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

The dynamic evolution of leach pad designs in Chile during the last decade

David Romo, Ausenco, Chile

Abstract

The heap leaching process is a technology that has been used for over four centuries to obtain metals from raw ores. The development of the global industry and developing technology during the last century has led to an accelerated-growth demand for raw materials such as precious metals, copper, nickel, and other base metals. In this challenging scenario, during the last couple of decades, the mining sector has been able to increase extraction, processing, and production rates with the utilization of new technology, software, equipment, machinery, materials, knowledge, and experience. In the heap leaching process, a series of improvements have been made during the last decade, adapting to more challenging market scenarios, reducing environmental risks, increasing production rates, reducing costs, increasing efficiency – and making the process feasible even in extreme geographic locations where success would not have been possible before.

Since the 1980s Chile has been the world's largest copper producer, producing over 30% of total global production. Ausenco (formerly Vector Engineering) has participated in the design of nearly 70% of the heap leach projects in Chile, witnessing and actively being part of the evolution of leach pad designs from the early 2000s to the present.

This paper reviews the most critical aspects and elements of the construction and operation of the most recent heap leach pad designs in the Chilean mining sector, and provides a comparison with the "old fashioned" design. This paper discusses several issues such as location, earthworks, overliner materials, liner system, leak prevention and monitoring systems, leach collection and recovery systems, and pond covers, among other issues. In addition, operational issues are discussed, such as the evolution of the stacking and reclaiming mechanized equipment, and solution application, as primary operational aspects. Finally, all of these improvements are analyzed in terms of mining trends in Chile, and of the impact of some of the new technologies on costs, timelines, and recovery.

Introduction

There is evidence that in Europe miners have used the principles of heap leaching since the sixteenth century. However, the modern process was established in the late 1960s in the state of Nevada, USA

(Hiskey, 1985), when heap leaching was first commercially developed. Through the 1980s and the 1990s there was a dramatic increase in the use of heap leaching for precious metals and copper due to its simplicity, and its low capital and operational costs compared to conventional milling for treating medium to low-grade ore bodies.

Development of heap leaching in Chile

In Chile, the leaching process in the large-scale copper industry was dominated by other techniques such as vat leaching until 1980, when Lo Aguirre mine started its operation. It was not until the 1990s that heap leaching technology was implemented in numerous operations – along with the development of the plastics industry (especially geosynthetics), and improvements in crushing and agglomeration techniques. By this time, a few mines were already processing copper sulfides through heap leaching, thanks to advances in bioleaching knowledge and techniques. In the case of Lo Aguirre mine, in 1987 the amount of oxides decreased sufficiently to force the mine to turn bioleaching from a secondary process into the primary and only leaching technique to process the ore (Lagos and Guzman, 2009).

During the first decade of the 21st century, the main large-scale mines in northern Chile were already operating permanent and on-off pads with mechanized stacking equipment (overland and mobile conveyors, and stackers or spreaders), utilizing high-density polyethylene geomembrane liners as impervious bases, and usually utilizing corrugated polyethylene perforated pipes to collect the leachate solution.

Challenges and design improvements during the last decade

Mining in Chile, and specifically heap leaching, has developed at a very fast pace during the last decade; however, an increasing number of barriers and challenges had to be dealt with to respond to the increasing demand. During the design phase of heap leach facilities a large amount of the risks related to these challenges can be minimized by acknowledging and analyzing them, as well as taking advantage of technological advances and engineering design innovations.

The ore grades of the main copper mining sites in Chile have been showing a continuous drop, so that a larger amount of ore needs to be processed in order to obtain the same amount of product. Additionally, power costs have increased dramatically over the last few years. This is part of the general challenges that the Chilean mining industry has being facing, pushing mining companies to increase production and reduce costs to deal with this adverse situation.

The following paragraphs present a brief analysis of the main issues projects have faced but successfully overcome, by incorporating new materials, new technology, improved designs, and lessons learned. All of these improvements have allowed the designer to optimize heap leach designs in terms of lower investment costs and/or operating costs. The analysis is broken down into six main areas: site location, ore stacking systems, liner systems, liner performance controls, overliner and solution collection systems, and solution ponds.

Leach pad site location challenges in the Atacama Desert

The northern regions in Chile have a general profile characterized by a steep uphill from the coastline sea level to the Andean mountain range, with elevations that peak at about 6,890 meters above mean sea level (Stratovolcano Nevado Ojos del Salado). The other main characteristic of the northern regions is a severely dry climate, making the Atacama Desert one of the driest places on earth. The high altitude areas of Northern Chile also experience drastic temperature changes, with very high temperatures during the day, dropping down to below freezing at night.

In this geographic situation, a significant number of Chilean large-scale mining sites are located at high elevations, in an extremely arid climate, with challenging conditions such as limited water supply, and great distance from populated areas.

Despite all these challenges, several mining companies have been able to develop large-scale operations since the beginning of this century. Some of them were already heap-leaching crushed or run-of-mine (ROM) ore; however, this was mainly feasible at a relatively low cost because the surrounding landscape had open and relatively flat areas with “friendly” natural grades. One of the most expensive items for leach-pad construction is the earthworks; therefore, having a large open area with relatively smooth grades is crucial to achieve a lower investment cost and, at the end of the day, a profitable project. Throughout this last decade, more aggressive projects have been successfully carried out, taking advantage of the lessons learned and of successful cases of valley-fill heap leach pads from other countries such as the USA, Mexico and Peru, along with the use of more flexible liners and more detailed geotechnical analyses. An example of this is the ROM dump leach of Caserones, which is located at over 4,000 m elevation in a mountainous area, and about 160 km southeast of Copiapó city. This operation is designed to process about 300 million tons of copper ROM ore in a valley-fill leach pad with rough and steep topography, and mean monthly temperatures that go from around –20ºC up to 20ºC.

One of the main issues that mining companies have faced this last decade is related to the limited water supply, which is critical in an environment such as the Atacama Desert, where water is very limited and has to be shared with downstream agricultural communities, populated areas, and others. Before the year 2010 most of the mining projects in northern Chile utilized fresh water from underground or superficial sources, and only a few operations utilized sea water. Nowadays most of the major copper mine projects have been forced to consider obtaining water from the sea, which may require desalination plants and long pipelines from the Pacific Ocean coast to the mine sites.

This situation has caused companies to look for alternative technologies to reduce water losses in the process, especially losses due to evaporation during the solution application on the heap active leaching surface and off the solution ponds. The use of drippers instead of sprinklers has been shown to significantly reduce water losses, and drippers have been used since the 1990s on copper heaps. Most of the heap projects are currently considering drippers. In some cases, dripper lines can be installed below the surface of the ore, further reducing evaporation losses. Another effective solution that has been used in arid locations is “thermofilm” liner covering the heap active surface, which can reduce evaporation losses to a minimum, even though this type of material is primarily used for other objectives, such as temperature control in cold climates.

In summary, in spite of the challenges the Atacama Desert creates for mining projects, new materials and design solutions have been put in practice, allowing control of the increasing costs associated with water shortage, rough terrain and other issues.

Changes in heap leach stacking systems

In terms of heap leach operation, the on-off pads have been improved from the classic approach, being adapted to the local conditions and utilizing alternative stacking and reclaiming equipment. The classic design of an on-off pad corresponds to a horse-race-track leach pad, which is operated with large stacking and reclaiming mobile equipment, such as track-equipped bridge conveyors. This system is based on a cyclical continuous operation with two bridges, one equipped with a stacker and the other with a bucket-wheel reclaimer.

Throughout the last decade, a few operations have adopted a modified version of the on-off pad utilizing a more flexible equipment assembly, consisting of mobile conveyors (also called grasshoppers) and a radial stacker, and trucks or a bucket-wheel reclaimer feeding a line of grasshoppers, for the reclaiming tasks. This material-handling equipment provides a more flexible operation and considerably reduces the earthworks for ground preparation compared to a classic on-off horse-race-track system, due to the flexibility of the pad shape, no special requirements for equipment maneuvering open areas, and more flexibility of pad grades.

In terms of equipment for stacking and reclaiming ore on on-off leach pads, some innovations can be highlighted, such as bridge conveyors with capabilities to operate a horse-race-track leach pad without a need for large turning areas. This is possible with a special bridge conveyor mounted on rotatory tracks that allows maneuvering in reduced areas to move from one pad to the other. In some cases, the cost savings on the earthworks for this configuration can pay for the special equipment and still result in a lower cost project.

In summary, it has been shown that during the design of an on-off leach pad, the stacking and reclaiming systems have to be carefully selected considering all aspects of each project, in order to avoid excessive capital costs on material handling equipment.

Liner systems

The containment system that isolates the leaching solutions and ore from the natural subgrade where a heap is to be constructed is the denominated liner system. The liner system will depend on local environmental regulations, local site conditions, risks involved if leakage occurs, operation characteristics, mobile equipment, compressive stress due to the ore loads, grain size distribution of over and underliner, and slope stability, among others.

The history of large-scale geosynthetic lined facilities starts around the 1970s on solar ponds; however, it wasn't until the 1980s that geosynthetic liners were used for heap leaching facilities in Chile (Breitenbach and Smith, 2006).

A common liner-system design in many heaps around the world includes a double containment system comprised of a geomembrane liner laid over a compacted clay liner (CCL) or a geosynthetic clay liner (GCL). This practice responds to regular conditions where the impact of leakage may affect a nearby water body and thus the surrounding environment and communities. In Chile, most of the large-scale leach pads are located in remote sites at high elevations and, in many cases, where the water table level is far below the natural terrain. On the other hand, due to geologic characteristics, there are very few large deposits of clay, which means that a CCL is impractical. In this scenario, the most common liner-system design in Chilean heap leach pads consists of a single geomembrane liner system laid over a compacted prepared surface.

Geomembranes can be made of a variety of materials such as polyvinylchloride (PVC), polyethylene (PE), polypropylene (PP), polyurethane (PUR), polyester (PET), chlorosulfonated polyethylene (CSPE), or bitumen (Peggs and Thiel, 1998). However, the most common geomembrane utilized in the Chilean heap-leach industry at the beginning of this century was high-density polyethylene (HDPE) and PVC (Smith, 1995). During the last decade, the continuous development of geosynthetics has propelled the industry towards more flexible and durable materials, such as low-linear-density polyethylene (LLDPE), without any compromise on the performance of the liners (Erickson et al., 2008). Nowadays most of the leach pad designs take into consideration the different properties of each liner material in terms of mechanical properties, installation, durability, flexibility, performance, compatibility with the operation, costs, and other aspects that will cause the designer to choose the most appropriate liner – even for different areas at the same facility (such as LLDPE and HDPE).

Geomembrane manufacturers have greatly increased the types and variety of geomembrane liners, adding different layers, resins, and compounds that add interesting new characteristics and properties to specialty geomembranes, such as white-surface layering that reduces wrinkles and helps to visually identify liner damage or defects, conductive liners that allow the performance of electric surveys for perforations through the liner even on composite liner systems, reinforced liners, and extra-flexible liners (Cornellier and Tan, 2014).

By the beginning of the century the global mining industry was comfortable and confident designing and operating heaps with a maximum nominal height of around 100 m, but since then the industry has been pushing to raise maximum heap heights to 150 m or even over 200 m (Thiel and Smith, 2003). One of the main restrictions for the height is the integrity of the thin impervious geomembranes that may suffer puncture damage due to the elevated pressure generated by the large columns of ore above them. The flexibility and high resistance provided by newly developed LLDPE liners make it possible to bear these extreme conditions and remain impervious throughout the life of the projects.

In some cases, the costs of the liner system can be as high as 30% to 35% of the total pad construction costs (mainly when earthworks and overliner costs are a lesser issue), therefore any savings related to this particular element will result in important savings for the project. As mentioned above, the proper selection of the geomembrane, specific to the use, area and conditions, will lead to important savings and risk reductions for the overall project.

Overliner and solution collection systems

Besides earthworks and geosynthetics, one item that has been historically one of the main cost drivers of heap leach projects in Chile is the overliner material, mainly due to the very limited availability of clean-gravel borrow sources in the Atacama. In addition issue, regulations for borrow sources permitting are very rigorous, making it very difficult to keep control of the project's costs and schedule. As a result, in most cases the contractor has to screen or crush local material, or even use sterile mine waste, to produce a material with the right grain-size distribution, maximum particle size, fines content, and durability. In this scenario, costs for production and placement may range from 10 to 50 US$/m^3, especially if the ideal particle-size distribution range is narrow.

The particle-size distribution of a good overliner material should provide enough small particles to fill the larger voids and to reduce the risk of damaging the geomembrane liner, but still leave enough voids, and have limited fine material, to allow a high hydraulic conductivity. During the last decade, the industry has seen improvements in materials, such as more flexible geomembranes with higher puncture resistance, which may ease one of the restrictions of the overliner material and thus, reduce the high costs of overliner production.

Different approaches have been studied and utilized in order to reduce overliner costs, including the use of more than one type of overliner materials, and the use of geosynthetics as an alternative to reduce the amount of overliner material. One tendency that has proved to significantly reduce overliner costs is to use a dual overliner system, reducing the amount of a high-permeability overliner and replacing it with a merely protective material, which has shown to be a cost-effective alternative in terms of phreatic level control within the heap (Echeverria et al., 2014). The distribution of the materials on a dual overliner system will depend on the design and the results of flow analysis to ensure both liner and pipes protection, and proper control of the phreatic level.

Smith and Zhang (2004) propose another system that may reduce the drainage gravel requirement, by utilizing geosynthetic drainage materials in combination with a reduced thickness of overliner. This is more innovative alternative that needs to be more closely studied in Chile.

In summary, in order to control the elevated costs for overliner production, designers have had to go through specific and more detailed design, evaluating different approaches in terms of configuration, use of more than one overliner material, and the use of more flexible liners.

Solution ponds

Once the solution is collected at the base of the heap, it is gravitationally conveyed through pipes from the base of the heap to the next process stage (solution ponds or the SX/EW plant). A common practice that was carried out on the design a decade ago was to utilize open channels to convey the solution from the leach pads to the pond areas, and between ponds. The environmental regulation authorities in Chile have become increasingly strict over the years, and on this specific topic, the tendency has been to switch to HDPE pipes in a lined trench. Even though this design obviously raises the costs of the project, it provides a safer design in terms of potential leaks into the environment, and it eliminates the risk of birds or animals being tempted to drink from a solution channel, or falling into it.

An important part of the heap leaching process is the solution ponds that store large amounts of solution through the operation, allowing damping peaks and shortages and handling planned partial stops without affecting the continuity of other areas. However, the ponds also play a negative role in terms of water balance due to evaporation, especially in the Atacama Desert, where make-up water is scarce and expensive. The other issue that usually has to be addressed is the risk of birds or animals looking for water in the desert.

One alternative that has been used for years to solve these issues has been to cover the ponds with a geomembrane such as PP, HDPE or even PVC (Touze-Foltz et al., 2008), which is fixed on the pond sides, and floats over the solution. Even though the floating covers solve the immediate evaporation problem, several other issues are raised during operation, such as the difficulty of operating equipment in the pond (skimmers, floating barge pumps, etc.). New products have been recently developed and implemented in some operations in Chile with good results, such as floating loose plastic balls, which are extremely easy and quick to install, and can cover any pond surface shape. More sophisticated variations of this type of floating cover systems are available, such as hexagonal units that reduce the inter-unit spacing, increasing the efficiency of coverage. Another alternative that has been developed is floating modular covers, which may provide a better performance in terms of sealing, wind lift-up and precipitation or snow infiltration.

Liner performance controls

The performance of the liner system throughout the life of a project and beyond is one of the most important risks that this kind of facility faces in terms of environmental contamination and the economics of the project due to pregnant solution losses. Throughout this decade, there has been a dramatic growth in the popular awareness of the environmental impacts of mining, which has been reflected in stricter regulatory authorities at the stage of permits approval.

On the other hand, there have been important advances in leakage prevention, monitoring, and detection with techniques that focus not only on the construction stages, but also on operation and even after closure.

There are several techniques and controls to prevent leakage; however, besides the manufacturer's quality control and installation quality control system, great improvements have occurred in the techniques, equipment, and market growth of electrical liner integrity survey services (ELIS), also known as leak location services. Ten years ago statistical economic analyses were performed to evaluate the cost benefits of using ELIS techniques, showing that the reduction of pregnant solution losses due to leakage may lead to savings of about 1.5 US$/m^2 (Thiel et al., 2005), without considering the potential costs of fines, remediation, rework, etc. Prota et al. (2014) shows through case studies in South American sites that the ELIS services costs are easily paid off throughout the operation when compared to the potential economic losses if leaks had not been detected. On the other hand, ASTM published in 2003 the first standard practices for leak location on two different methods: a water puddle system, and for geomembranes covered with water or earth materials (ASTM D7002 and ASTM D7007 respectively). ELIS started to gain more popularity in Chile as methods for preventing leaks as they provide operators with a robust tool to detect and repair defects or damage of the liner produced during construction, handling, shipping and/or manufacture of the material.

Another improvement in terms of evaluating the liner integrity during construction is the use of conductive geomembranes, which in conjunction with field electric leak location methods provide improvements in terms of water requirements, independent of subgrade conductivity, have no issues on wrinkles and slopes, and can be used on double-lined systems (Cornellier and Tan, 2014).

Recently developed leakage monitoring systems are able to provide a continuous real-time assessment of the existence, location, and extent of a leak, also called permanent electronic leak detection systems (ELDS). These systems have successfully been used since 2001 to monitor leakage through the liners during operation. In 2008, on-line ELDS was developed and installed in a lagoon in North America, and was able to provide continuous information to a control center (Nosko and Razdorov, 2013). Fiber optic sensors based systems have been used in Chile, USA, Laos, and Latvia, providing crucial structural information of strain and temperature of large earth facilities, which allows detecting and measuring the phreatic level continuously along the instrumented line (Fahrenkrog, 2007; Fahrenkrog and Fahrenkrog, 2012; Inaudi et al., 2013).

Challenges and opportunities for future projects in the short term

The main challenges that the industry of heap leaching design and operation should face in the next years are strongly driven by the turbulent economy of copper, environmental issues such as stricter regulations and regulators, an increasing impact of the communities on permitting issues, a high cost for energy, water availability, and lower ore grades.

New regulations for mine closure have been published, including law Nº20.551 and decree Nº41 of the Ministry of Mining in Chile, that will add more steps for companies to obtain the authorities final approval; therefore additional costs that were not required until now will be incurred.

Consultants and designers, on the other hand, will have to search for new or improved designs for leach pad, and look for opportunities to transfer technology from other industries, in order to provide their clients with alternatives to balance the aforementioned higher costs, and/or increase their recovery rates, to maintain the profitability of projects.

Opportunities to accomplish successful profitable heap leach designs are not too remote, if the ongoing research into various fields of monitoring, instrumentation, new materials, successful operation experiences, and new technologies are properly considered – turning the aim of leach pad designs to a fit-for-purpose design in order to meet each client’s different needs and restrictions.

Nowadays, many Chilean large-scale copper mines are running low on copper oxides and are, or will soon be, looking into processing large deposits of copper sulfides. This means that the main mines should start looking towards more concentrator plants or bioleaching processes than conventional heap leaching for copper oxides.

Conclusion

The national scenario where the mining industry and specifically the leach pad projects stood about a decade ago has gone through important changes in terms of national economics, environmental and social awareness, regulations, ore grades, and technological advances. These issues have driven major changes and new approaches in the design of heap leach pads, leading to more aggressive designs within stricter environmental and social restrictions and requirements, in order to protect project economies by lowering costs and/or increasing recoveries.

This paper presents a large compilation of facts from different authors and from the experience of Ausenco that clearly show the aforementioned tendencies, from the main construction items that drive the costs of a typical leach pad project such as earthworks, liner system and overliner, to operational aspects such as stacking/reclaiming equipment, and water saving.

The accelerated development of industries such as plastic materials and mining equipment, and the transfer of technology from other industries, have helped the heap leach design industry to go through a dynamic development in order to respond to adverse conditions and economics, and the client’s needs.

The understanding of the needs of each client, the overall scenario of a particular project, the lessons learned from successful projects recently developed, and the new advances in technology, materials and techniques, have been the key ingredients to overcome the challenges of this decade, with cost reductions that have allowed the success of many heap leach projects.

One important aspect of the years to come is that due to the new mining regulations and the new technologies, future leach pads in Chile will have to have very high standards in terms of environmental short- and long-term issues, social acceptance, and safety.

Acknowledgements

Besides all the valuable references mentioned throughout this document, much of the information in this paper was furnished and reviewed by a group of experienced and knowledgeable professionals closely related to the operation and design of heap leach pads – in particular, Mr. Allan Breitenbach (Ausenco Denver), Mr. Andrés Olea (Ausenco Chile), Mr. Cristián Clavería (Ausenco Chile), Mr. Iván Suazo (Independent consultant), Mr. Juan F. Schwarze (Ausenco Chile), Mr. Mario Letelier (Ausenco Chile), and Mr. Nicolás Echeverría (Ausenco Chile).

References

ASTM D7002-15, Standard practice for electrical leak location on exposed geomembranes using the water puddle method, ASTM International, West Conshohocken, PA, USA.

ASTM D7007-15, Standard practices for electrical methods for locating leaks in geomembranes covered with water or earthen materials, ASTM International, West Conshohocken, PA, USA.

Breitenbach, A. J. and Smith, M.E. 2006. Overview of geomembrane history in the mining industry, Proceedings 8th Bi-annual Meeting of the International Geosynthetics Society (8IGS), Japan.

Cornellier, M. and Tan, D. 2014. Use of premium HDPE liners in heap leach applications, Proceedings Heap Leach Solutions 2014, Lima, Peru: pp. 305–316. Vancouver, Canada: InfoMine.

Erickson, R.B., Thiel, R.S. and Peters, J. 2008. The ongoing quality issues regarding polyethylene geomembrane material manufacturing and installation, The First Pan American Geosynthetics Conference and Exhibition, 2–5 March 2008, Cancun, Mexico.

Echeverria, N., Romo, D. and Suazo, I. 2014. 3-D/2-D Comparative flow analysis in heap leach drain systems with two different overliner materials, Proceedings Heap Leach Solutions 2014, Lima, Peru: pp. 195–204. Vancouver, Canada: InfoMine.

Fahrenkrog, C. 2007. Instrumentation with fiber optic sensors emphasizing operation and closure of tailing dams, poster presented at the II International Seminar on Mine Closure 2007.

Fahrenkrog, C. and Fahrenkrog, A. 2012. Instrumentation with fiber optic sensors emphasizing operation of tailing dams and landfill monitoring, EACS 2012 – 5th European Conference on Structural Control, Genova, Italy.

Hiskey, J.B. 1985. Gold and silver extraction: the application of heap-leaching cyanidation, Fieldnotes, Arizona Bureau of Geology and Mineral Technology, 15(4): pp. 1–5.

Inaudi, D., Cottone, I. and Figini, A. 2013. Monitoring dams and levees with distributed fiber optic sensing, 6th International Conference on Structural Health Monitoring of Intelligent Infrastructure, Hong Kong.

Lagos, C. and Guzman, X. 2009. Biolixiviación: Desarrollo actual y sus expectativas, Dirección de Estudios y Políticas Públicas, COCHILCO.

Nosko, V. and Razdorov, P. 2013. Use of electronic leak detection system in 24/7 on-line mode to control construction and operation of lined CAL lagoons, Geosynthetics 2013 Conference, 1–4 April, Long Beach (CA), USA.

Prota, S., Parra, D. and Beck, A. 2014. Maximizing productivity in heap leach pads through dipole electrical leak location, Proceedings Heap Leach Solutions 2014, Lima, Peru: pp. 447–456. Vancouver, Canada: InfoMine.

Smith, M.E. and Zhang, A. 2004. Drainage net for improved service and cost reduction in heap, GFR Engineering Solutions Magazine, August 2004.

Smith, M.E. 1995. PVC-Lined copper leach pads in Chile, Geotechnical Fabrics Report, 13(2): pp. 12–13.

Thiel, R., Beck, A. and Smith, M.E. 2005. The value of geoelectric leak detection services for the mining industry, Geosynthetics Research and Development in Progress, Proceedings 18th GRI Conference, held in conjunction with Geo-Frontiers 2005; Austin, USA, ASCE: pp. 1–6.

Thiel, R. and Smith, M.E. 2003. State of the practice review of heap leach pad design issues, Proceedings 17th Annual GRI Conference Hot Topics in Geosynthetics – IV, Las Vegas, USA.

Touze-Foltz, N., Lupo, J. and Barroso, M. 2008. Geoenvironmental applications of geosynthetics, Keynote Lecture, Proceedings Fourth European Conference on Geosynthetics – Eurogeo 4, Edinburgh, Scotland.