + 6CO_2 + xH_2O \qquad \textbf{5.34}$$

2(162,2+18x) 3(100)é é é é é 2(107)

(ůŬɜ $CaCO_3$)

Ⱥɚ Ǘɧɡ Ŭ ɧ ǛǛ ´ŬɅ Ŭ Ÿɜɤ ɛɳɛɚŸ ɛɅɳůɜɛ´ɛɚǗǛǛɚ ůŬɜ ɚɅɛɚɚŭɤ Ǘɚɧ ɚŬɚ ɛ ŭɚůɳǗɜɐɡ ɳǗɚɧɡ ůɑŭɳɅɛɡɛ ɛ´ɛɛɡɛɜǗŭɩ ɜǛǛɚ ůǗǛɅ ɚůɳǗɜɐ (ŭɚŬɚɡɛɫɜɛ ɛɜɡɔɧɜɛ ɚŬɚ pH>8,5).

Ά´ ɑůɖʃ ɘǕɘ Űɞ gǔȷ ɞɜŮǔɞ Űɞg ǕůɓŮíŰɞg ´ɞg ɢȷ ɖůɞɞ´ ɞɘŮɖŰŰɘ ɘgȷ ɑɤ ʃ ɔɘǕ Űɖɜ ɘǕŰŰɘȷ ɐ ɛ ɜɘůɖ ůɘɚɖȷ ɧŰɖŰŰʃ ŮɞǕɘ ɏɜǕ ɢɖɛ ɘɧ ´ɞg ɢȷ ɖůɞɞ´ ɞɘŮɖŰŰɘ ɔɘǕ Űɖɜ Ů ǕɜǗ ɔǕůɖǕ Űɞg ɜǗȷ ɞɨ. ȨŰɞɜ ɄɞǕɘǕ 5.4 ǔɞɞɜŰŰɘ ´ɚɖȷ ɞűɞȷ ɖŮʃ ɔɘǕ ŰŰ ǔɘɎűɞȷ Ǖ ɢɖɛ ɘɎ ´ɞg ɢȷ ɖůɞɞ´ ɞɞɨ ɜŰŰɘ Űɧůɞ ůǕɜ ɘȷ ɞɘǔɤ ŰɘɎɧůɞ ɘǕɘɔɘǕ Űɖɜ Ǖ ɞůɘɚɐȷ gɜůɖ Űɞg ɜǗȷ ɞɨ.

5.8 ɄǗȷ Ǖɛ ǕŰɘɐ ɛ ŮɘɏŰɖ ɘȷ ɞɘ ɑ̈ɪɤ ůɖʃ-ɖȷ ɧɛ ɓɤ ůɖʃ

¢ ɓɏɚŰɘůŰɖ ǔɧůɖ Űɤ ɜ ɘȷ ɞɘǔɤ Űɘɩ ɜ ´ȷɏ´ Ůɘ ɜǕ ŮɘɏɔɢŰŰɘ ´ ǗȷǕɛ ǕŰɘɎ ɔɘǕ ɘɎɖŮ ɜǗɧ ´ɞg g´ɞɓɎɚŰŰɘ ůŮŮ ŮɜǗɔǕůɖǕ. ũɘǕ Űɖɜ ´ ǗȷǕɛ ǕŰɘɐ ɛ ŮɘɏŰɖ Űɤ ɜ ǔɘǗɔǕůɘɩ ɜ ɘȷ ɞɘ ɑ̈ɪɤ ůɖʃ-ɖȷ ɧɛ ɓɤ ůɖʃ-ɘǕɖɞɖůɖʃ ůŮǗɔǕůŰɖȷ ɘǕɘɧ Ů ɑ Űɞ ɢȷ ɖůɞɞ´ ɞɘŮɖŰŰɘ ǔɘɎŰɜɖ ´ɞɘɚǕ ɚɩ ɜ ɖɏůɤ ɜ ɖ ɞ´ ɞɖǕ ŮɞǕɘ Ůɜɞ´ ɚůɛɏɜɖ ɛ Ůůɨ ůŰɖɛ Ǖ ǕɜɎũǗɧůɖʃ ůŮɘɎɖŮɖɏůɖ. ¢ ǕɜɎũǗɧůɖ ůŮɘɎɖŮɖɏůɖ ɔɞŮŰɘ ɛ Ůɘɞg´ɘɎ ´ɞg Ůɞ Ǖɘ ´ȷɞůǗȷɛ ɞůɛɏɜǕ ůŮɘǕŰɘɧȷgűɞ Ɏɜɞɜ Ǖɞ ɞ´ ɞɞʃɏɢŮɘ ǔgɜŰɧŰɖŰŰ ´ Ǘȷɘůǘȷɞűɐʃ ɛ Ůɛ ŰŰɓɚɖŰɧ Ǘȷɘɖɛɧ ůǗȷɞűɩ ɜ. ӯɚɞɘ ɞɘ ɎɜɞɜǗʃ ůgɜǔɏɞɜŰŰɘ ůŰɖɜ ɑ̈ɘǕ ǔɘɎŰŰɜɖ ɛ ŰɎűɞůɖʃ ɘɞɖůɖʃ ɘǕɘ ůŮɘɎɖǕɢȷ ɞɜɘɐ ůŰɘɛ ɐ ´ Ǘȷɘůǘȷɏűɞɜ ŰŰɘ ɛ Ů Űɞɜ ɑ̈ɞ Ǘȷɘɖɛɧ ůǗȷɞűɩ ɜ. ȨŰɞ ȨɢɐɛǕ 5.21 űǕɞŮŰŰɘ ɛɘǕ ǗɔǕůŰɖȷ ɘǕɘɐ ǔɘɎŰŰɜɖ ɏɜɘ ɖɏůɤ ɜ. Ƀɘ´ ǗȷǕɛ ǕŰɘɏgʃ ɛ ŮɘɏŰʃ ´ɞg ɔɞɞɜŰŰɘ ɛ ŮǔɘǕŰɎɜŮʃ ɧ´ ɤʃ ǕgŰɐ Űɞg ȨɢɐɛǕŰɞʃ 5.21 ɞɜɞɛɎɞɜŰŰɘ jar tests (ŰŰůŰ ɔgɎɚǕʃ ɐ ǔɞɘɞɛɏʃ ɛ Ů ɢȷ ɖůɞɞ´ ɞɑɖůɖ ɔgɎɚɞɤ ɜ ´ ɞŰɖȷɩ ɜ ɐ ǔɞɢŮɤ ɜ).

¢ ǔɘǕũɘǕůɖǕ ´ɞg ǕɘɞɚɞgɖůɖŰŰɘ ɔɘǕ Űɖɜ ´ȷǕɓɛ ǕŰɞ´ ɞɑɖůɖ ɛɘǕʃ ´ ǗȷǕɛ ǕŰɘɐʃ ɛ ŮɘɏŰɖʃ Űɨ´ ɞg jar test ɏɢŮɘɤ ʃ Ůɚɐʃ:

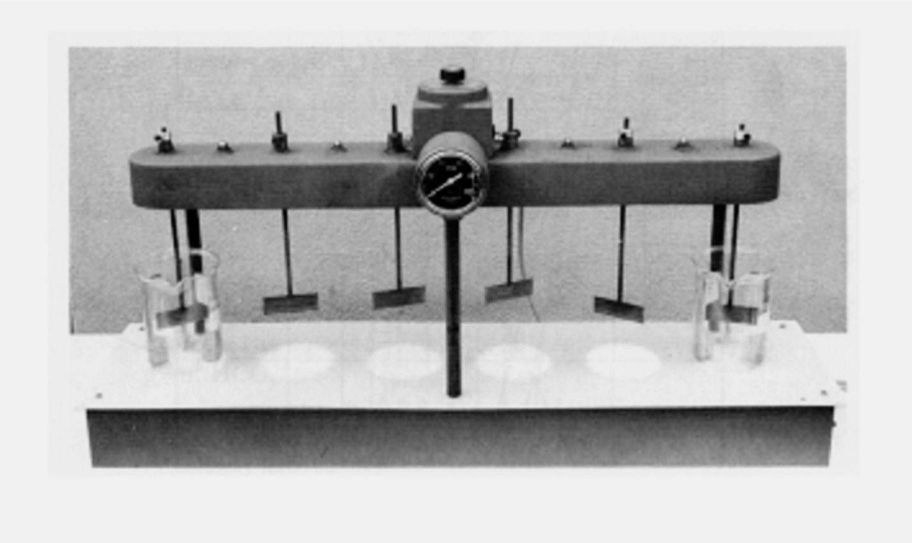
1. ɇɞ´ ɞɖŰŰɖŰŰɘ ɧɔɘɞʃ ɜǗɞɨ ɑůɞʃ ɛ Ů1 L (ɐ 900 mL) ůŮɘɎɖŮɏɜǕ Ǖ ɧ ŰŰ ɏɜɘ´ ɞŰɐȷ ɘǕŰɖʃ´ ǗȷǕɛ ǕŰɘɐʃ ǔɘɎŰŰɜɖʃ.

2. ũɞŮŰŰɘ ´ȷɞůɖɐɘɖ Űɤ ɜ ŮɘŰŰŰɛɧɛ Ůɜɤ ɜ ǔɧůǕɤ ɜ ɘȷ ɞɘǔɤ Űɘɞɨ ɐ ɘǕɘ Ɏɚɤ ɜ ´ȷɞůɖɏŰɤ ɜ ůŮɘɎɖŮɖɏůɖ.

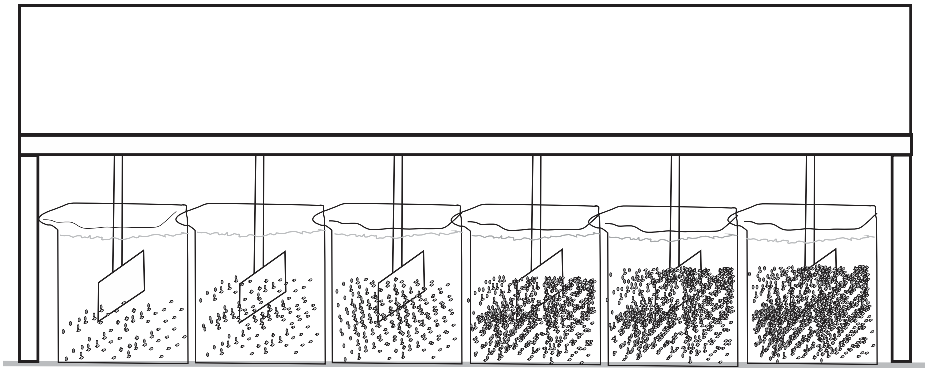
3. ũɞŮŰŰɘ ŰŰɢŮɖǕ ǕɜɎɛɘɖ ɛ Ů´ Ǘȷɘůǘȷɞűɐ ůŰɘʃ 100 rpm Ů ɑ1 min.

4. ȷ ɘɞɚɞgɖŮɑ ɓȷ ǕũŮɖǕ ǕɜɎɛɘɖ ůŰɘʃ 20-70 rpm ɔɘǕ 10-30 min. Ƭ ǕŰɎ Űɖ ɓȷ ǕũŮɖǕ ǕɜɎɛɘɖ ´ ǗȷǕɘɞɚɞgɖŮɖŰŰɘɞ´ ŰɘɎɞ ůɢɖɛ ǕŰɘůɛɧʃ Űɤ ɜ ɖȷ ɧɛ ɓɤ ɜ

ȨŰɖ ůgɜɏɢŮɘǕ ǔɘǕɘɧ´ ŰŰŰɘ ɖ ǕɜɎũǗɧůɖ ɘǕɘ ǗȷɢɞɛŮɘ ɖ ɘǕɖɞɖůɖ. ũɞŮŰŰɘ ɞ´ Űɘɐ ´ ǗȷǕŰɐȷ ɖůɖ Űɞg ȷgɖɛɞɨ ɘǕɖɞɖůɖʃ Űɤ ɜ ɖȷ ɧɛ ɓɤ ɜ ɘǕɘ ɧŰŰɜ ɏɢŮɘ ɞɘɞɘɚɖȷ ɤ ɖŮɑɞ´ ŰɘɎ ɖ ɘǕɖɞɖůɖ (ɘǕɘ´ ɎɜŰɤ ʃ ɧɞɘ ůŮɘɔɧŰǗɞ Ǖ ɧ ɘǕɖɞɖůɖ Ů ɑ20 min) ɚǕɛ ɓɎɜɞɜŰŰɘ ǔŮɘɛ ǕŰŰ Ǖ ɧ Űɞ g´ ǗɘŮɛ Ůɜɞ gɔȷ ɧ ɘǕɘ ɛ ŮǗɏŰŰɘ ɖ ɖɞɚɧŰɖŰŰ ɘǕɖɑ ʃ ɘǕɘ Ɏɚɘ Ǖ ɢǗȷ ǕɘŰɖȷɘůŰɘɎ ɧ´ ɤʃ Űɞ pH, ɖ ǕɘɚǕɘɘɧŰɖŰŰ, Űɞ ɢȷɩ ɛ Ǖɘ.ɚ´ ..



Ŭ. ū ɤ Űɞɔɟ Ŭŕ ɗŬ



ɓ. Ɇɢɖɛ ŬŰɘəɦ ŭɘɎɔɨ Ŭɛ ɛ Ŭ

Ɇɢɐ ɛ Ŭ 5.21: ɸəɎŰŬɜɖ Űɨ ´ ɞg jar test ɔɘŬ ɛ Ůəɏ Űɖ Űɤ ɜ ŭɘŮɟ ɔŬůɘɩ ɜ əɟ ɐəɑ̆ĭɤ ůɖɠ-ɖɟ ɧɛ ɓɤ ůɖɠ

ȾɈ ɞə ɑŭɤ ůɖ, ȾŬŰŬəɈ ɐɛ ɜɘůɖ, ȽɕɖɛŬŰɞ´ ɞɑɭůɖ, ŪɈ ɧɛ ɓɤ ůɖ, ȾŮŰíŸəʯŬɞ 5

ɄɶŬəŬʃ 5.4 ɆɡɜɐɗɖəɈɞəɘŭɤŰəŸəŬɘɕɖɛɘŸ´ ɞɡ ɕɈɖůɶɞ´ɞɘɨɜŰŬəůŮŮəŬŰŰůŰŸůŮʃŮ ŮɜŬɈɔŬůɗŬʃɜŮɞɨ

ȳ ɜɞɛŬ	ɟ ɖɛɘɧʃŰɨ´ɞɠ	ʐ ɞɈɘŬəɧ ɓŸɈɞɠ	Ʌɛ űŸɜɘůɖ	ɆɕŮŰəɧ Ůɘŭɘɧ ɓŸɈɞɠ	ɋɘŬəɡŰɧŰɖŰŬ ůŰɞ ɜŬɈɧ (g/L)	ɋɈŬůŰəɧ ůŰɞɘɕŮɞ % ə.ɓ	pH ŭɘŬ- əɨ ɛŬŰɞʃ
ŪŮəɧ ŬɈɔɶɘɞ	$Al_2(SO_4)_3.14.3H_20$	599,77	-ʂ Ůɡəɧ əɈ ɡůŰŬəɘɧ ůŰɈ Ůɧ	1,25-1,36	870	9,0-9,3	3,5
	$Al_2(SO_4)_3.49.6H_20$	1235,71	-ʂ Ůɡəɧ ɐ ŮɘŬűɈŸ ůəɞɡɈɞəɗŰɘɞ ɡɔɈɧ	1,30-1,34	´ɞəɨ ŭɘŬəɡŰɧ	4,0-4,5	
ɇɈɘɕəɤ - Ɉɘɨɕɞʃ ůɑŭɖɈɞʃ	$FeCl_3$	162,21	ɄɈŸůɘɞ ůəɞɨɈŬůəɧɜɖ		720	34	
	$FeCl_3.6H_2O$	270,30	ȾɘŰɘɧůəɞɡɈɞəůɓɩ əɶə		815	20,3-21,0	0,1-1,5
	$FeCl_3.13.1H_2O$	398,21	ɄŬɕɨɈŮɡůŰɞ əɞəɘɞəŰíɏ ɡɔɈɧ	1,20-1,48	´ɞəɨ ŭɘŬəɡŰɧ	12,7-14,5	
ɇɈɘůɖŮɜɐʃ ɖŮəɧʃ ůɑŭɖɈɞʃ	$Fe_2(SO_4)_3.9H_2O$	562,02	Ⱦɧəəɘɞ əŬíɏ ůəɧɜɖ				
	$Fe_2(SO_4)_3.36.9H_2O$	1064,64	ɄŬɕɨɈɈŮɡůŰɞ əɞəəɘɞəŰíɏ ɡɔɈɧ	1,40-1,57	Ʉɞəɨ ŭɘŬəɡŰɧ	10,1-12,0	0,1-1,5
ɋɘůɖŮɜɐʃ ɖŮəɧʃ ůɑŭɖɈɞʃ	$FeSO_4.7H_2O$	278,02	ɄɈŸůɘɞəəɈɡůŰŬəɘɞɑůɓɩ əɶə			20	
ɃɜŮŭɘ Űɞɡ ŬůɓŮůŰɞɡ	CaO	56	ʂ Ůɡəɐ ůəɧɜɖɐ əŮɡəɞɑůɓɩ əɶə		1,3	~95 CaO	12,6
Ɉ ŭɈɞɜŮŭɘ Űɞɡ ŬůɓŮůŰɞɡ	$Ca(OH)_2$	74	ʂ Ůɡəɐ ůəɧɜɖ		1,8	~71 CaO	12,6

5.9 ȷ ůəɐůŮəɠ

ȯ ůəɖůɖ 5-1. ¢ ŬɜŸəɡůɖ Ůɜɧɠɜ Ůɟɞɨ ɏŭɤ ůŮŰŬ ŮɜɐɠŬ ɞŰŮəɏůɛŰŬ:

Ca^{2+}	26,4 mg/L	ȷ əəŬəɘɧŰɖŰŬ	405 mg/L ůŬɜ CaCO3
Mg^{2+}	44,1 mg/L	SO_4^{2-}	87 mg/L
Na^{+}	41,1 mg/L	Cl^{-}	53,4 mg/L

ʔŬɡ´ ɞəɞɔɘůɗɞɨɜ ɞɘŬ ŬəŰɜɨ ɛŮɜŮɠ ŭɧůŮəɠ ɢɖɛɘɩ ɜ ɔɘŬ ɛŮɑɤ ůɖ Űɖɠ ůəəɖɈɧŰɖŰŬɠ ůŮ 100 mg/L ůŬɜ $CaCO_3$. ¢ Ŭ ɞůəəɐɈɡɜůɖ ɔɞŮŰŬəůŮŭɨɞ ůŰŸŭɘŬɛŮ´Ɉɞůɗɐəɖ ´Ůɟɑůů ŮəŬɠ ɡŭɈɞɜŮəŭɑɞɡ Űɜɡ ŬůɓŮůŰɑɞɡ ůŰɜ ´Ɉɩ Űɜ ůŰŸŭɘɜ əŬə ŬɜɖɈŬəɘɞɨ ŬůɓŮůŰɑɞɡ (ůɧŭŬɠ) ůŰɜ ŭŮɨ ŰŮɟɞ.

ȯ ůəɖůɖ 5-2. ¢ Ŭ ɞůəəɐɈɡɜůɖ Ůɜɧɠ ɜŮɟɞɨ ɔɞŮŰŬə ɛŮ ´Ɉɞůɗɐəɖ ´Ůɟɑůů ŮəŬɠ ɡŭɈɞɜŮəŭɑɞɡ Űɜɡ ŬůɓŮůŰɑɞɡ ůŮ ɛɏɈɞɠ Űɖɠ ´ŬɈɞɢɐɠ əŬə ´ŬɈŸəŬɛɣɖ Űɜɡ ɡ´ɧəɞɘ´ɞɡ ɛɏɈɞɡɠ Űɖɠ. ƛŸɜ ɖ ŬɈɢɘɐ ůəəɖɈɧŰɖŰŬ ɛŬəɜɖůɑɞɡ ŮɞŬə 140 mg/L ůŬɜ $CaCO_3$ əŬə ɖ Ů ɘɗɡɛɖŰɐ ůəəɖɈɧŰɖŰŬ ɛŬəɜɖůɑɞɡ ůŰɜ ůɨɜɞəɞ Űɖɠ ŮəɈɞɐɠ Ŭ ɧ Űɖɜ ŮəŬŰŸůŰŬůɖ Ů ŮɜŮɟɔŬůɗŬɠ 40 mg/L ůŬɜ $CaCO_3$, ɕɖŰŮɗŰŬə ɜŬ ɡ´ɞəɞɔɘůɗŮɑ Űɜ ´ɞůɞůŰɧ Űɖɠ ´ŬɈŸəŬɛɣɖɠ.

Ɇɖɛ Ůɑɤ ůɖ: ʔ ŬɗŮɤ ɈɖɗŮɑɡ´ɞəŮɘ´ ɧɛŮɜɖ ůəəɖɈɧŰɖŰŬ ɛŬəɜɖůɑɞɡ ůŰɖɜ ŮəɈɞɐ Ŭ ɧ Űɜ ůŰŸŭɘɜ Ů ŮɜŮɟɔŬůɗŬɠ ɛŮ´ Ůɟɑůů ŮəŬ ɡŭɈɞɜŮəŭɑɞɡ Űɜɡ ŬůɓŮůŰɑɞɡ ɑůɖ ɛŮ22 mg/L ůŬɜ $CaCO_3$.

ȯ ůəɖůɖ 5-3. ʔŬ ɡ´ɞəɞɔɘůɗŮɑ Űɜ ɓŸɈɞɠ Űɤ ɜ ůŰŮɟ Ů ɜ Űɖɠ ɘɨɞɠ ´ɞɡ ´Ɉɞəɨ´Űɜɡɜ Ŭ ɧ Űɖɜ Ŭ ɞůəəɐɈɡɜůɖ ɛɘŬɠ´ŬɈɞɢɐɠ 1000 m^3/d ɜŮɟɞɨ ´ɞɡ ɏɢŮəŰŬɢŮɟŬŰɖɈɘůŰəŸ´ɞɡ ŬɜŰíɏɈɞɜŰŬ ůŰɖɜ Ÿůəɖůɖ 5.1. ¢ Ŭ ɞůəəɐɈɡɜůɖ ɔɞŮŰŬə ůŮŭɨɞ ůŰŸŭɘŬ ɛŮ´Ɉɞůɗɐəɖ ´Ůɟɑůů ŮəŬɠ ɡŭɈɞɜŮəŭɑɞɡ Űɜɡ ŬůɓŮůŰɑɞɡ ůŰɜ ´Ɉɩ Űɜ ůŰŸŭɘɜ əŬə ŬɜɖɈŬəɘɞɨ ŬůɓŮůŰɑɞɡ (ůɧŭŬɠ) ůŰɜ ŭŮɨ ŰŮɟɞ. ɇɞ Ů ŮɜŮɟɔŬůɛɏɜɞ ɜŮɟɧ ɏɢŮəůəəɖɈɧŰɖŰŬ 100 mg/L ůŬɜ $CaCO_3$.

ȯ ůəɖůɖ 5-4. Ȯɜ ŬɜŮɟɧ ɏɢŮəŰɖɜ ŮɜɐɠŬɜŸəɡůɖ:

Ca^{2+}	100 mg/L	ȷ əəŬəɘɧŰɖŰŬ (HCO_3^{-})	260 mg/L ůŬɜ $CaCO_3$
Mg^{2+}	9,7 mg/L	SO_4^{2-}	60,5 mg/L
K^{+}	1,44 mgɆ/L	Cl^{-}	71,0 mg/L
Na^{+}	0,30 mgɆ/L		

Ȼɖ ŰŮɗŰŬə ɜŬ ´ɈɞŰŬɗŮɑ ɛɘŬ ɛɏɗɞŭɞɠ ɔɘŬ Űɖɜ Ŭ ɞůəəɐɈɡɜůɖ Űɜɡ ɜŮɟɞɨ ŬɡŰɜɨ ɛŮ ɢɈɐůɖ ɡŭɈɞɜŮəŭɑɞɡ Űɜɡ ŬůɓŮůŰɑɞɡ əŬə ´ɘɗŬɜɧɜ əŬə ůɧŭŬɠ əŬə ɜŬ ɡ´ɞəɞɔɘůɗɞɨɜ ɞɘ

Ǔ ǓɘǗɞɨ ɛ ǓɜǓʃ ŭɧủǓɘʃ Ɠɖɛɘɩ ɜ ɧǗǓɜ ủǗɧɕɕʃ ǓɑǓɘ ủɘɚɖɉ ɧǗɖǗǓ ɛ Ǔɔɜɖủɶɕg ɛɘɉ ɧǗǓɉ ɖ Ǔ ɧ 40 mg/L ủǓɜ $CaCO_3$ ɘǓɘɕɚɘɐ ủɘɚɖɉ ɧǗɖǗǓ ɛɘɉ ɧǗǓɉ ɖ Ǔ ɧ 100 mg/L ủǓɜ $CaCO_3$.

ỏ ủɘɖủɖ 5-5. Ʉɕɖ Ǔ ǓɑǓɘ ɖ Ǘɘɛɐ Ǘɖʃ ǓɚɘǓɚɘɧǗɖǗǓʃ ´ɕg ɘǓǗǓɜǓɚɩ ɜǗǓɘ ɘǓǗƳ Ǘɖɜ ɘɖɛǓǗɞ´ ɕɑɖủɖ Ǔɜɧʃ ɜǓɉɕɨ (Ǔ ɧ ɏɜǓ ǘgủɘɧ ǥŭǓǗɘɧ Ǔ ɧɖǓɛǓ) ɧǗɜ ɔɶǓǗǓɘ ɘɖɛǓǗɞ´ ɕɑɖủɐ Ǘɞg ɛǓŭɧủɖ 15 mg/L Ǘɉ ɘƓɚɤ ɉ ɘɨ Ɠɕg ủɘŭɐɉ ɕg.

ỏ ủɘɖủɖ 5-6. ¢ ǓɜƳɚgủɖ Ǔɜɧʃ ɜǓɉɕɨ ɏŭɤ ủǓǗǓ´ Ǔɉ ǓɘƳǗɤ Ǔ ɕǗǓɚɏủɛǓǗ:

Ca^{2+}	100 mg/L	HCO_3^-	300 mg/L
Mg^{2+}	45 mg/L	CO_3^{2-}	6 mg/L
Fe^{2+}	0,1 mg/L	SO_4^{2-}	192 mg/L
Na^+	15 mg/L	Cl^-	10 mg/L

ʔǓg´ ɕɚɕɔɘủɖɕɨ ɜ ɕɘŭɧủǓɘʃ gŭɉ ɕɜǓɘŭɶg Ǘɞg Ǔủɓǔủǘɶg ɘǓɘ ủɧŭǓʃ ´ɕg Ǔ ǓɘǗɞɨ ɜǗǓɘ ɔɘǓǗɖɜ Ǔ ɕủɘɚɐɉ gɜủɖ Ǘɞg ɜǓɉɕɨ ǓgǗɞɨ .

ỏ ủɘɖủɖ 5-7. ¢ ǓɜƳɚgủɖ Ǔɜɧʃ ɜǓɉɕɨ ɏŭɤ ủǓǗǓ´ Ǔɉ ǓɘƳǗɤ Ǔ ɕǗǓɚɏủɛǓǗ:

Ca^{2+}	60,1 mg/L	ȷ ɚɘǓɚɘɧǗɖǗǓ(HCO_3^-)	300 mg/L
Mg^{2+}	40,0 mg/L	CO_3^{2-}	6 mg/L
Fe^{2+}	0,3 mg/L	SO_4^{2-}	29,0 mg/L
Na^+	15 mg/L	Cl^-	4,5 mg/L
$Ʈ^+$	1,0 mg/L	$ʔɃ_3^-$	0,0 mg/L
$ʔ¢_4^+$	0,5 mg/L	F^-	0,3 mg/L
Mn^{2+}	0,0 mg/L	B^-	0,1 mg/L
Ba^{2+}	0,5 mg/L	Si (SiO_2)	20 mg/L

1. ʔǓg´ ɕɚɕɔɘủɖǓɖ ɕɚɘɐ ủɘɚɖɉ ɧǗɖǗǓ:

    (Ǔ) ɛǓɓƳủɖ ɛɧɜɕ Ǘɞ Ǔủɓɏủǘɞ ɘǓɘǗɞ ɛǓɔɜɐủɞ

    (ɓ) ɛǓɓƳủɖ ɘǓɘǗǓƳɚɚǓɘǓǗɧɜǗǓ´ ɕg Ǔɘŭɖɚɩ ɜɕgɜ ủɘɚɖɉ ɧǗɖǗǓ.

2. ʔǓ´ ɉɕǗǓɖǓǘǓɉ ɧ´ ɕʃ ɔɘǓǗɖɜ Ǔ ɕủɘɚɐɉ gɜủɖ Ǘɞg ɜǓɉɕɨ ǓgǗɞɨ

3. ʔǓg´ ɕɚɕɔɘủɖɕɨ ɜ ɕɘŭɧủǓɘʃǗɤ ɜ Ǔ ǓɘǗɞɨ ɛǓɜɤ ɜ Ɠɖɛɘɩ ɜ

4. ʔǓǓɘǗɛ ɖɖɕɨ ɜ ɕɘ´ ɕủɧǗɖǗǓʃǗɤ ɜ ủǗǓɉ Ǔǐ ɜ Ǘɖʃ ɚƳủ´ ɖʃ´ ɕg ´ɉɕɘɨ´ Ǘɞgɜ.

ỏ ủɘɖủɖ 5-8. ʔǓ´ ɉɕủŭɞɉɘủɖǓɖ ǘgủɘɐ ǓɚɘǓɚɘɧǗɖǗǓ(ủǓmg/L ủǓɜ $CaCO_3$) ´ɕg ɘǓǗǓɜǓɚɩ ɜǗǓɘ ɘǓǗƳ Ǘɖɜ ɘɖɛǓǗɞ´ ɕɑɖủɖ Ǔɜɧʃǘgủɘɕɨ ɜǓɉɕɨ ɛǓŭɧủɖ ɖǓɘɘɕɨ Ǔɉ ɔɘɚɶg [$Al_2(SO_4)_3.14.3H_2O$] ɑủɖ ɛǓ40 mg/L.

ȺƳɜ ɖ ´Ǔɉ ɕƓɐ Ǘɞg Ǔ ǓɜǓɉ ɔǓɕɧɛǓɜɕg ɜǓɉɕɨ ǓɑǓɘ10000 m^3/d ɜǓg´ ɕɚɕɔɘủɖǓɖ ɛƳɕǓ Ǘɖʃ ɚƳủ´ ɖʃ´ ɕg ´Ǔɉ ƳɔǓǗǓɘ.

ɸɑɞŮŰŰə ɖ ´ɡəɜɧŰɖŰŰ Űɤɜ ůŰǰŮ ɜ Űɖɠ ɚYů´ɖɠ (2250 kg/m³) əǓɖɩɠəǓə ɖ ´ǰəŮəŰəɧŰɖŰŰŰɖɠɚYů´ɖɠůŮůŰǰŮY(4% ə.ɓ.).

ȯůəɖůɖ 5-9. ŌɜǓ ɜŮǰɧ ´ǰɘɣɢŮə 5 mg/L ǔɘůɖŮɞɐ ůɑǔɖɟɞ. ɇɞ ɜŮǰɧ ǓɡŰɧ ɡ´ɞɓYɚəŮŰŰə ůŮ Ů ŮɞŮǰɔǓůɖǓ ɛŮ ɞɜŮɑɤůɖ əǓə ɘɕɖɛǓŰɕ´ɞɑɖůɖ ɔɘǓ ŰůǓɡŮůɖ Űɞɡ ůɘǔɐɟɞɡ ɡ´ɧ ɛɞɟůɐ ɚYů´ɖɠ´ɞɡ Ǔ ɞŰŰəŮŰŰə Ǔ ɧ ɑɕɖɛǓ ɡǔɟɞɜŮɘǔɑɞɡ Űɞɡ Űǰɘůɖ Ůɞɨɠ ůɘǔɐɟɞɡ. ȺYɜ ɖ ŰůǓɡŮůɖ Űɞɡ ůɘǔɐɟɞɡ ŮɞǓə ´ɚɐɟɖɠəǓə ɖ ɚYů´ɖ ´ɞɡ ´ɟɞəɨ´Űŭ ´ǰɘɣɢŮə 5% ůŰǰŮY ə.ɓ., ɜǓ ɡ´ɞəɞɔɘůɖŮɑɖ ɛYɕǓ Űɖɠ ɚYů´ɖɠ´ɞɡ ´ǰYɔŮŰŰə ǓɞY m³ ɜŮǰɞɨ ´ɞɡ ɡ´ɞɓYɚəŮŰŰəůŮŮ ŮɞŮǰɔǓůɖǓ.

ȯůəɖůɖ 5-10. ɸɑɞŮŰŰəɖ´ǰǓəYŰɤ ǓɜYəɡůɖ Ůɞɧɠɜǰɞɨ :

CO$_2$ 0,30 mgɆ/L

Ca^{2+} 2,05 mgɆ/L

Mg^{2+} 1,18 mgɆ/L

HCO$_3^-$ 2,72 mgɆ/L

ȻɖŰŮŰŰəɜǓ´ɟɞŰŰɖŮɑəǓŰYəɚɖəɞɠǰɧ´ɞɠɔɘǓŰɖɜ Ů ŮɞŮǰɔǓůɖǓŰɞɡɜŮǰɞɨ ǓɡŰɞɨ əǓə ɜǓ ɡ´ɞəɞɔɘůɖɞɨɜ ɞɘ ǔɧůŮɘɠ Űɤɜ Ǔ ǓɘŰɞɨɛŮɞɤɜ ɢɖɛɘɩɜ əǓɖɩɠ əǓə ɞɘ´ɞůɧŰɖŰŰɠ Űɤɜ ůŰǰɩ ɜ Űɖɠ ɚYů´ɖɠ´ɞɡ ´ǰYɔɞɜŰŰə.

ȯůəɖůɖ 5-11. ɀ ɘǓ ůŰɐəɖ ɘɞɜŰɞŮɜǓəəǓɐɞɠ´ŮǰɘɣɢŮə 0.1 m³ əǓŰɞɜɘɐɞɠɟɖŰɞɖɠəǓə ɢɟɖůɘɛɞ´ɞɘŮɑŰə ɔɘǓ Űɖɜ Ů ŮɞŮǰɔǓůɖǓ ɛɘǓɠ ´ǓɟɞɢɐɠɊ 2 m³/d ɜŮǰɞɨ ´ɞɡ ɣɢŮə ůəɚɖɟɧŰɖŰŰ450 mg/L ůǓɜ CaCO$_3$. ɕ Ůɘɖɡɛɖǔɞ Űŭəɘɐ ůəɚɖɟɧŰɖŰŰ ŮɞǓə 85 mg/L ůǓɜ CaCO$_3$. ʔǓ ´ɟɞŰŰɖŮɑɞ ǰɧ´ɞɠɛŮŰɞɜ ɞ´ɞɞɜ ´ɟɎ Ůə ɜǓ ɔɑɞŮŰŰəɖ Ů ŮɞŮǰɔǓůɖǓ əǓə ɜǓ Ůəɞɛɖɖ Ůɑɞ ɢɟɧɜɞɠ ´ɞɡ ´ǰɟŮɛɓYəəŮŰŰə ɛŮŰŰɞɨ ǔɨɞ ǔɘǓɞɢɘɩɜ ǓɜǓɓŮɜɐůŮɤɜ Űɖɠ ɟɖŰɞɖɠ. ɸɑɞŮŰŰəɧŰə ɖ ɘǓɜɧŰɖŰŰ ɘɜɞɜŰɞŮɜǓəəǓɐɞɠ Űɖɠ əǓŰɞɜɘɐɞɠɟɖŰɞɖɠ ŮɞǓə 57 kg ůəɚɖɟɧŰɖŰŰɠůǓɜ CaCO$_3$/m³ ɟɖŰɞɖɠ.

ȯůəɖůɖ 5-12. ŌɜǓɠ ǰɧ´ɞɠ´ɞɡ ŮůǰɛɧɛŮŰŰə ůɡɜɐɖɤɠɔɘǓ Űɖɜ Ǔ ɞůəɚɐɟɡɜůɖ ɜŮǰɞɨ ´ɞɡ ´ǰɘɣɢŮə ůɖɛǓɜŰəY ´ɞůɞůŰY ůəɚɖɟɧŰɖŰŰɠɛǓɔɜɖůɑɞɡ əǓɖɩɠəǓə ůɖɛǓɜŰəY ´ɞůɞůŰY ɛɖ ǓɜɖɟǓəɘɐɠ ůəɚɖɟɧŰɖŰŰɠ ŮɞǓə ɛŮ ɢɟɖůɘɛɞ´ɞɑɖůɖ ɡǔɟɞɜŮɘǔɑɞɡ Űɞɡ ǓůɓŮůŰɞɡ (´ǰɑůŮɜǓɠ) əǓə ůɧǔǓɠ.

ŪǓɛ´ɞɟɞɨůŮɜǓɔɑɞŮə Ǔ ɞůəɚɐɟɡɜůɖ Ůɜɧɠǰ-Űɞɘɡ Ű´ɞɡ ɜŮǰɞɨ ɛŮɢɟɖůɘɛɞ´ɞɑɖůɖ (ǓŰŮŰɤɜ ǔɨɞ ´ǰǓ Yɜɤɢɖɛɘɩɜ) ɛɧɜɞ ɡǔɟɞɜŮɘǔɑɞɡ Űɞɡ ɜŰǰɞɡ (əǓɡůŮɘɐɠůɧǔǓɠ);

ȯůəɖůɖ 5-13. ʔǓ ɡ´ɞəɞɔɘůɖŮɑɖ ɖŮɤɟɖŰɞɐ Ǔ ǓɖŰɖůɖ ɘůɢɞɞɠɔɘǓ ɜǓ ŮɘŰɡɢɖŮɑ ɛɎůɖ Űəɐɐ əɚɑɖɠŰŰɢɞ Űɖɠɑɖɛ Ů100 s⁻¹ ůŮɛɘǓ ǔǓŮɜǓɛŮɞɐ ɧɔəɞɡ 2000 m³.

Ƀɘ ɡ´ɘəɘɔɘůɛɘɑ ɜŬ ɔɶɘɡɜ ɔɘŬ ɗŮɈɛɘəɈŬůɗŬ ɜŮɈɘɨ 25 °C (ɟ=997,0 kg/m^3, ε=0,890·10^{-3} N s/m^2) əŬə5 °C (ɟ=999,9 kg/m^3, ε=1,519·10^{-3} N s/m^2).

ȯ ůəɖůɖ 5-14. ɛɘŬ ŭŮɜŬɛŮɜɐ ɗɈɧɛɓɤ ůɖɠ ɏɢŮə ɛɐəɘɠ 20 m, ´əƳŰɛɠ 12 m əŬə ɓƳɗɘɠ ɜŮɈɘɨ 5 m. ¢ ´ŬɈɘɢɐ Űɛɡ ŰɈɘűɘŭɘŰɛɨ ɛŮɜɘɡ ɜŮɈɘɨ ŮɶŬə 50000 m^3/d. ¢ ŭŮɜŬɛŮɜɐ űɏɈŮə ŰɈŮɠ ´ŮɈɘůŰɈŮίɧɛŮɜɘɡɠ Ƴɜɘɜ ŮɈɠ əƳɗŮŰɛɡɠ əŬŰƳ Űɖɜ ɏɜɜɘɘŬ Űɛɡ ɛɐəɘɡɠ Űɖɠ. ɆŮ əƳɗŮ Ƴɜɘɜ Ŭ ɏɢɘɡɜ ´ɈɘůŬɈɛɘůɗŮɑ ŰɏůůŮɈŬ əɘɡ´ɘƳ əŬə əƳɗŮ əɘɡ´ɑ ɏɢŮə ɛɐəɘɠ 11.0 m əŬə ´əƳŰɛɠ 0.3 m. Ɉ ƳɗŮ Ƴɜɘɜ ŬɈɠ ´ŮɈɘůŮɈɏűŮŰŬə ɛŮ 2 rpm əŬə ŰŬ ƳəɈŬ Űɤɜ əɘɡ´ɘɑ ɜ ŭɘŬɓɈƳűɘɡɜ əɨəəɘ ŭɘŬɛɏŰɈɘɡ 4.0 m. ¢ ɗŮɈɛɘəɈŬůɗŬ ŮɶŬə 15 °C (ɟ=991 kg/m^3, ε=1,1349·10^{-3} N s/m^2) əŬəɘ ůɡɜŰŮŬůίŰɐɠɘ´ɘůɗɏəəɘɡůŬɠ əŬɛɓƳɜŮŰŬəɑɘɠ ɛŮ 1,9.

Ȼɖ ŰŮɗŰŬ ɜŬ ɡ´ɘəɘɔɘůɗŮɑɖ əəɑůɖ ŰŰɢɨ ŰɖŰŰɠ G əŬə Űɛ ɔɘɧɛŮɜɘ GT.

ȯ ůəɖůɖ 5-15. ɀ ɘŬ ŭŮɜŬɛŮɜɐ ɗɈɧɛɓɤ ůɖɠ Ŭ ɘŰŬŮɗŰŬə Ŭ ɧ ŰɈɗŬ ŭɘŬɛŮɈɑɛŬŰŬ ůŰɖ ůŮɈ Ƴ. Ƀɘ ŭɘŬůŰƳůŮɜɠ əƳɗŮ ŭɘŬɛŮɈɑɛŬŰɛɠ ŮɶŬɜ ´əƳŰɛɠ 4 m, ɛɐəɘɠ 4 m əŬə ɓƳɗɘɠ 4 m (ŮəŬɨ ɗŮɈɘ ɨɣɘɠ 0,5 m). ɆŮ əƳɗŮ ŭɘŬɛɏɈɘůɛŬɡ´ ƳɈɢŮə ɛɘŬ ŭɘƳŰŬɖ ŬɜƳŬɡůɖɠ ɛŮəɘɡ´ɘƳ. Ɉ ƳɗŮ ŭɘƳŰŬɖ ´ŮɘŬɛɓƳɜŮə 12 əɘɡ´ɘƳ. ȼ Ŭ əɘɡ´ɘƳ ŭɘŬəɈɶɘɜŰŬɤ ɡ´Ɉɘɠ Űɖɜ Ŭ ɧůŰŮɐ Űɛɡɠ Ŭ ɧ Űɛɜ Ƴɜɘɜ Ŭ´ŮɈůŮɈɘűɐɠ ůŬŰɈŮɠ ŰŮɈƳŬɠ. ȼ Ŭ əɘɡ´ɘƳ əƳɗŮ ŰŮɈƳŬɠ Ŭ ɏɢɘɡɜ Űɖɜ ɑɘŬ Ŭ ɧůŰɖ Ŭ ɧ Űɛɜ Ƴɜɘɜ Ŭ´ŮɈůŮɈɘűɐɠ. ¢ ŭɘƳɛŮɈɘɠ´ɘɡ ŭɘŬɓɈƳŰŰŬ Ŭ ɧ ŰŬ ɛɏŮ Űɛɡ ´əƳŰɛɡɠ Űɤɜ əɘɡ´ɘɑ ɜ ŮɶŬə 1,30 m ɔɘŬ Űɖɜ ´ɈɩŰɖ ŰŮɈƳŬ, 2,00 m ɔɘŬ Űɖɜ ŭŮɨŰɈɖ ŰŮɈƳŬ əŬə 2.70 m ɔɘŬ Űɖɜ ŰɈɗŰɖ ŰŮɈƳŬ. ¢ ɗŮɈɛɘəɈŬůɗŬ ŮɶŬə 15 °C (ɟ=991 kg/m^3, ε=1,1349·10^{-3} N s/m^2) əŬə ɘ ůɡɜŰŮŬůίŰɐɠɘ´ɘůɗɏəəɘɡůŬɠ əŬɛɓƳɜŮŰŬəɑɘɠ ɛŮ 1.9. ʔ Ŭ ɡ´ɘəɘɔɘůɗŮɑɖ ŰŰɢɨ ŰɖŰŰ ´ŮɈɘůŮɈɘűɐɠ Űɛɡ Ƴɜɘɜ Űɛɡ ´Ɉɩ Űɛɡ ŭɘŬɛŮɈɑɛŬŰɛɠ ´ɘɡ Ů ɘŰɈɔɢɜŮə əəɑůɖ ŰŰɢɨ ŰɖŰŰɠ 80 s^{-1} əŬɗɑ ɠŮ ɑɖɠ əŬə ɖ ůɢɨ ɠ´ɘɡ ŬɜŰůŮŰɛɘɗŮɑ ȺƳɜ Űɛ ŭŮɨ ŰŮɈɘ ŭɘŬɛɏɈɘůɛŬ ɘŬŰɛɡɈɔɗŮůŮ Ůɑ Ůɶɘ əəɑůɖɠ ŰŰɢɨ ŰɖŰŰɠ 60 s^{-1} əŬə Űɛ ŰɈɗɛ ůŮ Ůɑ Ůɶɘ 40 s^{-1} ɕɖŰŰɗŰŬ ɜŬ ɡ´ɘəɘɔɘůɗŮɑɘ ŬɈɘɗɛɧɠ Űɤɜ ůŰɘűɨɜ ɛŮŰɛɜ ɘ´ɘɶ ´ɈɏŮɜŬ ´ŮɈɘůŮɈɏűŮŰŬɘ Ƴɜɘɜ Ŭɠ Űɤɜ əɘɡ´ɘɑ ɜ Űɛɡ ŭɘŬŰŮɈɘɡ ŭɘŬɛŮɈɑɛŬŰɛɠ əŬɗɑ ɠ əŬə ɘ Ƴɜɘɜ Ŭɠ Űɤɜ əɘɡ´ɘɑ ɜ Űɛɡ ŰɈɗɛɡ ŭɘŬɛŮɈɑɛŬŰɛɠ.

ȯ ůəɖůɖ 5-16. ɀ ɘŬ ɛŬɘŬŭɈɘɐ ŭŮɜŬɛŮɜɐ ɗɈɧɛɓɤ ůɖɠ űɏɈŮə 15 ɢɤɈɑɛŬŰŰŬ əŬə ɖ ɈɘɐɔɶŰŰŬɔɨɈɤ Ŭ ɧ Űɛ ƳəɈɘ əƳɗŮɢɤɈɑɛŬŰɛɠ. ¢ ŰŰɢɨ ŰɖŰŰ Űɛɡ ɜŮɈɘɨ ŭɘŬ ɛɏůɘɡ əƳɗŮ ŭɘŬɛŮɈɑɛŬŰɛɠ (´ɘɡ ŭɖɛɘɡɈɔɗŰŬ Ŭ ɧ ŭɨɘ ŭɘŬŭɘɢɘɘƳ ɢɤɈɑɛŬŰŰ) ŮɶŬə 0.2 m/s əŬə ŭɘŬ ɛɏůɘɡ Űɛɡ ŬɘɐɛŬŰɛɠ Ů ɘɘɜɤɜɗŬɠ ɛŮŰŬɨ əƳɗŮ ŭɨɘ ŭɘŬŭɘɢɘɑ ɜ ŭɘŬɛɈɘůɛŮƳɤɜ 0,5 m/s. ¢ ´ŬɈɘɢɐ ŮɶŬə 0,3 m^3/s, ɘ ɡɘɈŬɡɘɘɧɠ ɢɈɧɜɘɠ ´ɈŬɛɘɜɐɠ 25 min əŬə Űɛ ɓƳɗɘɠ ɜŮɈɘɨ 2 m. ȺƳɜ ɖ ɗŮɈɛɘəɈŬůɗŬ Űɛɡ ɜŮɈɘɨ ŮɶŬə 10 °C (ɟ=999,7 kg/m^3, ε=1,1307·10^{-3} Ns/m^2), ɕɖŰŰɗŰŬ ɜŬ ɡ´ɘəɘɔɘůɗŮɑ ɖ əəɑůɖ ŰŰɢɨ ŰɖŰŰɠ ´ɘɡ Ů ɘŰɈɔɢɜŮə ɖ ŭŮɜŬɛŮɜɐ ɗɈɧɛɓɤ ůɖɠ əŬɗɑ ɠ əŬə ɖ Űɛɐ Űɛɡ ɔɘɜɛɜɏɘɡ GT.