CONTRIBUTIONS OF DR RIPU DAMAN LAMA TO GAS OUTBURST AND CONTROL AND STRATA MANAGEMENT SYSTEMS

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GAS OUTBURST AND CONTROL

With a rapid increase in underground coal mining in Australia, the problem of outbursts and high gas emissions has become very serious. In 1978, while working with the CSIRO Division of Applied Geomechanics, Dr. Lama started to work in the area of outbursts of gas and coal and control of gas in coal mines. Since that time, he was deeply involved in this work. The main thrust had been in the following directions:

1. Gas content estimation.
2. Characterisation and prediction of outbursts and control of outbursts in operating mines.
3. Pre-drainage of gas in coal mines – optimisation of hole spacing.
4. Post-drainage and control of gas in longwall operations.

The main concepts put forward by him can be listed as follows:

1. For successful and efficient control of coal and gas outbursts, gas content determination up to 100 m ahead of an advancing heading requires development of new methods which give accurate values within six hours of sampling.
2. There is a need to develop techniques for the prediction of dislocations (shears) in coal to predict outburst sites.
3. Because of the contraction of coal matrix on application of suction, the flow rates can be greatly increased when high suction is applied to the boreholes.
4. Flow rates (post-drainage) are highly dependent upon the joint direction and fracture development in the floor of the coal seams.
5. While planning for ventilation, gas emission rate cannot be taken proportional to production. This relationship is not linear. Also in mixed gas situations gas the liberated has a different composition from the in-situ gas content of coal.

Summary of the research findings of Dr Lama:

- Research in the area of gas content measurements showed that the use of cuttings can give gas content and gas composition values within 10% of the actual value. This method has the advantage that there is no need of a core and can be applied in underground conditions where core recovery is difficult.

- A number of methods for the prediction of shear zones in underground mines have been proposed and researched. These include methods based upon differential sorption properties of coal as these change under the effect of a shear structure, gas pressure measurements which change as a result of changes in the permeability of the structure and fracture density measurements. The fracture density and sorption properties change up to 20 m away from the shear structure, but gas pressure changes can occur up to 100 m away from the structure.

- Threshold values of gas content of coal both for CO_2 and CH_4 were proposed for the mining of the Bulli seam and these have now become more or less an industry standard.

- A new method for the prediction of outburst potential of a coal seam on regional basis was proposed and was applied in a Queensland mine.

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- Research in the area of in-seam and post-drainage indicated the effect of high suction on increasing flow rates from the Bulli seam by a factor of three. This allowed successful drainage of the Bulli seam hitherto considered as undrainable. This was acknowledged as the first most successful research project funded by the Commonwealth Government of Australia. Research also showed that the optimum spacing of holes, effect of jointing and stress, and geological discontinuities, all play an important role in improving gas recovery. Together with power generation, this research project was awarded the Engineering Excellence Award of NSW in 1985.

- In the case of mixed gas emissions, research showed that the gas compositions change with time. A model was developed that allows prediction of changes in gas composition. Research showed that even when the gas composition in in-situ coal is 60% CO_4, the gas liberated will be 85% CH_4 and this aspect must be taken into account in ventilation planning, evaluation of gas reserves and in the estimation of threshold values for safe mining of the Bulli seam. The method suggested by Ripu for true estimation of gas composition is now an accepted practice in the coal industry of Australia.

STRATA MANAGEMENT SYSTEMS

Most studies on the strength of rock are based upon small samples tested in the laboratory where, neither the field conditions, nor the size effect can be taken into consideration. As such, the results of laboratory tests cannot be applied directly in the prediction of field behaviour. For the application of laboratory results to field behaviour certain reduction factors are used. Ripu felt that this concept is not necessarily applicable.

The concepts he developed in this area include the following:

1. For any geomechanical data to be reliable, tests must be conducted in the field or on sample sizes which can adequately represent the field samples e.g. behaviour of jointed rocks.
2. In brittle rocks, the behaviour is related to the development of cracks and classical theories representing field behaviour and material softening are not applicable. This is true for intact and fractured rock e.g. time dependent deformation of rock.
3. In the design of underground structures, it is essential that data be collected using back analyses of such parameters which have most effect on the design e.g. angle of internal friction in pillar design.
4. Each case must be analysed taking into account the geology which plays an important role e.g. massive beds in subsidence.

In the area of basic geomechanics, Dr. Lama conducted research in the following areas:

1. Mechanical properties of intact and jointed rocks.
2. Time dependent behaviour of jointed rocks.
3. Prediction of rock failure.

In the area of applied geomechanics, research was conducted in the following areas:

1. Pillar design under high horizontal stresses and yield pillar design.
2. Roof bolting design.
3. Early strength packing materials and stability of wide headings.
4. Ground movement of narrow and subsidence over wide openings.

Summary of the research findings of Dr Lama:

- Research conducted on testing of large samples in the field and comparison of the results on smaller samples in the laboratory showed that when field data is required for mine design, laboratory results are not applicable particularly in fractured rocks with high density of joints such as coal. The data is not only quantitatively but also qualitatively unreliable. The compressive strength of the samples is dependent upon the stress distribution on the bearing surfaces of the samples and this shows up in the power relationship of strength and (height/diameter) dimensions. If the stress distribution is uniform, as is the case with brush platens, then the (height/diameter) effect vanishes. The volumetric effect is important and this is related to the number of defects and the type of defects in the rock. For a sample to be representative of the rock mass, it must contain at least 100 – 150 such defects.

- The dynamic failure of rock is a result of the relative stiffness of the roof and floor rocks as well as the change in the loading conditions of the rock. When the state of stress suddenly changes from triaxial to uniaxial, the extra energy is suddenly released in the form of rock bursts and also in the form of outbursts of gas and coal.

  Stress distribution in jointed rocks is determined by the mobility of the joints and this determines the strength of the jointed system. The closeness of the joints and the angle of orientation of the joints, joint continuity are all important. The post-failure behaviour is determined by the joint density. Rocks with high joint density have much smaller post-stiffness and fail gradually.

- The time-dependent behaviour of intact rocks is the result of crack propagation. The amount of strain before failure that the material will undergo is determined by the post-failure curve of the rock. The material must deform so much such that the time-dependent strain induced approaches the post-failure curve for the stress conditions imposed. For this reason, the intact rock will undergo a large amount of deformation. Fractured rock, on the other hand, already lies close to the post-failure curve and hence the fractured rock will show very small time-dependent deformation. This is also supported by the fact that the effect of rate of loading on intact samples of rock is considerable, but the effect of displacement rate on frictional behaviour of joints is very small. This research was awarded the Heico Gold Medal by the Indian Geotechnical Society in 1978.

- Research on prediction of failure using micro-seismic studies showed that the higher frequency noise increases at a faster rate as the ultimate failure approaches, though the energy associated with lower frequencies is higher. Using theoretical modelling and experimental results, it was shown that as the fractures develop in a model or a system, the resonance frequency of the system moves towards the lower frequency spectrum.

- When rock joints are filled with clay, the thickness of the fill plays an important role. When the thickness of the fill is small, there is some dilation and displacement values at peak decrease with increase in thickness, but as the thickness of fill increases, there is consolidation of the joint followed by a continued increase in displacement at peak shear. The effect of this is that the behaviour of the filled joint is not governed by the behaviour of the material filling the joint. Even at a fill thickness of twice the asperity height, the joint is stronger than the fill material.

- Research based on an industry wide survey of roof conditions on the stability of roadways particularly under high stress conditions showed the direction of drivage of the heading with respect to the principal horizontal stress is important. Roadways driven at angles of 30 – 90 degrees to the major stress undergo greater displacement and greater damage as the angle increases. Analysis showed the drivage of the first roadway can relieve the stresses in the next roadway to be driven. The distance to which the relief can be expected is linearly related to the height of the caving. In the design of the longwall layouts, this is the most important consideration in Australian mines.

- It is important that the roof bolting design must take into consideration not only the strength and stress parameters but also the actual deformation values that the roadway undergoes.

Keeping this in mind a computer program was developed which incorporates the field measurements and optimises the rock parameters to arrive at the optimum values of bolt requirements. Research using this program clearly indicated that in cases where the roadway has to be placed at very high angles to the major stress or where the depth of excavation is large, it is essential that the roof bolting system be optimised by allowing some displacement of the rock and using yielding roof bolts. Otherwise the roof bolting density will be too large and uneconomical. The concept of immediate support will not be appropriate under these conditions.

- Under a NERDDC Project, he conducted studies in roof bolting with a view to increase development drivage rates. He demonstrated that by reducing bolting cycle time through application of high pre-tension to full-column grouted bolts. For this work, he had the 1995 ACARP Award of Excellence in the Underground Category.

- The design of pillars particularly under conditions of high horizontal stresses must take into account the behaviour of the rock in-situ as the pillar behaviour and fracturing gets modified under such conditions and pillar design using classical methods, based upon vertical stress as the major principal stress, are not applicable as these give much higher values. A special technique was developed which is based upon the measurement of fractured zones using air permeability. This allows the calculation of the in-situ friction angle of the coal pillars which gets modified depending upon the roof, floor and stress condition. This allowed design of 10 m wide stable pillars for depths of 465 m for a 3-heading development and were introduced in KCC mines. The results also showed that the width of the pillar will depend upon the direction of drivage. This result cannot be deduced from classical pillar design theories.

- The results of a major tapering pillar experiment also showed that the width of a yielding pillar for the layout of a 3-heading gate road development to combat high stresses during the mining of a retreat longwall panel is about 8 m. The results of this research were applied to the design of longwalls 12 – 14 at West Cliff Mine and these resulted in an increase in productivity by a factor of two compared to longwall 11 mined in the same area. This technique was consistently used in the set-up heading when stresses are high in all longwalls at West Cliff and Tahmoor mines and was adopted in other mines.

- Studies on subsidence under massive sandstone beds showed that the effect of chain pillars on the surface is absent. The surface behaviour is governed by the bending of the massive beam the stable thickness of which develops as the critical width of the excavations is reached. This thickness under Southern coal field (NSW) conditions was found to be about 100 m. This has eliminated the requirement for modification of longwall layout to control subsidence damage.

- A new system of gate road development based upon Shortwall mining with a central pump pack was proposed. This system can develop roadways faster than any other existing systems and is cost effective. A major study under this project conducted showed that the coal wash reject, 10 mm, can be pumped up to 2 km at solid density of 82% and can be placed in position with a compressive strength of 0.25 MPa within 2 hours. At 450 m depth this system with a roadway width of 15 m is stable. It was suggested that this may be the best method where 3-heading development is needed due to high stress and high gas conditions.

CONTRIBUTIONS OF RIPU DAMAN LAMA

PROFESSIONAL CONTRIBUTIONS

Dr. R. D. Lama graduated from Punjab University (India) in 1957 majoring in Physics and Chemistry and obtained his B.Sc. Mining Engineering from Banaras Hindu University (India) in 1961, with a first class . He was awarded a Government of India Scholarship for studies in Poland where, in 1966, he obtained his PhD. from the Academy of Mining and Metallurgy in Kraków. Based on his research, he obtained DSc. degree from the Indian School of Mines in 1994 and also DSc. Mining degree from the Kemorovo Mining Research Institute of the Russian Academy of Sciences, Siberian Branch in 1995.

On his return from Poland, he joined as Reader in Coal Mining at Banaras Hindu University where he served till 1971. From December 1971 to December 1974 he was Senior Research Scientist at the Institute of Soil and Rock Mechanics, University of Karlsruhe, Germany. In 1975 he joined the Division of Applied Geomechanics, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, first as Senior Research Scientist and then as Principal Research Scientist (1976) and Section Head of Coal Mining Geotechnology (1979). In 1981 he was offered a position as Manager, Mining Technology, Kembla Coal and Coke Pty. Ltd. (RTZ-CRA Group); the position he occupied until his death.

Since his graduation, Ripu worked in universities, teaching and performing research in India, Poland and Germany (13 years), research in CSIRO (7 years) and in the Coal Mining Industry (14 years). His technical expertise can be divided into the following areas:

- Design of coal mines (from exploration to execution, with particular reference to geologically disturbed areas and deep mining)
- Mine evaluation, economic analysis, feasibility reports for coal mines
- Geomechanics applied to coal mining and civil engineering in tunnelling, slope stability and large underground chambers
- Gas from coal seams, gas drainage and utilisation and gas outburst in coal mines
- Dust control in mines

He has written 128 papers and 91 consulting reports in the area of geomechanics, gas control and outbursts in coalmines, and mine planning and design. He has co-authored five books in geomechanics and mine ventilation which are standard references and these have been translated into Chinese and Japanese. The four volume book *Handbook on Mechanical Properties of Rocks* published by Trans Tech (Germany) is a standard reference book on the subject and the fifth book *Environmental Engineering in Mines*, published by Cambridge University press, is a standard text book for undergraduate and post-graduate mining students. These books have been translated into Japanese and into Chinese. He was also the editor of the proceedings of the *International Symposium cum Workshop on Management and Control of Outbursts in Underground Coal Mines* which was held in Wollongong in 1995.

He has been a consultant to mining companies in many countries including USA, Australia, New Zealand, China Germany, India, Poland and Greece. He has run advanced courses in the areas of his expertise and lectured in many countries in Europe, Asia and North America. He is also an Adjunct Professor of the Beijing Graduate School of Mining and Metallurgy, Beijing, China. Ripu was co-supervisor of five students who successfully completed PhD Thesis. He was also been an examiner of MSc and PhD Theses submitted at the Universities of NSW, Wollongong and Monash.

Dr. Lama was a member of many national and international bodies on which he represented Australia. He was a recipient of the Robertson Medal of MGMI (India), B.H.U. Gold Medal and Nand Lal Gold Medal from Banaras Hindu University (India), Heico Gold Medal from the Geotechnical Society (India), Engineering Excellence Award from the Institution of Engineers, NSW (Australia) and Research Excellence Award from the Australian Coal Research Association. In 1991 the International Bureau of Rock Mechanics nominated him for the Japan Prize, the highest award in engineering. He was listed in **Who is Who in Engineering** published by The Association of Engineering Societies, USA. In 1995 Dr. Lama was elected to the Corresponding Member of the Russian Academy of Natural Sciences.

PERSONAL TRIBUTES

Ripu Lama demonstrated the true value of good science to the improvement of both the safety and economics of the mining process. He was a person of prodigious intellectual capacity and generous disposition whose contribution to the industry cannot be adequately measured by conventional metrics. I am a better Engineer and Manager for having worked with Ripu. I have no doubt there are many individuals in our industry that will reflect on his contribution to their own personal development and feel the same. While we mourn his loss, we should celebrate his life and his achievements.

Mark Cutifani, Managing Director, Sons of Gwalia Limited

Ripu was a person of innovative ideas, tremendous enthusiasm and energy. He was an early advocate and researcher of many current practices in gas drainage and strata control. I remember, that on many occasions, when an underground mine was experiencing ground control problems, Ripu would be called to advise on the causes and possible solutions. He was a good colleague, greatly missed.

Colin Seaborn, formerly General Manager Technical Development, Kembla Coal & Coke

I have had the priviledge of working with Ripu over a number of years – trying to assist him in unravelling the complexity, and mystery coals porosity and certain coals' gas holding capacity – not to mention the phenomena gas-desorption. Unashamedly, I confess to my envy and admiration for Ripu's ability to solve a mathematically based hypothesis in his head, without having to put numbers on paper while I was fumbling with my advanced HP-Scientific calculator to get to the same answer.

However, much more important and memorable to me was the pleasure to work with Ripu for his inescapable kindness and readiness to listen to anyone's problems (of which there were plenty) and offer his immediate help – not just promises. Such irrepressible kindness was of particularly great help and encouragement to the numerous post graduate students whom he supervised, and visiting overseas professionals with whom Ripu had collaborated.

With fond memories – that will be with me – as with your other friends and associates in the "Sciences and Mysteries of Coal Mining"

Michael Pretor, Austral Coal

I first met Dr Ripu Lama when he attended a conference in the mid 1970s. He was always dedicated to his work and to research. He was a driver and was a very efficient person who had the ability to analyse a problem and put it into simple perspective.

Lew Griffiths

Ripu or "Rip" as he was affectionately known on the minesite possessed the ability to relate his practical knowledge equally well to the machineman on the face, as those esmerized by his technical presentations at world class symposiums. His record of enlisting the enthusiasm and support of managers in applying the results of his research in providing practical solutions to a broad range of mining problems gained him unparalleled respect and admiration.

Ripu's dedication to the improvement of the industry and its people, rather than reflection upon his past achievements remains a measure of the calibre of the man - we miss him.

Bob Miller, General Manager, Springvale Coal Pty Ltd

I have known and worked with Ripu Lama since the late 1970's, when he first came to work at West Cliff from the CSIRO.

During the next 20 years Ripu, was personally worked at the leading edge in the development of gas drainage and rock mechanics technologies. He had the exceptional ability to not only carry out detailed and comprehensive pure research, but was able to translate this information into practical solutions and applications that were well accepted by operational personnel.

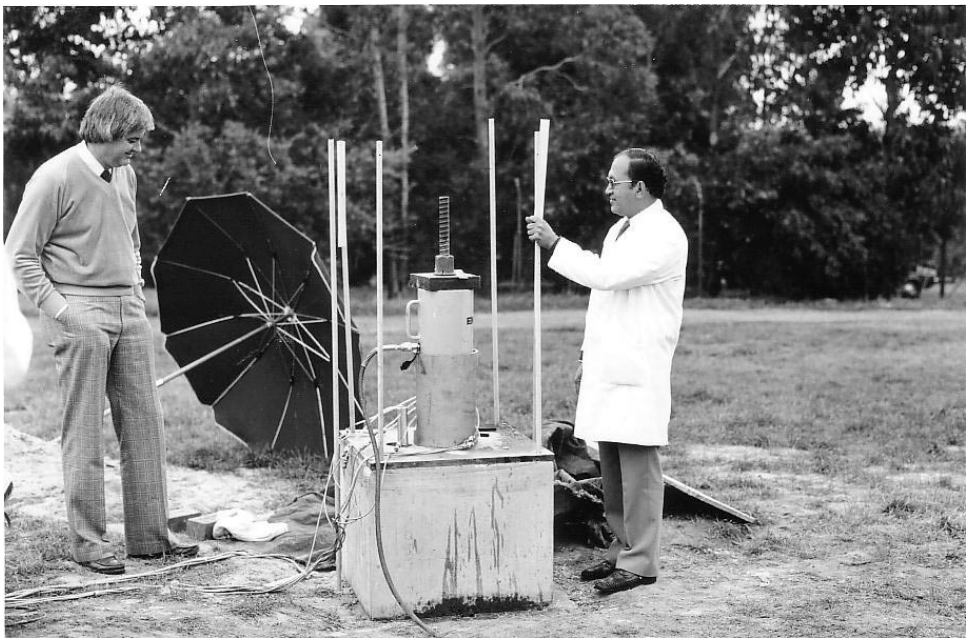
One of his key skills was that he was able to communicate equally well with all levels within the industry, from academic researchers, to business leaders and technical personnel right through to the miner at the coal face.

In my opinion, his greatest contribution to the coal industry was the technical support given to the elimination of the risk of gas outbursts in the Bulli Seam by the development and implementation of outburst management plans. Without this, the future of many mines in the Southern District would have been less than secure.

Ripu Lama will always be well remembered and respected by all those withwhom he worked. We all miss him.

Ian Sheppard, Manager Engineering Services, Tahmoor Colliery

Ripu at Kembla Coal & Coke Office, Wollongong



Ripu at CSIRO Syndal, Victoria

Ripu at CSIRO Syndal, Victoria

Underground visit by Ripu

Ripu visiting China 1990 with Ken Cram

Ripu and Barbara at NSW Blue Mountains, 1992

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