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The New Measure to Prevent Core Zone from Freezing in Snowy Cold Region

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ABSTRACT:
Rumoi-Dam is “central core type rock-fill dam” constructed in Hokkaido, the northernmost part of JAPAN. In winter it’s very cold in this region, so we usually pave the top of the core zone with permeable materials such as rock materials about 1 meter, to prevent core zone from freezing. In the following spring, we remove them and resume banking the core. But, we used the last layer of core zone as freeze prevention layer in constructing Rumoi-Dam. In this way, we can bank the core depending on a weather condition and maintain the quality of the core at the time of the freeze prevention layer removal. In addition we can achieve cost reduction, too.
We installed a temperature observation instrument during winter and investigated the influence that a weather change gave a core zone. As a result, we confirmed that the core was not affected by the frost damage.

Keywords: Rock-fill dam, freeze prevention

1. INTRODUCTION

Rumoi-Dam is “central core type rock-fill dam” constructed in Hokkaido, the northernmost part of JAPAN. The lowest temperature in this area is - 30 degrees or less. So it is very important to prevent core zone from freezing when we interrupt construction in winter.

Table 1. Specifications of Rumoi-Dam

Height	41.2m
Length	440.0m
Reservoir capacity	23.3 million m^3

Figure 1. Location

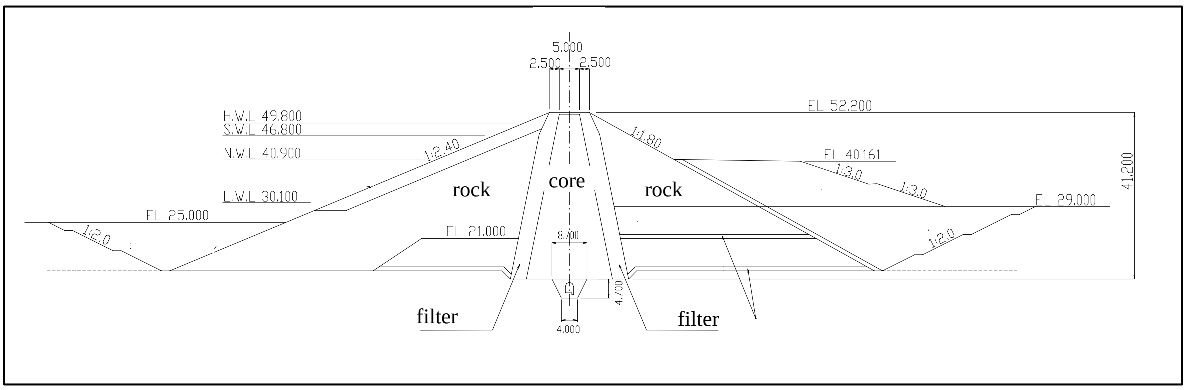

Figure 2. Section view of Rumoi-Dam

To prevent core zone from freezing ,we usually pave the top of the core zone with rock materials used for dam body. In the following spring, we remove them and resume banking the core. (I call this method "the usual method" in this paper.)

But this construction method has following problems.

(1) Once you pave the top of the core zone with rock materials to prevent freezing, it becomes difficult to resume banking the core even if the weather getting better.

(2) It's highly likely that you have to bank the last layer of core zone again because rock materials of the freeze prevention layer cut into the core materials, and the core becomes loose or is removed at the time of freeze prevention layer removal.

Thus, we used the last layer of core zone as freeze prevention layer in constructing Rumoi-Dam. (I call this method "the new method" in this paper.)

In this way, we can bank the core depending on a weather condition and maintain the quality of the core at the time of the freeze prevention layer removal. In addition we can achieve cost reduction, too.

2. CONSTRUCTION OF FREEZE PREVENTION LAYER

For comparison, we constructed freeze prevention layer by the new method in central part of the bank, and by the usual method in side part of the bank.

In the case of new method we used the last layer of core zone as freeze prevention layer, so we pave the top of the core zone with core materials 0.2m thick. In the case of usual method we paved the top of the core zone with rock materials 1m thick.

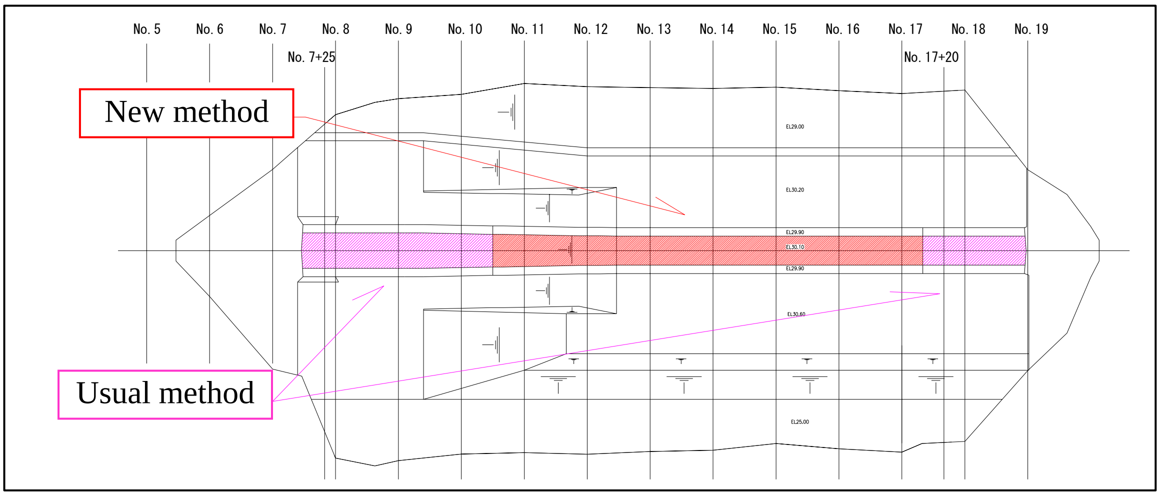

Figure 3. Location of prevention layer

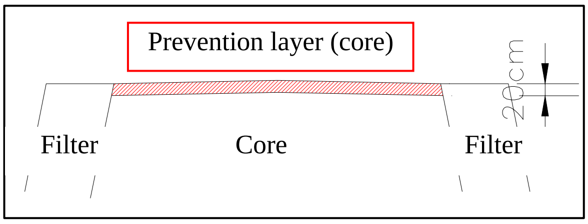

Figure 4. Section view of the new method

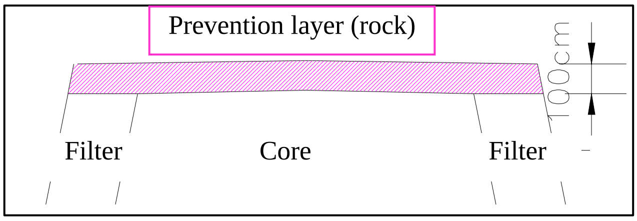

Figure 5. Section view of the usual method

Figure 6. Paving prevention layer (the new method)

Figure 7. Paving prevention layer (the usual method)

3. TEMPERATURE CHANGE WITHIN THE CORE ZONE IN WINTER

(1) Method of mesuring temperature

The most important role of the prevention layer is prevent the core zone from freezing when the temperature falls.
We mesured temperature of prevention layer and core zone at 4 places (every 2 places each method) on the centerline of the dam. We placed thermocuples at 0cm, 5cm, 10cm, 20cm, 40cm, 60cm, 80cm, 100cm depth from the surface of the last layer of core zone, and measured temperature every hour from November 17th to March 31th. To check the effect of rock material, we also placed thermocuples at 30cm, 60cm depth from the surface of the rock layer.

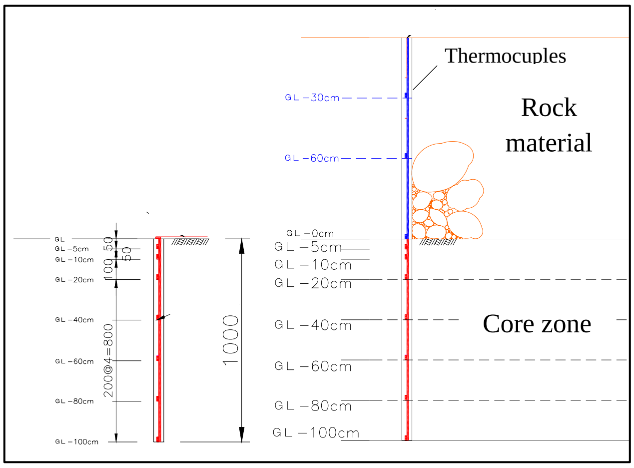

Figure 7. Section view of location of thermocouples

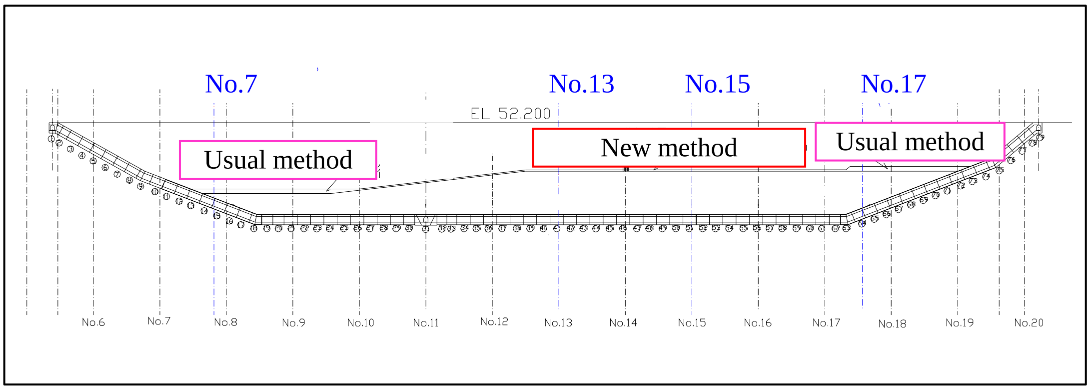

Figure 8. Section view of location of thermocouples

(2) Result

The result is shown in Figs.9 to 12 and Table 2.
A) In the beginning of winter, the temperature of the surface falled under the influence of cold external temperature. But after it began to snow, the snow maintained the surface at constant temperature.
B) The temperature of core zone became high with depth in both methods.
C) In the case of the new method, temperature of the surface of prevention layer (GL -0cm) dropped to below freezing, but the other (GL less than -5cm) didn't.
D) In the case of the usual method, temperature of prevention layer (rock material) dropped to below freezing, but the core zone (GL -0cm or less) didn't.

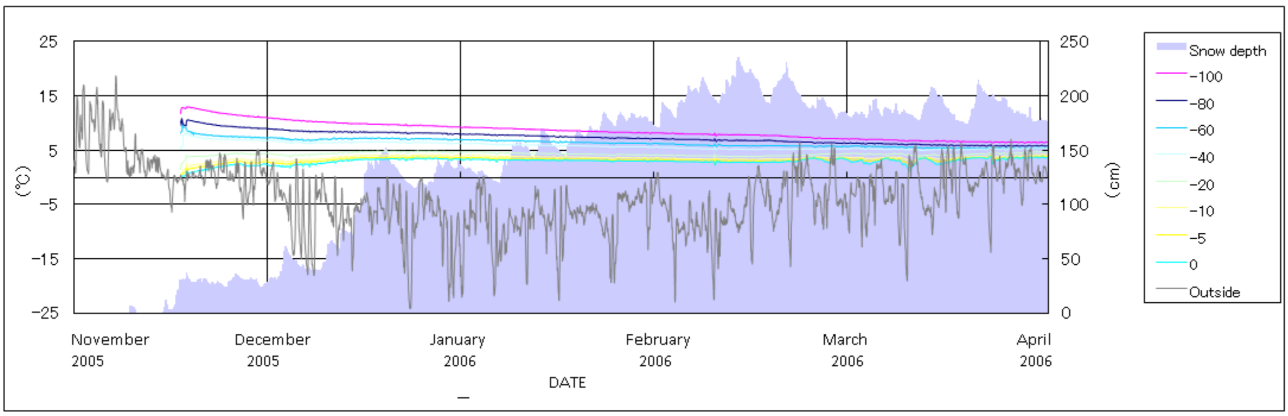

Figure 9. Change of temperature (the usual method No7)

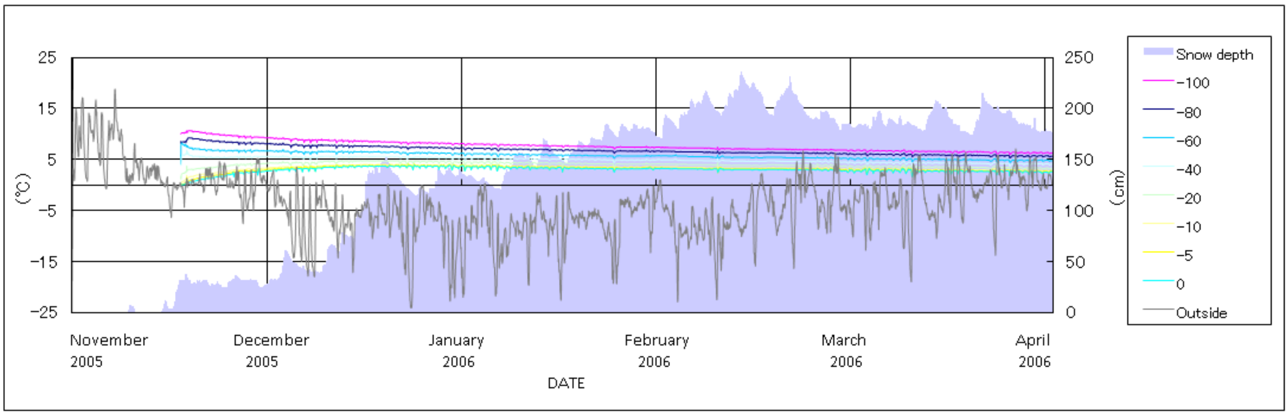

Figure 10. Change of temperature (the usual method No17)

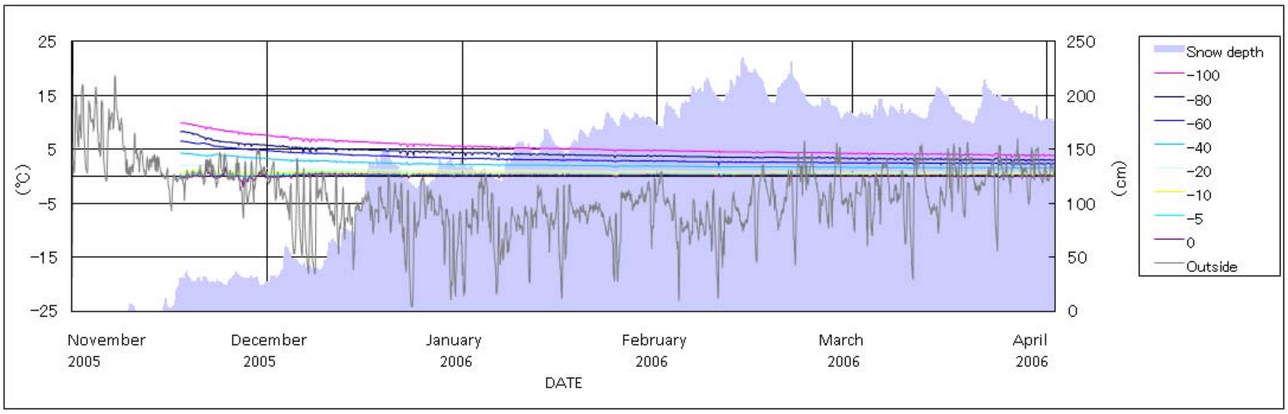

Figure 11. Change of temperature (the new method No13)

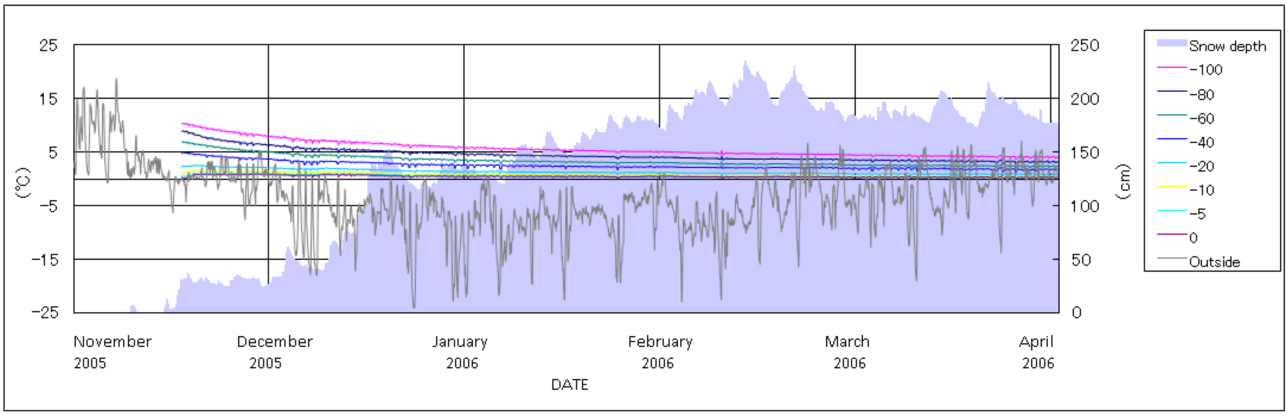

Figure 12. Change of temperature (the new method No15)

Table 2. Lowest temperature of each point

			Rock		Core zone							
			GL-30cm	GL-60cm	GL-0cm	GL-5cm	GL-10cm	GL-20cm	GL-40cm	GL-60cm	GL-80cm	GL-100cm
Usual method	No.7	Date	2006/2/8	2006/2/8	2005/11/17	2005/11/17	2005/11/17	2005/11/17	2006/3/11	2006/3/22	2006/3/23	2006/3/28
			11:00	11:00	16:00	16:00	16:00	16:00	18:00	12:00	12:00	11:00
		Minimum temperature (inside)	-9.0	-6.1	0.2	0.3	0.3	1.5	4.9	5.1	5.5	6.3
		Minimum temperature (outside)	-22.5	-22.5	-1.0	-1.0	-1.0	-1.0	0.9	-8.7	-13.8	-5.1
		Snow depth (cm)	196	196	30	30	30	30	176	201	200	181
	No.17	Date	2006/2/9	2006/2/9	2005/11/17	2005/11/17	2005/11/17	2005/11/17	2006/3/25	2005/11/17	2006/3/25	2006/3/25
			2:00	8:00	17:00	17:00	17:00	17:00	11:00	16:00	10:00	10:00
		Minimum temperature (inside)	-8.0	-4.0	0.0	0.0	0.1	1.2	3.6	4.1	5.2	6.0
		Minimum temperature (outside)	-15.5	-15.5	-1.0	-1.0	-1.0	-1.0	-2.9	-1.0	-2.9	-2.9
		Snow depth (cm)	195	200	30	30	30	30	196	30	196	196

					Core zone (prevention layer)				Core zone			
					GL-0cm	GL-5cm	GL-10cm	GL-20cm	GL-40cm	GL-60cm	GL-80cm	GL-100cm
New method	No.13	Date			2005/11/27	2005/11/17	2006/12/22	2006/3/23	2006/3/23	2006/2/8	2006/3/23	2006/3/25
					6:00	16:00	16:00	13:00	13:00	10:00	12:00	12:00
		Minimum temperature (inside)			-2.0	0.0	0.2	0.5	1.3	2.0	2.7	3.5
		Minimum temperature (outside)			-7.6	-1.0	-21.5	-13.8	-13.8	-22.5	-13.8	-2.9
		Snow depth (cm)			31	30	119	199	199	196	200	195
	No.15	Date			2006/3/10	2006/3/10	2006/3/10	2006/3/10	2006/3/23	2006/3/25	2006/3/23	2006/3/25
					10:00	9:00	10:00	10:00	12:00	14:00	13:00	14:00
		Minimum temperature (inside)			-0.2	0.0	0.0	0.2	1.2	2.0	2.9	3.7
		Minimum temperature (outside)			-19.0	-19.0	-19.0	-19.0	-13.8	-2.9	-13.8	-2.9
		Snow depth (cm)			183	183	183	183	200	190	199	190

3. QUALITY OF CORE ZONE NEXT SPRING

We restart banking by the flow diagram shown in Fig 13. In the case of the new method, we removed the last layer of core zone (t=20cm) used as freeze prevention layer carefully by backhoes. (See Figs.14 and 15)

In the case of the usual method, we remove the rock materials used as freeze prevention layer in the same way.

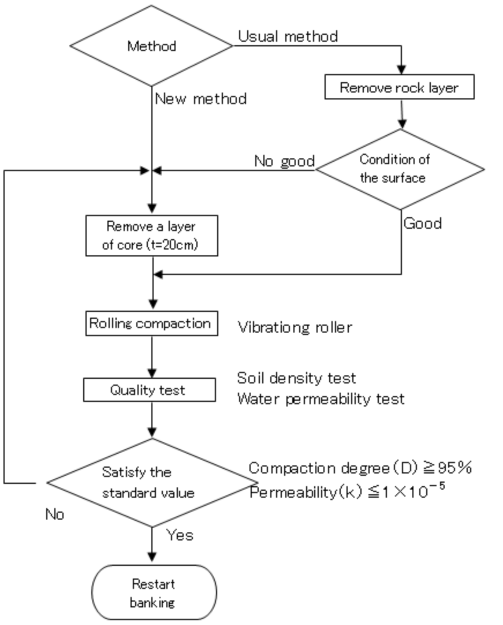

Figure 13. Restart flow diagram

In the case of the usual method, rock materials digged into the core and the surface of core zone was severely damaged after prevention layer removed. So we remove a layer of core zone (t=20cm)

Figure 14. Removing prevention layer (the new method)

Figure 15. After removing prevention layer (the new method)

Figure 16. After removing prevention layer (the usual method)

Figure 17. Rock materials digged into the core

Removal of the surface of the core could lead to looseness of the core below, so we did rolling compaction by vibrating roller. (See Fig.18)

Figure 18. Rolling compaction by vibration roller

To check the quality of core zone after removing prevention layer, we did soil density test and water permeability test on site. We did tests at the point where we measured temperature (see Fig.18).
The results are shown in Table 3.

As a result of soil density test, it is confirmed that water content ratio (W) is 0.7% - 2.5% lower than optimum water content ratio (Wopt) in the case of the new method, and that W is 1.6% - 2.5% higher than Wopt in the case of the usual method. But compaction degree (D) satisfy the standard value needed to control quality (D>95%) in both cases.

As a result of water permeability test, it is confirmed that coefficient of permeability (k) satisfy the standard value needed to control quality ($k<10^{-5}$) in both cases.

4. CONCLUSION

It is confirmed that temperature of core zone didn't drop to below freezing even in the coldest season, and the prevention layer in both method prevent core zone from freeze damage. As a result of quality verification testing, it is confirmed that compaction degree (D) and coefficient of permeability (k) satisfy the standard value needed to control quality in both cases and both methods are appropriate for prevent freezing.
But in the case of the usual method the surface of core zone was severely damaged after rock layer removed and it was needed to remove a layer of core zone.
In the case of new method, top of the core zone is used for prevention layer, so we can bank the core until the very last minute regardless of schedule of freeze prevention. And in this case, we need to remove less prevention layer when restart banking and we can reduce preparation for restart. In this way we can achieve 40% cost reduction.
Thus the new method is a very efficient method in cold region that can shorten work periods and reduce cost.

Table 3. Result of quality verification test

					Density test				Permeability test
	Line	Point	Max dry density (t/m^3)	Optimum water content ratio Wopt (%)	Dry density ρd (t/m^3)	Water content ratio W (%)	Compaction ratio D (%)	W − Wopt	Permeability k (cm/s)
Standard value	–	–	–	–	–	–	95≦		$\leqq 1\times10^{-5}$
Usual method	No.7	−4	1.771	17.6	1.746	20.0	98.6	2.4	7.06E-07
	No.7	0			1.763	19.3	99.6	1.7	2.26E-06
	No.7	+4			1.758	19.2	99.3	1.6	1.33E-06
	No.17	−4	1.781	17.5	1.784	20.0	100.2	2.5	3.02E-06
	No.17	0			1.771	19.2	99.4	1.7	4.77E-06
	No.17	+4			1.773	20.0	99.6	2.5	3.17E-06
New method	No13	−4	1.781	17.5	1.787	15.6	100.4	−1.9	4.87E-06
	No13	0			1.756	15.0	98.6	−2.5	3.48E-06
	No13	+4			1.768	15.8	99.3	−1.7	1.65E-06
	No15	−4			1.741	16.8	97.8	−0.7	5.50E-06
	No15	0			1.759	16.4	98.8	−1.1	3.47E-06
	No15	+4			1.764	16.0	99.0	−1.5	3.77E-06