Improved flotation performance at Karee Platinum Mine through better level control

by J.H. Schubert*, R.G.D. Henning*, I.R. Gebbie*, and M. Valenta†

Synopsis

Mintek has developed a level-control system, FloatStar, for use in flotation circuits. Instead of controlling levels separately in each unit, the controller monitors levels throughout the circuit. It can thus take account of the global effects of any control actions.

A collaborative project between Mintek and Karee Platinum Mine has begun, looking at aspects of flotation control. Karee plant was chosen as the site for this work because of its good existing control infrastructure. As a first stage of the joint project FloatStar was installed. Analysis during installation and running of the FloatStar has illustrated how circuit design and measurement technology can affect process control. Severe interactions have been observed in the levels of adjacent banks.

The effect of FloatStar on flotation performance was tested and an improvement in level control was observed. Similarly, a faster settling of the plant after start-ups was observed. Both the improved level control and faster start-ups lead to higher platinum recovery.

Introduction

Karee Platinum and Mintek have embarked on a co-operative programme of looking into improved control of the flotation circuit at Karee, which involves both stabilization and optimization work. As a first step a Mintek FloatStar was installed on the plant to provide stabilization for the circuit. A two-month trial was run to establish the effect on recovery due only to stabilization. This will allow the effects of further work to be separated from the stabilization effect.

In the process of installing and maintaining the FloatStar at the plant, a number of unexpected effects due to the layout of the circuit were discovered and had to be dealt with. Different control schemes were also implemented and tested on the surge tank in an effort to remove disturbances before they entered the flotation plant.

Karee plant

The flotation plant of Karee Platinum Mine is especially suited for doing test work. It is well instrumented and has a modern PLC and Scada system which are vital for seeing what effect changes have on the plant and for collecting the necessary information. The plant has a Courier system for on-line analysis of a number of plant streams. It has an excellent system for controlling reagent flowrates. Finally the milling circuit is controlled to give a fixed-density feed for flotation, particle size is monitored with an Outokumpu PSI and a surge tank is used to control the flowrate of pulp to the flotation plant.

The flotation plant consists of 11 flotation banks with ultrasonic level measurements linked to proportional and integral (PI) level control loops on the existing programmable logical controller (PLC). The plant runs on a ROM blend of Merensky and UG2 ores and even minor changes in blend (i.e. less then 0,5 per cent) affect the froth characteristics of the flotation circuit.

Mintek's FloatStar control system

Flotation plant stabilization is by no means trivial. When each bank is controlled by its own PI loop, the loops cannot be tuned too tightly, as disturbances encountered in one bank will be passed downstream by the control loop. Badly tuned loops might even amplify the disturbances. It is therefore common practice to tune loops slightly sluggishly, to allow banks to buffer incoming disturbances rather than passing them downstream.

The FloatStar was developed in the Measurement and Control Division at Mintek as a multivariable level controller designed to stabilize flotation circuits to a degree not possible with conventional individual PI

* *Measurement and Control Division Mintek.*

† *Karee Platinum Mine.*

 SA ISSN 0038–223X/3.00 + 0.00. Paper received Jul. 1998; revised paper received Aug. 1998.

loops[1]. By taking possible interactions between the banks into account, the FloatStar neutralizes disturbances, which would otherwise spread throughout. Loops can then be tuned more tightly. More effective disturbance neutralization combined with fast loops allows for effective stabilization of the whole circuit.

It is to be expected that the overall recovery of a circuit will be improved by stabilizing the circuit, with the estimated improvement being in the order of 1 per cent. This estimate was shown to be correct by previous tests, one of which was carried out on another South African platinum flotation plant[2] and the other on an Australian Gold plant[3,4]. The improvements in recovery were 0,75 per cent and 1,27 per cent respectively. While these improvements may not be excessively large, a carefully planned trial was used to prove that they are statistically significant. A proven increase in recovery of even 0,5 per cent is financially significant on most flotation plants.

It was decided to use the same testing technique at Karee as had been used at the other sites. This involved running the FloatStar for two days, followed by the PI loops on the plant PLC for 2 days, etc. (The first transitional shift of every on or off period was discarded to remove the effect of the plant dynamics.) This method is far superior to using long on-off periods, as medium- to long-term changes in metallurgy and operating conditions affect both systems equally. This immediately removes any bias that such changes in metallurgy and operating conditions would have introduced and allows for statistically significant results to be achieved even with relatively small changes in recovery.

Circuit design and instrumentation effects

Every circuit contains its own difficulties and challenges. The circuit at Karee is no different. While most banks presented no problems there were a few challenges in implementing the FloatStar at Karee, which will be discussed here.

The first three roughers

The large number of roughers connected in a row was considered to be ideal for the FloatStar. Unfortunately the specific arrangement of the first three banks relative to one another was not ideal and prevented tight control. The head difference between the banks was small, which was due to both the installed head and the difference in operating pulp levels (these cells had previously been used as conditioning tanks and had been converted to flotation banks). This meant that the three levels were highly interdependent and, while the valves in the top two cells had very little effect on the levels in their respective tanks, the valve in the third tank could not be controlled too tightly for fear of destabilizing the other two levels. The final effect of these difficulties was that the loops on these three cells had to be tuned very conservatively.

Another common problem on a flotation plant is caused by incorrectly sized valves. Figure 1 shows how an undersized valve in bank 3 was unable to cope with a large feed flowrate which started flowing into the banks at about 1:00. As the froth depth decreased away from set point, the control action (i.e. the signal sent out to the control valve) started increasing. It very quickly saturated at 100 per cent and caused the froth depth to decrease (and the level to rise) further in bank 3 as shown in Figure 1. Note that the froth depth is the inverse of the pulp level, so that as the level rises, the froth depth will decrease and visa versa.

The effect of this rise in the level of bank 3 on banks 1 and 2, which are located above bank 3 is shown in Figure 2. The level in bank 2 rose together with that of bank 3 because of the small difference in height between the banks. In an effort to counteract the rise in level, the valve on bank 2 opened substantially, but it hardly managed to affect the level. At the same time the level in bank 1 was hardly affected (except that the quality of control decreased slightly) because the difference in levels between bank 3 and bank 1 was large enough and as a consequence the control valve on this bank hardly moved.

From about 3:00 the feed flowrate to bank 3 started to decrease again, which caused the froth depths in both banks 2 (Figure 2) and 3 (Figure 1) to start increasing (i.e. the pulp level started dropping). Some over-compensation on the level of bank 2 is visible just after 4:00, which is due to the conservative control mentioned above.

Note: The arrows on Figures 1 and 2 indicate which axis applies to each graph.

Quality of measurement

Another point which has become increasingly obvious is that the degree of achievable stabilization is strongly dependent on the quality of the level measurement. During the trial it

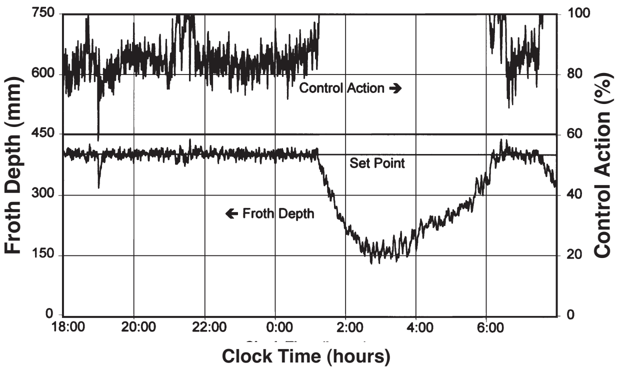

Figure 1—The effect of an undersized valve on the level in Bank 3

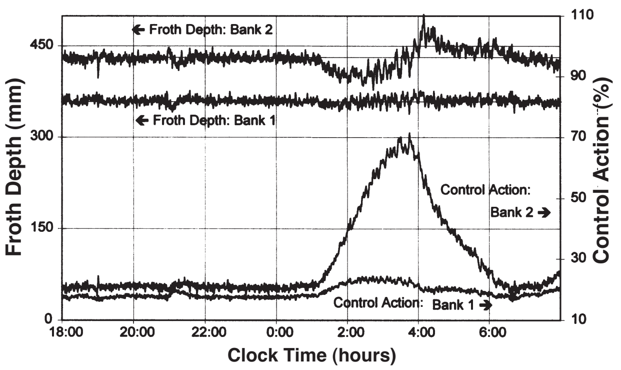

Figure 2—The effect of level in Bank 3 on levels in Banks 1 and 2

was discovered that the ultrasonic level probes used were not entirely suitable for the application. They were very reliable, but were designed for use over a range of 9 m at a resolution of 17 mm. This resolution can clearly be distinguished in the trend displayed in Figure 3, especially in the fourth quarter where a 1 second filter was used (the use of filters is described below). When one is attempting to control to within a few millimetres of set point, this is inadequate. It must be borne in mind that a difference of 17 mm in froth depth can have significant effects on the mass pull and hence on the grade of concentrate being produced by a flotation bank.

These level probes are often supplied for use on flotation plants. The poor resolution is hidden by using a digital filter with a large time constant in the measurement device to smooth the measurement signal. In this particular case the measurement output which was used for control was smoothed with a 10 second filter, the result of which can be seen in the first quarter of Figure 3. The use of a filter is not a satisfactory solution for poor measurement, though. While it seems to give a more continuous reading, it limits the bandwidth of the control loop, which in turn prevents tight control. Notice the first order response in the measurement as shown by the fin-shaped curves just before the start of the 5 second filter section. This is entirely due to the response of the filter and is not caused by the dynamics of the process.

Reducing the filter on the measurements with such large resolution is not a solution as it causes excessive valve movement. The cycling of the measurement between two points becomes most noticeable in the last quadrant, where a 1 second filter was used. Note how the control action mirrors the measurement causing the valve to open and close continuously. The results reported in this paper were achieved using these measurements with the poor resolution masked by 10 second filters, but the devices have since been replaced and control has improved noticeably.

Results of the FloatStar trial at Karee

The overall perception of FloatStar performance on the plant is positive, and the FloatStar is well received by the operations staff. The FloatStar at Karee has been running reliably for two-and-a-half years. This section will discuss the results of two tests, which were conducted to test how FloatStar performance improved on normal PI control.

Plant start-ups

One of the main benefits of FloatStar reported by plant operators was the faster stabilization time of the whole plant on start-up. This was also the view expressed by operators on other plants. A thorough investigation of this point was planned and carried out by metallurgical staff. After two maintenance shutdowns, during which the entire flotation plant was drained, samples of the final tailings stream were taken every 5 minutes following start-up and analysed for remaining PGM. The results of the two start-ups are shown in Figure 4. It can be seen that the final tails grade drops to normal values after about 50 minutes when the FloatStar was controlling, while it only reached these values after about 150 minutes when PI control was used. Quicker settling times mean that far less PGM material is lost to final tails during start-up or after plant disturbances.

Metallurgical results

As mentioned above, a test series was conducted to determine the effect of the stabilizing control of FloatStar. The FloatStar and PLC control were alternatively used to control the plant for two days each, starting on 3 October and ending on 12 December 1996. During this period the on-off schedule was maintained except for one period of interruption from 4-5 November due to a plant shut down and for another from 28 November to 2 December when control was not switched over to the FloatStar for 4 days. Altogether the test was run for 70 days. After the transitional shifts and those shifts for which the data was incomplete were removed, the total number of shifts available was 160, 76 of which were on FloatStar and 84 on PI control

The data used are the shift assays, as collected and analysed by the plant assay laboratories. PGM recoveries were calculated using the two-product formula. The means and the standard deviations for the PGM recoveries as well as those for the feed, the tailings and the concentrate for the two different conditions were calculated. The overall mean and overall standard deviation for data set were also calculated. For each data set the overall mean has been subtracted from the respective means, so that only the difference in means between the systems is of significance. The standard deviations are the true calculated standard deviations.

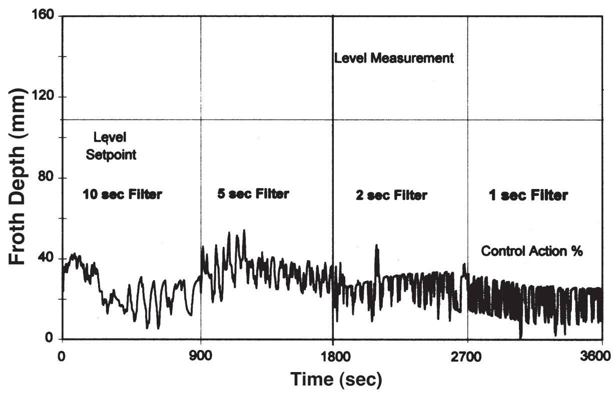

Figure 3—Level measurement using different filters

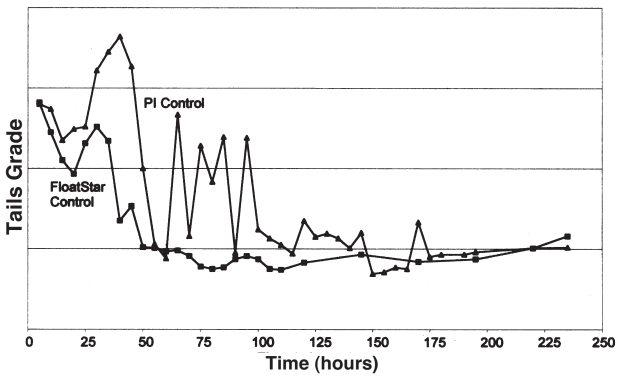

Figure 4—FloatStar and PI start-up times compared

The result of most interest was obviously the increased recovery of PGMs by using the FloatStar. The PGM recovery was improved by just more than 0,5 per cent at a significance of 87,2 per cent. Another independent analysis of the data came to the same conclusion that the increase due to FloatStar was about 0,5 per cent. The duration of the test would have had to have been extended to have increased the significance of the result, but it was felt that as the results confirmed previous assumptions, an extended test was not necessary.

Figure 5 shows the results of this test in graphical form. Each point represents the averaged shift results for a period of FloatStar or PLC control (usually 5 samples for two days after the first shift following a changeover was removed). The data reflects the high variability in recoveries recorded on the plant, which also shows up in the relatively high standard deviations for the PGM recoveries in Table I. It is interesting to note that the FloatStar and normal PI recoveries tend to rise and fall together. This validates the technique of using short on-off periods as both systems are equally affected by medium and long-term changes in plant conditions.

T-tests were also performed on the feed data, tailings data and concentrate data to determine what the cause was of the improved recovery. The average feed grade is slightly lower for the FloatStar shifts but the difference is not statistically significant (with a significance of only 55 per cent) which means that the feed did not favour either system. Similarly, the average concentrate grade was much the same, with the difference of 1,76 g/t having a low significance of 64,2 per cent. As expected, the major difference lies in the reduction of the tailings grades at a significance of 92,3 per cent.

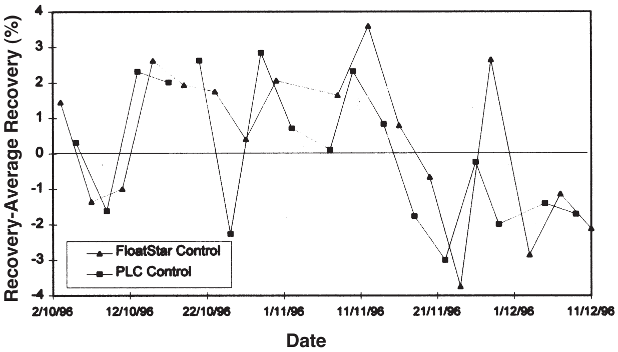

Figure 5—FloatStar test at Karee: PGM recoveries

The influence of head grade

The comparison in the previous section used a standard t-test to compare means. An alternative approach is to use analysis of variance techniques, as these can give more sensitive results. In particular, analysis of covariance allows one to take into account factors which influence the test, but which cannot be controlled. At Karee a good example of this is the head grade, which affects the recovery as shown in Figure 6. Low head grades correspond to low recoveries and in general a rich feed grade will correspond to a high recovery. The relationship between feed grade and recovery has a correlation co-efficient of 0.61, which is significant at a $p < 0.05$ level. Although a linear regression is shown, the actual relationship will probably saturate at high head grades.

Using ANCOVA methods to compare mean PGM recoveries while compensating for the effect of feed grade more than doubles the significance of the results quoted in the previous section. The significance of the increase in PGM recovery with FloatStar controlling rises to 93.7 per cent.

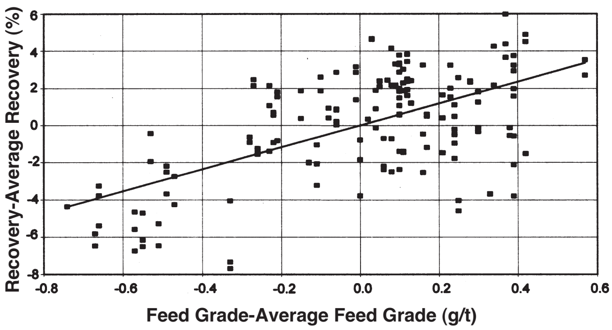

Figure 6—Recovery vs head grade

Table I

Results of FloatStar test at Karee

	PGM recoveries		PGM feed grade		PGM tails grade		PGM concentrate grade	
	FltStar	PI	FltStar	PI	FltStar	PI	FltStar	PI
Mean—overall mean	0.277	-0.250	-0.0034	0.0031	-0.0109	0.0099	-0.9276	0.8393
Standard deviation	2.827	3.009	0.295	0.307	0.096	0.087	31.308	39.193
Sample number	76	84	76	84	76	84	76	84
	Results of one-sided T-test with unequal variances							
Difference of means	0.527		-0.0065		-0.0208		-1.7669	
Pooled std. deviation	2.927		0.300		0.092		35.566	
T-statistic	1.142		-0.136		-1.431		-0.316	
Degrees of freedom	158		157		152		156	
Probability	0.128		0.446		0.077		0.376	
Significance (%)	87.2		55.4		92.3		62.4	

Another way of compensating for the effect of head grade is to divide the data set into a series of subsets, each subset corresponding to a particular range of head grades. The mean recoveries within each subset can then be examined, allowing a comparison of FloatStar and PI performance with low head grades, medium head grades and high head grades. The intervals used to divide the data set are shown in Table II. Once again the overall mean (for all tests) has been subtracted from each value.

These results are plotted in Figure 7, where a clear trend can be seen. Recoveries are higher under FloatStar control in each category except the sixth, in which they are almost identical. Note that the seventh subset contains a total of only five data points and the large difference in FloatStar's favour is possibly anomalous. Based on this graph and similar results from other plants it can be speculated that for a high head grade feed (which is likely to be rich in fast-floating material), performance will be similar for FloatStar and other control systems. The main benefit of FloatStar will be seen for intermediate and low head grades, where greater stability of operation becomes crucial.

Conclusions

The FloatStar was installed at the Karee plant and has been operating satisfactorily for two-and-a-half years. Some problems in the plant layout and instrumentation have been identified and analysed. Both, poor resolution of measuring instruments and undersized valves impact negatively on the quality of control that is achievable. These have been addressed and rectified as far as possible during the course of the past year.

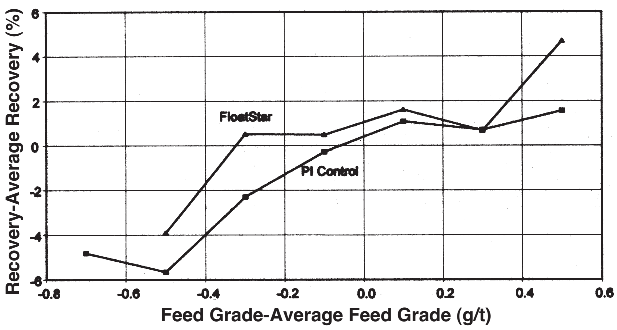

Figure 7—Recovery vs head grade—binned results for PI-control and FloatStar

Tests have shown that plants under FloatStar control are stabilized after start-up in about one-third of the time normally required if PI control is used. This represents a considerable saving, as less PGM material is lost in the final tails during start-up.

A two-month test of 2 days on, 2 days off was carried out to evaluate the performance of the FloatStar. This showed that the increase in recovery due specifically to the stabilizing effect of FloatStar was above 0,5 per cent at a statistical significance of 87,2 per cent which is the result of an average reduction in tailings grade. If the tests were to have been repeated now that high-resolution level measurements have been installed, the improvement would be greater still.

Further analyses were done to take into account the influence of head grade, since it is known that higher head grades tend to give higher recoveries. These analyses confirm that the improved stabilization due to FloatStar leads to higher recoveries.

Acknowledgements

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Table II

Comparison of recoveries at different head grades

Subset no.	Range of head grades	No. of points: PI control	No. of points: Floatstar	Mean recovery: PI control	Mean recovery: FloatStar
1	HG ≤ -0.6	7	0	-4.82	--
2	-0.6 < HG ≤ -0.4	3	12	-5.66	-3.9
3	-0.4 < HG ≤ -0.2	9	10	-2.30	0.52
4	-0.2 < HG ≤ 0.0	10	13	-0.28	0.49
5	0.0 < HG ≤ 0.2	31	22	1.09	1.62
6	0.2 < HG ≤ 0.4	21	17	0.70	0.67
7	0.4 < HG	3	2	1.56	4.69

Mintek CEO stresses need for more S&T*

In his 1998 Annual Review, Mintek's President, Dr Aidan Edwards said, 'The new South African government has realized that, if the economy is to become competitive internationally, it needs to be underpinned by a strong and dynamic science and technology effort. The Ministry of Arts, Culture, Science and Technology (DACST) was formed to ensure that science and technology (S&T) is promoted vigorously, and this subsequently led to its declaration of 1998 as South Africa's first Year of Science and Technology.

'South Africa's eight science councils—Agricultural Research Council, Council for Geoscience, CSIR, Foundation for Research Development, Human Sciences Research Council, Medical Research Council, Mintek, and the SABS—have participated by holding activities and events in their specialized fields throughout the year.

'Mintek, through its Minquiz science competition, and various other initiatives, has been especially proactive in the Year of Science and Technology. It has played a dual role in that Minquiz stresses to students the importance of the exploitation of South Africa's minerals for the well-being of the country, as well as stimulating interest in careers in the minerals and metallurgical field.

Only one in every 20 pupils in grade 12 in South Africa leaves school with a higher-grade pass in mathematics and science. Regrettably, many from this small percentage are being lost to the country.

'From the 1960s to the 1980s, South Africa could rely on the immigration of skilled people to supplement its human resources. The past three years, however, have seen net losses through the emigration of engineers, technologists, medical specialists, dentists, accountants and educationists.

'These losses make the inadequacies of our education system in mathematics and science all the more serious.

'Of all the degrees, diplomas and certificates awarded in 1995 only 6% were in engineering and 3,7% in the natural sciences.

'If our country intends to participate in, or hopefully, to spearhead the thrust of the African renaissance, suitable initiatives must be nurtured and given the support they deserve. South Africa has become a major economic leader on the continent as a result of its mineral wealth. In recent years there has been a growing awareness of the potential financial rewards of adding value to our mineral products by downstream beneficiation. However, the availability of qualified manpower remains a major concern. South Africa's ratio of practising scientists and engineers per 1000 of population is 3.3. Brazil, which is also a developing country, has 11,2 and Japan boasts 71,1 while the US has 21.6.' ◆

* *Issued by: Communications Division, Mintek, Private Bag X3015, Randburg 2125,*

Mintek to administer new bridging initiative*

The Masifunde Educational Support and Improvement programme, which is supported by Billiton Ltd, Ingwe Coal Corporation, Samancor, Gold Fields Ltd, and Impala Platinum, supports 60 schools in seven of South Africa's provinces.

The Masifunde Bridging Initiative will be launched in 1999 in terms of which selected post-matriculation students from Masifunde schools will be offered a year of intensive upgrading in mathematics and physical science to enable them to enter tertiary education in engineering and related fields, and to qualify for bursaries.

The Initiative, administered by Mintek, will be run along the same lines as Mintek's successful MAP programme, which has offered maths and science upgrading to more than 1000 under-privileged students since 1992.

The full-time course will be run at the Johannesburg College of Education in Parktown, and the students will write the Independent Examinations Board's Senior Certificate maths and science examinations.

Students selected for the Initiative will have all their costs covered, including residence, meals, tuition, books, and examination fees, and will receive a monthly study grant. Depending on their results, they will have a good opportunity of being awarded a bursary for tertiary studies in the engineering or minerals related field.

Secondary schools in the Masifunde Project will be invited to send interested candidates to a venue in each region to undergo an initial screening test. Selected applicants will be invited for further testing at Mintek early in 1999.

For more details contact Mr Neville Melville on cellphone no. 082-579-3821 or Dr Glyn Moore at Mintek on (011) 709-4271. ◆

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