ANNUAL REPORT COVER SHEET

for

UNITS, CENTRES & INSTITUTES

Name of Unit, Centre or Institute: The Light Metals Research Centre

Name of Director/s:

Mark Taylor, Honorary Professor, Chemical and Materials Engineering

Attach: **Annual Report for 2005**
Financial Statement for 2005

Signed by: **Director …… Date ……..……**

Dean …….. Date ……...

Send to: **The Manager**
Research Office

Advisory Board Membership

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Assoc Professor Pare Keiha, Associate Dean, Faculty of Maori Studies, AUT
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Professor Mark Taylor, UniServices (Chair)
Associate Professor Margaret Hyland, Chemical and Materials Engineering
Professor John Chen, Chemical and Materials Engineering
Professor Jim Metson, HOD, Department of Chemistry
Mr Gary Putt, UniServices

Light Metals Research Centre – Participating Members

Department of Chemistry
Professor Jim Metson

Chemical and Materials Engineering
Professor JJJ Chen
Professor WG Ferguson
Professor Wei Gao
Professor Mohammed Farid
Associate Professor Margaret Hyland
Dr. Yu Lung Chiu
Dr Mark Jones
Dr Mike Hodgson
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Department of Mechanical Engineering
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Department of Engineering Science
Professor David Ryan

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University of New South Wales
Professor Maria Skyllas-Kazacos

Auckland University of Technology
Professor Thomas Neitzert, Engineering
Associate Professor Zhan Chen

University of Waikato

Dr Brian Gabbitas, Engineering
Assoc. Professor Deliang Zhang, Engineering
Professor Alfred Sneyd, Mathematics

LMRC Team

Prof Mark Taylor	Director
Prof Jim Metson	Associate Director
David Cotton	Technical Manager
Marcus Gustafsson	Research Scientist, Computer Modelling and Control
Jenny Lee Roper	Office and Industry Coordinator
Dr Stian Madshus	Post Doctoral Fellow
Dr Zhang Wei	Post Doctoral Fellow
Tatyana Groutso	Research Scientist - XRD and Metallurgical
Professor NaiJun Zhou	Honorary Visiting Researcher
Ian Paine	Business Development Manager – LAM
Dr Jimmy Bester	Manager – NZ Manufacturing
Simon Oakley	Research Engineer
Eng Fui Siew	Research Engineer
David Wong	Research Engineer
Yashuang Gao	Research Engineer
Serguei Panov	Research Engineer
Ronny Etzion	Doctoral Researcher
Rob Wallace	Doctoral Researcher
Pablo Navarro	Doctoral Researcher
Sankar Namboothiri	Doctoral Researcher
Gaurav Tandon	Doctoral Researcher
Chuong Nguyen	Doctoral Researcher
Marco Stam	Doctoral Researcher
Maryam Al Jallaf	Doctoral Researcher
Mark Cooksey	Doctoral Researcher
Nic Pennington	Master of Engineering – Manufacturing Projects
Gaya Bulasinghali	Master of Engineering – Smelter Design and Control
Derek Seret	Master of Engineering – Smelter Design and Control
Nick Depree	Master of Engineering – Smelter Design and Control
Vishesh	Project Student, Chem + Mat Eng
Alex Hughes	Project Student, Chem + Mat Eng
David Lazarus	Project Student, Chem +Mat.Eng.
Heidi Lim	Project Student, Chem + Mat.Eng.
Liren Li	Project Student, Chemistry
Commencing 2006:	
Najeeba Aljabri	ME – Superheat Control (February.)
Abdulla Zarouni	ME – Large Cell Instability (April)
Haiam Abbas	PhD – Large Building Ventilation
Mr Tang	Honorary Research Fellow (SAMI)
Mr Sun	Honorary Research Fellow (SAMI)

Summary of Centre Activities

The Light Metals Research Centre is a UniServices managed centre, hosted by the Faculty of Science, and both Science and Engineering Faculties are contributing strongly to the Centre's activities by participating in its increasing range of research projects.

2005 has been another year of growth for the Centre, which now comprises more than 25 full time researchers.

Thanks to the efforts of the Centre's staff, and those of the participating members within University Departments, the Centre has delivered some important results in 2005. In addition, and after an ahead of plan year in 2004, the Centre's financial performance in 2005 was strong – with a Revenue of $2.8m and a surplus of $341,000.

A highlight of the year were the Centre's educational contributions

- Teaching a large group of staff from the Gulf smelters – this was a one week course in Smelter Operations and Technology fundamentals. The project required collaboration with University of Bahrain and the Aluminium Company of Bahrain and may have further benefits in the future on a UoA scale in the Gulf region.
- Holding a Short Course in Smelter Control at the TMS Annual Meeting in San Francisco. This one day course attracted over 40 people from industry and academia and was the best attended of the TMS Short Courses this year.
- The Centre Director was asked to lecture for a week at the TMS Aluminium Smelter Technology Course in Knoxville, Tennessee, which is run every two years and involves a group of world experts in smelting. Sixty people participated from around the world.
- A number of Centre members were also asked to present keynote addresses to conferences in Bahrain, and … and also to serve as Session Chairpersons for the TMS Annual Meeting in 2005.

One challenge for the Centre is to build on the FRST contract to grow the NZ business now through strategic partnerships with NZ companies. This work has begun with several companies – ADL, Hamilton Jet, Fletchers AL, Glucina Alloys, CentraCast and Axiam Group.

Centre contracts and finances were both managed very well by UniServices in 2005, with the information provided to the Director and management team being timely and detailed enough to keep the many contracts and the overall Centre margin on track. This is an essential requirement for successful operation of research centres within the University.

Lastly, and as in 2004, 20% of the Centre's surplus has been accrued as a dividend for the Faculties in which the Centre operates – Science and Engineering.

In 2006 a number of LMRC courses will be run at the University itself, including research and operational workshops in various specialised fields. The Postgraduate Certificate in Light Metals Reduction Technology will also be run in the second semester of 2006.

Several personal highlights were also registered during 2005 including

- Promotion of the Associate Director Jim Metson to Professor, and soon after to HOD Chemistry.
- The award of the James Cook Scholarship to Professor Wei Gao in the Chemical and Materials Engineering Department.

R+D highlights were many during the year as a number of technologies near their industrial testing stages and some fundamental process insights were gained. In particular

- Planning began for the testing at Boyne Smelters in Australia of the University's new heat exchange and heat recovery technology for furnaces
- Three patents were applied for in heat exchanger, process control and alumina manufacturing technologies, one of which is entering its final stages.
- Journal publications by the Centre came out in *Aluminium* and in the new *APT journal* , along with other international journals. All of these journals are important communication and technology disclosure vehicles for the light metals and materials community internationally. A significant number of TMS papers were also produced by the Centre members and other publications as listed below.
- Several novel electrowinning processes were tested in the laboratories of LMRC and may prove to be viable alternatives to the present energy intensive and environmentally undesirable industrial processes. These will be pursued in 2006.
- Casting, extrusion and surface finishing technologies continued to be developed under the FRST grant which commenced in 2004. Several new processes for surface finishing and control of surface structure and composition are emerging from this project in Objectives 1 and 2, and may be available for prototyping in 2006.
- Fundamental research in the areas of alumina structure and processing, and intelligent control of complex processes have been advanced in 2005 and are now attracting industrial interest from international companies. Funding for both areas should increase in 2006.
- Titanium and magnesium related projects have started to become important for LMRC in 2005, but in their primary production rather than their downstream processing and properties. The titanium smelting work is developing into a significant research project with a large multi-national company in 2006.
- New smelting company support contracts were commenced in 2005 for companies in Germany, Holland, USA and China, along with additional contracts with Dubal in the UAE. Further work with Aluminium Bahrain (Alba) has also become a strong possibility by the end of the year.

As foreshadowed in last year's annual report, a Senior Research Scientist – NZ Manufacturing was employed early in 2005. This role has assisted greatly in growing a successful NZ-based research portfolio at the higher technology end of light metals manufacturing – specifically in casting of high value marine and automotive products. Two new contracts of this type were secured with innovative NZ companies in 2005. The New Zealand research portfolio is important for the long term future of LMRC as it moves towards achieving its potential as a major research institute in New Zealand – as tabled with the UniServices Board in April 2004.

The increase in technology support projects has justified the employment of three research engineers in the last three months, all from the Department of Chemical and Materials Engineering, and one of whom is in the final stages of completing his doctorate.

Placement of the Centre's two Post Doctoral Researchers onto permanent contracts is another step taken at the end of 2005 and early 2006 to safeguard and grow the Centre's intellectual capacity as it matures.

In 2006 an intensive industry-focused R+D training programme is planned at the Centre – both for LMRC staff and participants from international companies who are working with, or wish to work with LMRC.

Papers Delivered

In 2005 a number of papers were delivered to international conferences by members of the LMRC. These papers are as follows:

1. M Hyland and P Patel, ”Electrolytic Carbide Wear of Cathodes” CARBOMAT Symposium, SINTEF/NTNU, Trondheim, Norway, Sept 17, 2005
2. M. Hyland and J Metson, "Applications of Synchrotron Radiation in Aluminium Reduction Technology” Canadian Chemistry Conference, Bancroft Symposium, Saskatoon, Canada, May 30, 2005.
3. M. Hyland, “Environmental Control: Fluoride Emissions”, REGAL Annual Meeting, Laval University, Quebec City, Canada, May 27, 2005.
4. M. Hyland and M Taylor, “Potroom Dust Survey”, Aluminium and Alumina Health & Hygiene Workshop, Gladstone, Queensland, May 16, 2005.

Publications List

In addition to the published versions of the above presentations, the following papers have been published:

Journal Articles, refereed

1. Evan W Andrews , Mark P Taylor, Greg L Johnson, Ian Coad, The Impact of Anode Cover Control and Anode Assembly Design on Reduction Cell Performance – Part 2, *TMS Light Metals*, pp. (2005). Delivered by M.P. Taylor.
2. Mark P Taylor and John JJ Chen, Advances in Process Control for Aluminium Smelters, *APPA05 (2005),*Bahrain
3. John JJ Chen and Mark P Taylor, Fluid Mechanics in a Metallurgical Reactor with particular reference to the Aluminium Reduction Cell, *APPA05* (2005), Bahrain
4. Taylor M.P., Chen J.J.J. Manufacturing Control for Aluminium Smelters. *APT Aluminium* – Process & Product Technology, Vol. 2, Issue 1, 44-52. (ISSN 1745-0330)
5. Chen J.J.J., Taylor M.P. Control of Temperature and Aluminium Fluoride in Aluminium Reduction. Aluminium, Intl. *Journal of Industry, Research and Applications*, Vo. 81, (7/8), 678-682, 2005. (ISSN0002-6689).
6. Gadd, M.D., Taylor, M.P., Welch, B.J., Heat Transfer and the Effect of Additives in Cryolitic Melts, *Metallurgical and Materials Transactions B*, in press
7. M. Glucina and M Hyland “Laboratory-scale performance of a binary CuAl alloy as an anode for aluminium electrowinning. In Press, *Corrosion Science*. Accepted October 2005.
8. F. Budde, B.J. Ruck, A. Koo, S. Granville, H.J.Trodahl, A. Bittar, G.V. Williams, M.J. Ariza, B. Bonnet, D.J.Jones, J.B. Metson, S. Rubanov, P. Munroe, P. Stabilization of amorphous GaN by oxygen. *Journal of Applied Physics* 98(6), p. (2005).
9. J.B.Metson. Seeing Things in a New Light: Synchrotron Science and the Australian Synchrotron Project. *Chemistry in New Zealand.* 69(4), p. 2-9 (2005).
10. T. Moriga, M. Mikawa Y. Sakakibara, Y. Misaki, K. Murai, I. Nakabayashi, K. Tominaga and J.B. Metson. Effects of introduction of argon on structural and transparent conducting properties of ZnO–In_2O_3 thin films prepared by pulsed laser deposition. *Thin Solid Films.* 486, (1-2), p.53-57, (2005).
11. J. Lee, W. Gao, Z. Li, M. Hodgson, J. Metson, H. Gong and U. Pal. Sputtered deposited nanocrystalline ZnO films: A correlation between electrical, optical and microstructural properties. *Applied Physics A.* 80**,** p 1641-1646 (2005).
12. S. Verdier, S. Delalande, N. Van der Laak, J. Metson and F. Dalard. Monochromatised X-ray Photoelectron Spectrometry of the AM60 magnesium Alloy after Treatments in Fluoride based Ti and Zr Solutions. *Surface and Interface Analysis.* 37, p.509-516 (2005).
13. J.B. Metson, B.J.Ruck, U.D.Lanke, F.Budde, *H.J.Trodahl and A.Bittar. Characterisation of Amorphous GaN Films. *Applied Surface Science* 244, Issues 1-4, p. 264-268, (2005).
14. G.Xiong, K.B.Ucer, R.T.Williams, J.Lee, D.Bhattacharyya, J. Metson and P. Evans. Donor-Acceptor Pair Luminescence of Nitrogen Implanted ZnO single Crystal. J of *Applied Physics*, 97(4**)**, 1 (2005).

Refereed Conference Proceeding

1. Evan W Andrews , Mark P Taylor, Greg L Johnson, Ian Coad, The Impact of Anode Cover Control and Anode Assembly Design on Reduction Cell Performance – Part 2, *TMS Light Metals*, pp. (2005). Delivered by M.P. Taylor.
2. Chen J.J.J. & Nilmani M. An analysis of impeller performance based on an air-water model *Light Metals*, pp. 911-914, 2005.
3. Taylor M.P., Chen J.J.J. (Invited Keynote Paper) Advances in Process Control for Aluminium Smelter. *2nd APPA 2005, International Conference on Advances in Production and Processing of Aluminium*, 5-7 December 2005, Bahrain.
4. Chen J.J.J., Taylor M.P. (Invited Keynote Paper). Fluid mechanics in a metallurgical reactor with particular reference to the aluminium reduction cell. *2nd APPA 2005, International Conference on Advances in Production and Processing of Aluminium*, 5-7 December 2005, Bahrain
5. S iew E.F., Ireland-Hay T., Theobald-Stephens G., Chen J.J.J. & Taylor M.P. A study of the fundamentals of pothole formation. *Light Metals*, pp. 763-769, 2005.
6. M. Hyland and M.P. Taylor, "Origins and Effects of Potroom Dust', *Light Metals 2005*, Edited by Halvor Kvande TMS (The Minerals, Metals & Materials Society), 141-145, 2005
7. J Metson, M.M. Hyland and T. Groutso, "Alumina Phase Distribution, Structural Hydroxyl and Performance of Smelter Grade Aluminas in the Reduction Cell." *Light Metals 2005*, Edited by Halvor Kvande TMS (The Minerals, Metals & Materials Society), 127-131, 2005
8. M. Glucina and M. Hyland, "Laboratory Scale Testing of Aluminium Bronze as an Inert Anode for Aluminium Electrolysis", *Light Metals 2005*, Edited by Halvor Kvande TMS (The Minerals, Metals & Materials Society), 523-528, 2005
9. Hiltmann, P. Patel and M. Hyland, "Influence of Internal Structure on Behaviour During Electrolysis Part I: Properties of Graphitic and Graphitised Material.", *Light Metals 2005*, Edited by Halvor Kvande TMS (The Minerals, Metals & Materials Society), 751-765, 2005
10. P. Patel and M. Hyland, F. Hiltmann, "Influence of Internal Structure on Behaviour During Electrolysis Part II: Porosity and Wear Mechanisms in Graphitised Cathode Material." *Light Metals 2005*, Edited by Halvor Kvande TMS (The Minerals, Metals & Materials Society), 756-762, 2005
11. T. Moriga, T. Sakamoto, S. Takashi, R. Saki, K. Murai, I. Nakabayashi, J.B. Metson, *Physica Scripta*, T (0281-1847); Volume: T115; p. 312-313 (2005)
12. J. Lee, J. Metson, P. Evans, and D. Bhattacharyya. Effects of implantation on microstructure and properties of ZnO thin films. *International SAMPE Symposium and Exhibition (2005), 50 (New Horizons for Materials and Processing Technologies)*, p.2255-2262. (2005).
13. J. B. Metson, M. M. Hyland and T. Groutso. Alumina Phase Distribution, Structural Hydroxyl And Performance Of Smelter Grade Aluminas In The Reduction Cell. *Light Metals 2005 Edited by Halvor Kvande.* The Minerals, Metals & Materials Society, p.127-131, (2005).
14. J. Lee, W. Gao, Z. Li, M. Hodgson, A. Asadov and J. Metson Microstructure And Properties Of Annealed Zinc Oxide Thin Films Deposited By Magnetron Sputtering. *Acta Metall. Sin.(English Letters)* Volume: 18 (3). p.177-183, 2005 ISSN: 1006-7191

Technical Reports

1. M.M.Hyland, "Final Report on Potroom Dust Scoping Study", September 2004
2. Tandon G., Taylor M.P., Chen J.J.J., Peterson R., & Moran K. The voltage behaviour and control on NZAS Cell 52(CCS Bar-Breaker) (Nov-Dec 2004): A Preliminary Analysis UniServices Report to New Zealand Aluminium Smelters, 13 pp. January 2005
3. Siew E.F. & Chen J.J.J. "The wear behaviour of cathodes in aluminium smelting cells – Pothole graphitisation relationship" UniServices Report to Comalco Aluminium Ltd. E9218, 27 pp. August 2005.
4. Siew E.F. & Chen J.J.J. "The wear behaviour of cathodes in aluminium smelting cells – Neural Network Analysis" UniServices Report to Comalco Aluminium Ltd. E9218, 36 pp. August 2005.

5. R. Etzion, J.B. Metson, M.P. Taylor. Update on in-cell trials of a range of SNBSC refractories: 7pp. November 2005. No. 1029500
6. J.B.Metson and M.M.Hyland. Organics in Bayer Gibbsite. 16pp. October 2005. No. 1117500
7. S. Oakley, M. Taylor, J. Metson. Pedersen Process Development update: 8pp. September 2005, No. 1134500
8. S.Panov, J.B.Metson. A Technology for High grade Titania Production – Report #2. 11 pp. August 2005. No. 11760.00
9. S.Panov, J.B.Metson Chemical Processing of Westport Ilmenite to Obtain a High Grade Titania Product. 23pp. July 2005. No. 11760.00
10. J.B.Metson and M.M.Hyland. Organics in Bayer Gibbsite – Progress Report. 9pp. May 2005. No. 1117500
11. R. Etzion, J.B. Metson, M.P. Taylor. LIRR Progress Report May 2005: 11 pp. May 2005 No. 1029500.
12. R. Etzion, J.B. Metson, M.P. Taylor. LIRR Progress Report April. 8pp. April 2005 No. 102950

2006 Plan

Context

The Centre's portfolio of contracts is now quite extensive as the 2006 Plan Revenue Statement indicates. While it is always important to generate new contracts for the future, we are for the first time in a position where the full year ahead has sufficient work planned to maintain the Centre's activity at a high level – and in fact extra staff have been employed.

In 2006 therefore the Centre will focus on two things primarily:
1. Delivery of the existing research contracts at a high level.
2. Training of staff to increase the capability of the organisation as a whole, for the future.

Research Targets

2006 sees several technologies come to the point of commercial testing:
- Design of a prototype heat exchanger for reduction cell walls (Comalco PhD project)
- Design of a new refractory materials test for Silicon carbide (LIRR, PhD project)
- Control of bath composition at Boyne Smelters.
- In-cell dry scrubbing and calcination of alumina (RUSAL)
- Testing of new anodising technology for cast components and products in New Zealand.

In addition to these technologies, the more pervasive and long range research directions continue:
- Advanced control and sensing of thermal balance in reduction cells (Aluar PhD, Dubal and Heraeus Electronite projects)
- Potroom dust fingerprinting and causation (Alcoa, BHPB and Comalco)
- Understanding of the cathode wear mechanisms at work in the Cathode Testing apparatus in the Centre (SEC and SGL).
- Saving cell voltage at NZAS, in the face of rapidly escalating power price and limited availability.
- Surface behaviour investigations for specific cast and extruded aluminium and magnesium alloys which can increase the market for existing and new components.
- Demonstrations of new multivariate, intelligent control techniques across a broad range of industries, possibly sponsored by a NERF Grant and incorporating researchers from a number of different disciplines and Departments within the University.
- Analysis and improvement of the control of high pressure die casting of aluminium to prevent scrap generation and potentially improve product quality for critical applications.

- A process and material design pathway which will allow the use of hydrogen to replace carbon as the main reductant for alumina in the production of aluminium.

New research challenges for 2006 are:

- The design of a different alumina production process, which is inherently lower cost.
- Use of new materials technology to improve the life of graphitised cathodes (Dubal Potlife project and SEC cathode mechanisms project).
- The design of carbon anodes using materials which are more sustainable than used at present – including new pitch materials and filler carbons. (CSIRO Light Metals Flagship Cluster project)

Twelve postgraduate students are members of the LMRC team, and this will increase to fifteen in the first three months of 2006. A somewhat more structured approach to project management is being introduced in 2006 to manage the number of projects now being undertaken and to ensure that adequate time continues to be devoted to the supervision of the above postgraduate researchers.