Proceedings of Heap Leach Solutions, 2015
September 14-16, 2015, Reno, Nevada, USA
Published by InfoMine, © 2015 InfoMine, ISBN: 978-0-9917905-8-6

Evaluation of agglomerates using the Kappes Percolation Test

Randall Pyper, Kappes, Cassiday & Associates Australia Pty Ltd, Australia
Daniel W. Kappes, Kappes, Cassiday & Associates, USA
Terence Albert, Kappes, Cassiday & Associates, USA

Abstract

Agglomeration of high clay ores or ores with significant fines content can be the key step in good field performance of gold and copper heap leach operations. The Kappes Percolation Test was developed as a quick method of determining binder requirements for high clay ores and is employed in many laboratories to select optimum binder levels for heap leach column testing. It is also used at many heap leach operations for quality control evaluation of field agglomerates. However, the test is often not run correctly or is used as a substitute for general permeability testing. This paper presents the history of the development of the test, test procedures and techniques, equipment requirements, shortcomings, interpretation of results and use in operating heap leach projects.

Introduction

For ores with high clay or fines content, agglomeration is often the most critical step in the ore treatment process for achieving suitable heap permeability and ultimate metal extraction (McClelland et al., 1983; Chamberlin, 1986). The Kappes Percolation Test is a useful method of determining the agglomeration requirements of ores in laboratory heap leach testing as well as for quality control of field agglomeration operations. The test involves soaking cured pellets in a percolation column for a set period of time followed by tapping the column wall to release the wall effects. Measurement of slump and maximum flow of water through the ore bed along with other details such as pellet collapse, bubble formation, fines release, etc., provides a basis for a comparative assessment of pellet strength. The test presents a graphic indication of pellet quality as well as data for comparison of laboratory and field agglomerating conditions and tracking of field data.

The test was developed by Dan Kappes in 1986 when preparing to commission the agglomerating/stacking system at the Exhibition Heap Leach Project of Kia Ora Gold in Marvel Loch, Western Australia. Preliminary testing of grab samples of ore indicated that the ore would not form adequate pellets using the parameters determined in the Kappes, Cassiday & Associates (KCA) laboratory in Reno, Nevada. As sometimes happens, the samples sent to KCA in Reno were nothing like the actual ores, so a bit of panic ensued. Dan cobbled together a set of percolation columns and over a 5-day period we agglomerated and tested multiple samples at varying conditions until we were satisfied that we could specify the cement dose, moisture content and residence time in the agglomerating drum to produce pellets of sufficient strength. Indeed, early data from the operation indicated gold recoveries approaching 90% (Pyper and Pangbourne, 1988) compared to an expected 75% recovery.

While the general test technique had been employed in the KCA laboratory prior to the Marvel Loch experience, the intensive nature of the testing and usefulness in simulating “worst case” field conditions became apparent and the test procedure became more formalized. When KCA set up the Kappes, Cassiday & Associates Australia (KCAA) laboratory in Australia in 1988, the procedure became generally established in the local industry and began to be employed by other commercial laboratories. It has become informally known as the Kappes Test, but the specific procedures and data interpretation are not always conducted or interpreted correctly.

The test technique, while involving “worst case” treatment of pellets, is more representative of field operations and ore treatment than other agglomerate quality evaluation techniques.

The test procedure

The general procedure for the Kappes Percolation Test is presented below. Usually a 2 to 4 kg portion of agglomerated, cured ore is employed in the test using a 75 to 90 mm diameter Plexiglas column. However, if the topsize of the material to be tested is larger than 25 mm, then a larger charge and larger percolation columns are required. Note that this is not a leach test and the typical column diameter to rock size minimum ratio of 6 does not apply.

1. Place a wad of shadecloth or suitable drainage material in the base of the column prior to adding the pellets.
2. Place the pellets in one of the percolation columns to a height of approximately 400 mm.
3. While loading the pellets, tap the sides of the column several times with the rubber mallet to settle the pellets and eliminate hang-up on the column walls.
4. Measure and mark the height of the ore in the column. Record this height as H1.
5. Slowly fill the column with water from the bottom inlet. Fill rate should be approximately 10 mm or 1 cm) per second with the goal of displacing all air in the pellet interstices.
6. Fill the column to approximately 50 mm above the height of the ore in the column. Close the valve to prevent water from draining out of the column.

7. Record time of filling.
8. Allow the ore and water to sit in the column for a minimum of 2 hours. Do not bump or jostle the column during the soak period.
9. After the soak period, mark and measure the height of ore. Record this level as H2.
10. Using a rubber mallet, tap the sides of the column sharply 9 to 12 times or until the ore bed height remains stable. This breaks the surface tension between the pellets and the column wall to simulate "worst case" field conditions.
11. Mark and measure the height of ore. Record this as H3.
12. Place a wad of shadecloth or similar mesh material above the ore.
13. While adding additional tap water to the top of the column to maintain a constant head of water in the column, open the drain valve and collect the water in the graduated container.
14. Using a stopwatch, time a measured volume of water as it drains out of the column.
15. Record time in seconds along with other observations regarding pellet behavior during the overall test period. These observations include fines migration during filling, breakdown of pellets during wetting or soaking, bubbles present in the pellet bed after soaking, fines generation or total pellet collapse during the tapping procedure, and an estimate of the quantity of fines that wash out during the flow measurement step. Additional information collected could include drain solution pH and turbidity.
16. Calculate the outlet flow in $L/h/m^2$ based on column diameter. The minimum acceptable value for high clay ores is 10,000 $L/h/m^2$ and 1,000 $L/h/m^2$ for high-fines (non-clay) ores.
17. Calculate slump as follows:

$$\text{Auto Slump} = 100 \times (H1 - H2) / H1 \quad (1)$$

$$\text{Tapped Slump} = 100 \times (H1 - H3) / H1 \quad (2)$$

18. Use the slump, percolation rate and other data to compare pellet performance against other agglomerating conditions.

Variables that can be employed in a grid of agglomeration / percolation tests include binder type(s) and doses, water or other liquid addition, water regime (2-stage addition), agglomerating time, cure time, etc. The test has been used successfully in laboratory situations for gold, silver and uranium ores in alkali conditions as well as copper (Efthymiou et al., 1998), nickel and uranium ores in acid conditions. Field operations include heap leaching of gold and silver ores in alkali conditions and copper ores employing acid leaching.

Shortcomings

One shortcoming of the test technique is that it is subjective and operator dependent. It is possible that duplicate tests will not yield identical results, especially if conducted by different people. The final call on pellet quality or fines loss depends mostly on the technician's visual assessment. The tapping step in particular is a critical but sensitive step – it can be "under done" or the columns mercilessly bashed, leading to unreliable results. In this regard, it should be considered a "comparative" test where a series of tests are conducted by the same person and the results compared within the data set.

Another issue with the test relates to accurate sample splitting at coarse crush sizes. A split with a higher proportion of fines will behave quite differently to one with a shortage of fines. One approach employed by a uranium operator was to pre-screen a large sample into multiple fractions then further split each fraction into the number of samples required. This was followed by recombining to ensure each split had an identical particle size distribution (PSD).

Agglomerating residence time in a field operation is often limited; however, in a laboratory situation using a cement mixer for agglomerating, residence times can be unlimited. In this situation, it is recommended to get the desired pellet consistency irrespective of the time it takes to achieve it. Then when the "final" agglomerating conditions have been determined, try to achieve the same results within the expected timeframe of a field operation – typically 60 to 120 seconds.

For monitoring pellet quality at an operating heap leach, samples of agglomeration drum discharge are collected on an hourly (or other) basis and used to generate shift composites. These composite samples are then delivered to the site laboratory for percolation testing. Unfortunately, the samples have to be allowed to cure for a minimum of 24 hours before the quality control (QC) percolation tests can be conducted. While the results are obtained "after the fact", the data are still useful for monitoring overall agglomeration operation performance and for tracking trends related to operating crew, average shift temperature, ore types, etc.

Uses

As mentioned above, the uses pertain to laboratory determination of optimum agglomerating conditions and to assessment of the quality of field pellets. In regard to the former, it must be remembered that the procedure was developed for assessing of high clay ores, some of which were almost pure clays – thus the resulting high flow target of 10,000 $L/h/m^2$ – which is 1,000 times the expected acceptance rate of typical field operations which operate at solution application rates of 10 $L/h/m^2$ or less. The test offers a worst-case scenario that is highly unlikely to ever be experienced in field operations. However, extensive KCA field experience on dozens of ores has vindicated the test technique and target percolation value for identifying appropriate operating conditions for field leaching.

Slumping is actually a more critical criterion, especially when evaluating field pellets. The maximum slump target of 10% in the test relates directly to KCA experience in field operations where heap slumpage of 10% or higher will result in a noticeable loss of gold recovery over the short term.

In field situations, the test is recommended to be employed on composite samples of shift agglomerates after a suitable cure period. KCAA have incorporated the procedure in heap leach operations in Australia, Kazakhstan, Philippines, Turkey, China and Mongolia involving gold, silver and copper mines. Given the nature of operating mines, less information on detailed pellet performance is collected and it is more of a “rough and ready” evaluation procedure of pellet quality. The procedure is used to generate the following information on a shift basis:

- cement / binder dosage
- moisture content / addition
- % +25 mm (or other)
- tapped slump
- percolation rate
- general pellet quality.

The information is coupled with other information on ore type, crush size, etc. to form a database for review of overall heap operations. The key information is tracked and supplied to management on a routine basis. In one operation where the agglomeration step was the absolute key to good leaching, the results of the Kappes Test were incorporated into the calculation of operator salary and bonuses.

Figures 1 and 2 present the range of visual results although some ores will experience complete collapse. Figures 3 and 4 present photos of QC testing at operating heap leach projects while Figures 5 and 6 present monthly operating data at a multi-lift gold heap leach operation where the pellet performance data are closely monitored. The information from the QC percolation tests was employed to track the effects of changes to agglomerating condition, including cement dosage and, most importantly, increased water addition.

The result was a much higher percentage of shift composites passing both the percolation target (>10,000 $L/h/m^2$) while maintaining slump below 10%. This resulted in noticeably improved gold production in the following months.

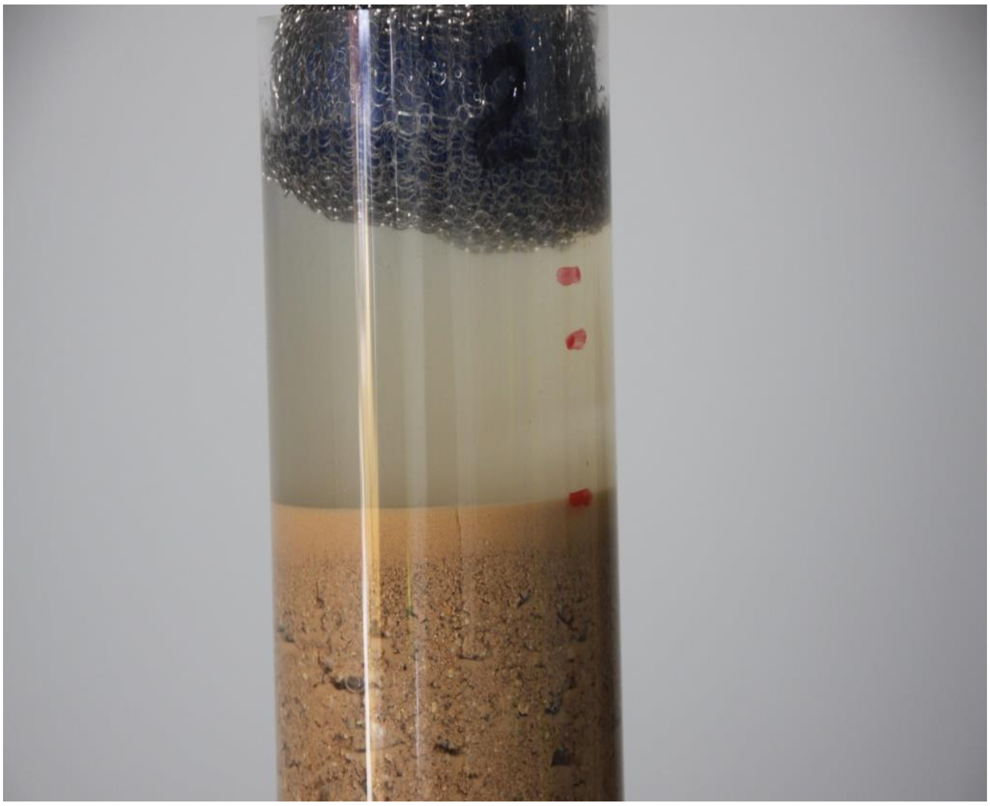

Figure 1: Loss of pellet definition, fines generation and excessive slumping

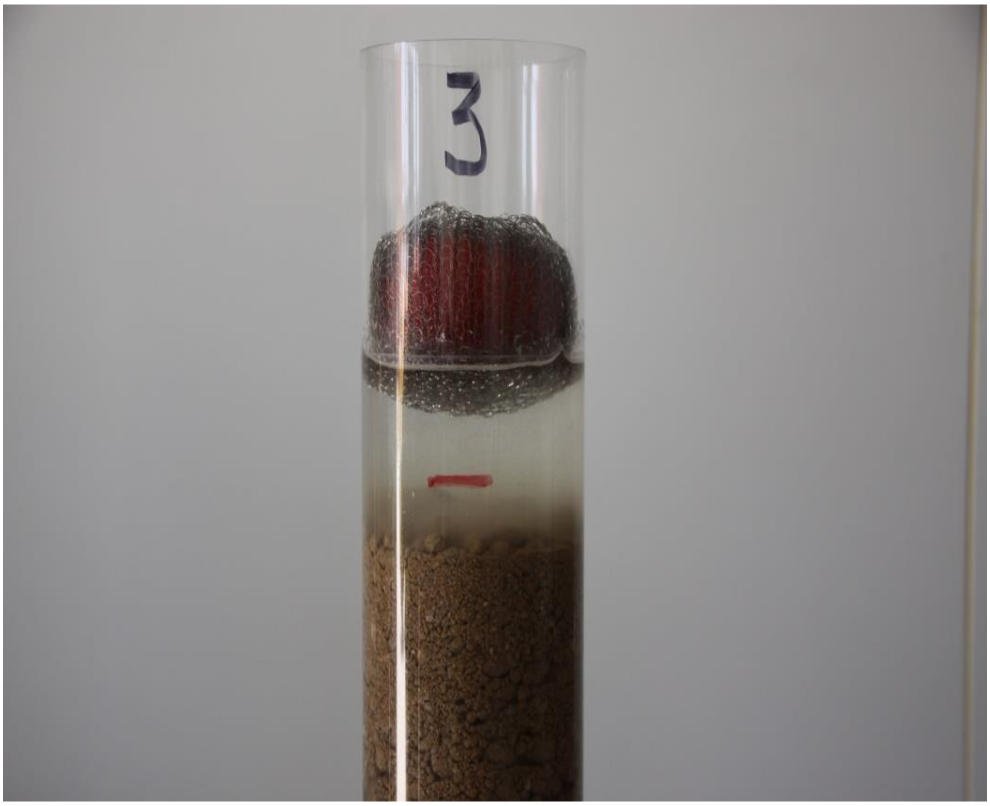

Figure 2: Stable pellets with minimal slumping

Figure 3: QC pellet testing at a gold heap leach operation in Kazakhstan

Figure 4: QC pellet testing at a gold heap leach operation

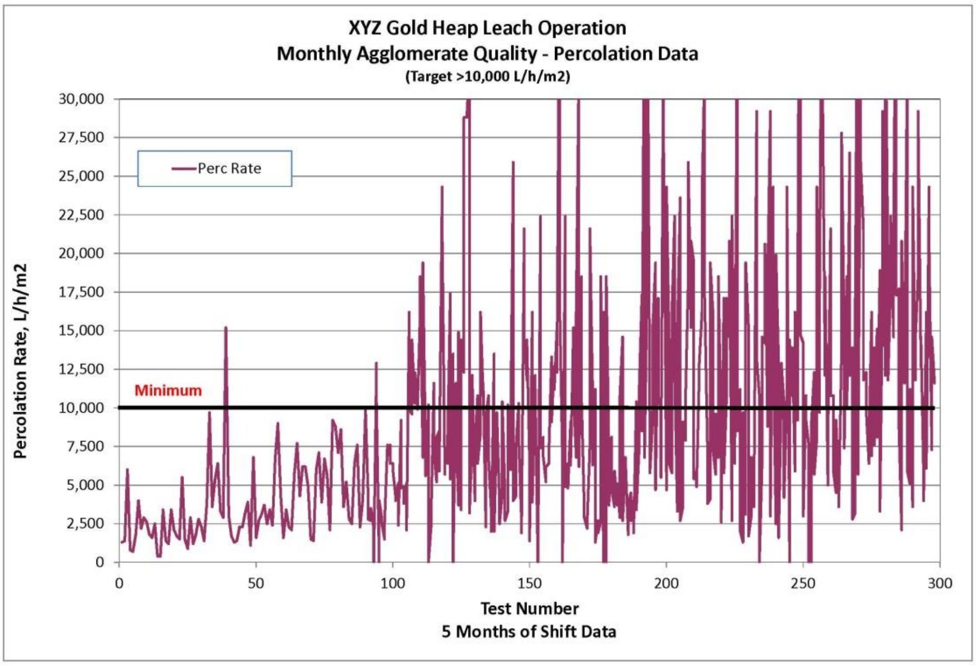

Figure 5: Production percolation data by shift at a gold operation

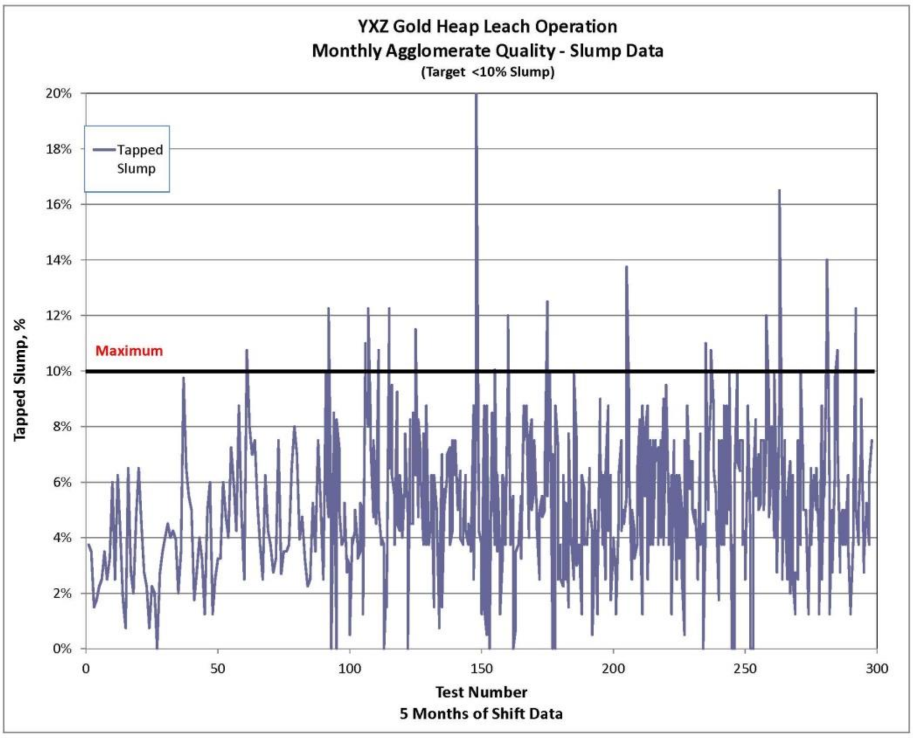

Figure 6: Production slump data by shift at a gold operation

Misuses and misconceptions

Commercial laboratories employing a version of the Kappes Test sometimes do not have the complete procedure while laboratory technicians and supervisory metallurgists do not have specific experience in heap leach operations or agglomeration to understand the purposes of the test or to interpret the data appropriately. Hopefully the information presented in this paper will be of use in this regard.

Also, the test targets for slump and flow have been employed for permeability analyses of crushed, unagglomerated ore to determine whether agglomeration is required. In virtually all cases, these ores fail to meet the percolation rate criterion – which indicates that agglomeration is required when it may not be. This type of evaluation should rightly employ the standard falling head permeability test used in soils analysis – or something similar.

Often, the role of water / moisture is overlooked in the evaluation. For a series of tests employing cement agglomeration, higher cement dosages demand higher water additions to achieve similar pellet consistencies. This is because cement requires water to hydrate and form the silicate bridging bonds; thus higher cement dosages without compensatory water additions may result in water-starvation of the cement, with poor performance indicated at the higher dose.

Water addition is often more critical than cement addition in field agglomeration. We have 2 guidelines in this regard:

1. An ore can be agglomerated with water and no cement – but it can’t be agglomerated with cement and no water.
2. In most cases of field agglomeration, wetter is better.

Of course, water-only agglomeration only imparts (very) short-term pellet strength. And a high moisture content of agglomerates can cause downstream chute blockages, build-up on conveyor idlers, etc., so operators tend to reduce water addition. The optimum mix of water addition and cement is critical to good leach performance, but monitoring of pellet quality is considered essential to those operations that process ores with high clay / high fines content.

Conclusion

The Kappes Percolation Test is an experience-based procedure that has been demonstrated to be extremely useful in determining optimum agglomeration requirements in the laboratory as well as for monitoring field pellet quality. Although the test results are more qualitative than quantitative, they are graphic in nature so laboratory as well as operating personnel can “see” the difference between good and poor quality pellets.

KCA have been involved with heap leach testing, design, construction and operations since 1972, and were instrumental in setting up the first major heap leach project in Australia at the Haveluck Mine of Whim Creek Consolidated in 1976 where Dan actually trialled agglomeration in the laboratory. We have obvious interests in seeing all heap leach operations succeed, and hope that the information presented herein will assist in this regard.

References

Chamberlin, P.D. 1986. Agglomeration for the heap leaching of gold and silver ores, Society of Mining Engineers Preprint Number 86-106, presented at the SME Annual Meeting, New Orleans, Louisiana, March, 13 pp.

Efthymiou, M., Henderson, L. and Pyper, R. 1998. Practical aspects of the application of Extract-Ore® 9560 for heap leach agglomeration at Nifty Copper Operation, published in the proceedings of the ALTA 1998 Copper Hydrometallurgy Forum, 15 pp.

McClelland, G.E., Pool, D.L. and Eisele, J.A. 1983. Agglomeration-heap leach operations in the precious metals industry, US Bureau of Mines Information Circular 8945, 16 pp.

Pyper, R.A. and Pangbourne, A. 1988. Marvel Loch Gold Mine's Exhibition Heap Leach Project, presented at the Conference on Economics and Practice of Heap Leaching in Gold Mining, Cairns, Queensland, Australia.