

UNIVERSITY OF TECHNOLOGY, SYDNEY: FACULTY OF DESIGN, ARCHITECTURE AND BUILDING
MASTER OF DESIGN (BY THESIS)

A study of the Design Considerations and Emerging Technologies in the area of Major Surgical Lighting



Sinclair Park

JUNE 2007

CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Production Note:

Signature removed prior to publication.

Signature of Candidate

Acknowledgements

Firstly I would like to thank my supervisor, Associate Professor Douglas Tomkin for his gentle support, astute guidance and wholehearted encouragement.

I thank Brett Iggulden of Planet Lighting for his support and guidance, and his invaluable knowledge of the medical lighting industry. I would also like to acknowledge Dave Kavanah, whose ideas were the original starting point for this research.

John and Elizabeth Cowley of Fibreoptic Light-guides, for their generosity in sharing both their knowledge and their time, and their kind support over many years.

Dr. Hadrian Fraval, Managing Director of Rofin Australia, for his knowledge in the area of liquid light-guides and light-guide light sources.

Lester Partridge, Nathan Groenhout, Dr Daniel Ellerman and Bassett Applied Research for their assistance in the production of the Computational Fluid Dynamics images that have enabled me to test my ideas, describe some very complex interactions and produce some exciting conclusions, as well as add a bit of colour to an otherwise monochrome text.

Stuart Clifton of SC Medical, Kathy Barkovic of Berchtold Pacific, and Frank Clarkson, biomedical engineer at RPA for sharing their wealth of knowledge and experience in the area of surgical lighting.

And last, but not at all least, I would like to thank my wife Kathryn, for her loving support, encouragement and endless patience.

Contents

Title Page	I
Certificate	ii
Acknowledgement	iii
Table of Contents	iv
List of Illustrations	vi
Glossary	viii
1. Abstract	ix
2. Introduction	1
3. Background and Context	3
3.1. General Literature	3
3.1.1. Literature produced by governing bodies	3
3.1.2. Literature produced by private or independent sources	3
3.1.3. Manufacturers' sales literature	3
3.2. Design Related Literature	4
3.3. Hygiene	4
3.4. Safety, general	4
3.5. Retinal damage to patient and staff	5
3.6. Photo-toxicity (UVB, UVC)	5
3.7. Burns	5
3.8. Fire	6
3.9. The use of coloured lighting in operating procedures	6
3.10. Laminar Air Flow	6
4. Definitions and Standards	7
4.1. General	7
4.2. Requirements	8
4.2.1. Central Illuminance	8
4.2.2. Light Field diameter	8
4.2.3. Shadow dilution	8
4.2.4. Depth of Illumination	8
5. Design Issues	9
5.1. Brightness	9
5.2. Colour	10
5.2.1. Colour temperature	10
5.2.2. Colour Rendition Index (CRI)	10
5.3. Shadow control	11
5.4. Uniformity of Light	11
5.5. Maneuverability	12
5.6. Heat Management	12
5.7. IR and UV Filtering	13

5.8. Bulb Replacement	14
5.9. Hygiene	14
5.10. Cavity Illumination	15
5.11. Focus and Depth of Field	16
5.12. Integration with Laminar Air Flow theatres	17
5.12.1. Introduction	17
5.12.2. Integration	18
6. Design Opportunities	21
6.1. Protection of delicate tissues	21
6.2. Integration with L.A.F. systems	21
7. Light Guide technologies	22
7.1. Existing Products	22
7.2. Solid core vs. Liquid core	23
7.3. Light sources	23
7.4. Dangers	24
8. Proposal	24
8.1. Removing Heat Source	26
8.2. Reducing Drag	26
8.3. Less Restricted Light Source	26
8.4. More Effective Filtering	26
8.5. Spectral Distribution Adjustment	26
8.6. Automatic Spectral "Tuning"	26
8.7. Independent Adjustment of Brightness and Colour Temp.	27
8.8. Hygiene	27
8.9. Multiple Theatre Illumination	27
8.10. Reduced Weight	27
8.11. Single light source for multiple illuminators	27
9. Testing	28
10. Results	31
10.1. Streamlines	32
10.2. Vector Fields	34
10.3. Temperature Distribution	37
10.4. Speed Distribution	41
11. Conclusion	46
Appendix	47
Comparison of current products	47
Sales Brochure: Steris "DeepSite"	50
Sales Brochure: Lumitex "Bard Light"	51
Sales Brochure - Lumitex "SaphLite"	52
Sales Brochure - Lumitex "LightMat"	53
Sales Brochure: Rofin "Polilight 500"	54
Transmission Spectrum for liquid light guide	58
Transmission Spectrum for fibre optic light guide	58
Interview with Stuart Clifton of S. C. Medical	59
Interview with Frank Clarkson, Bio-medical Engineer	61
Bibliography	63

List of Illustrations

Front Cover: The Old Sick Ward of St. John's Hospital, Bruges. By Johannes Beerblock, 1778

a. Operating theatre and light dating back to 1822, St Thomas's, London.	vii
1. Circa 1900	1
2. Circa 1920	1
3. Circa 1940	1
4. Circa 1950	1
5. Circa 1970	1
6. Circa 2000	1
7. Charnley's original "greenhouse". Photo - Howorth Surgicair, 1962	17
8. Modern LAF system	18
9. Laminar/Turbulent airflow, sales document, Brandon Medical Co. Ltd.	19
10. Laminar/Turbulent boundary of Heraeus G8	
11. Proposed light guide head.	25
12. Martin 1001/Berchtold C950 computer model	28
13. Heraeus G8 computer model	29
14. Proposed "Lightguide" computer model	29
15. ML1001/C950 Streamlines	31
16. G8 Streamlines	32
17. Lightguide Streamlines	32
18. ML1001/C950 Vector Fields (side view)	33
19. ML1001/C950 Vector Fields (end view)	34
20. G8 Vector Fields (side view)	34
21. G8 Vector Fields (end view)	35
22. Lightguide Vector Fields (side view)	35
23. Lightguide Vector Fields (end view)	36
24. ML1001/C950 Temperature (lateral)	37
25. ML1001/C950 Temperature (transverse)	37
26. G8 Temperature (lateral)	38
27. G8 Temperature (transverse)	38
28. Lightguide Temperature (lateral)	39
29. Lightguide Temperature (transverse)	39
30. ML1001/C950 Speed (lateral)	40
31. ML1001/C950 Speed (transverse)	41
32. ML1001/C950 Speed (close up)	41
33. G8 Speed (lateral)	42
34. G8 Speed (transverse)	42
35. G8 Speed (close up)	43
36. Lightguide Speed (lateral)	43
37. Lightguide Speed (transverse)	44
38. Lightguide Speed (close up)	44
39. Sales Brochure: Steris "DeepSite"	49
40. Sales Brochure: Lumitex "Bard Light"	50
41. Sales Brochure - Lumitex "SaphLite"	51
42. Sales Brochure - Lumitex "LightMat"	52

43. Sales Brochure: Rofin "Polilight 500"	50
44. Transmission Spectrum for liquid light guide	57
45. Comparison of Transmission Spectrum for liquid core vs. fibre optic light	57



Figure a). Operating theatre and light dating back to 1822, St Thomas's, London.

Glossary

M.S.L.	Major Surgical Lighting
L.A.F.	Laminar Air-Flow
C.F.D.	Computational Fluid Dynamics; computer based fluid dynamics modeling
Lux (lx)	SI unit of illuminance; One lux is equal to one lumen per square metre, where 4π lumens is the total luminous flux of a light source of one candela of luminous intensity.
Photo-toxicity	harmful effects of light inc. UVB and UVC radiation
IR	Infrared
UV	Ultraviolet
CRI	Colour Rendering Index; a measure of the ability of a light source to reproduce the colors of various objects being lit by the source , developed by the International Commission on Illumination
HEPA	High Efficiency Particulate Arresting Filter; typically removing 99.97% of all air borne particles larger than 0.3 μm
OR	Operating Room
Laminar flow	fluid flow in parallel layers, with no disruption between the layers
Collimated	light with parallel rays
NA	Numerical Aperture; a dimensionless number that characterizes the range of angles over which the system can accept or emit light
Asepsis	the practice to reduce or eliminate contaminants from entering the surgical field

ABSTRACT

The basic principles of Major Surgical Lighting (M.S.L.) have not changed significantly in the last 80 years; one or more light sources located in front of a large diameter reflector(s), suspended over the patient with some ability for positioning and focus. However, over the same period, surgical procedures and methods have progressed dramatically, as have other areas of operating theatre technology.

10 There have also been many other developments in the field of general lighting technology that may be useful in M.S.L. that to date, have not been fully explored. New research was needed that looked at the design considerations of M.S.L., taking into account these advancements, exploring any challenges or opportunities they presented.

Current literature and research in the field of surgical lighting and related issues has been investigated and summarised. This research revealed that perhaps the most pressing design issue of M.S.L. has been created by advancements that have been made in other areas of Operating Theatre technology. The use of ultra clean Laminar Air-Flow (L.A.F.) systems, which have been shown to reduce post-operative infection by up to 50%, has been
20 becoming more prevalent since the technology was first introduced in the 60's. However, a number of studies have also shown that the effectiveness of any laminar flow system is severely compromised by current surgical lighting design.

This research proposes the use of flexible light-guides to enable the remote location of the light source, thereby greatly reducing both the heat output and physical disruption to any L.A.F. system. New opportunities for improvements in light delivery such as adjustable spectral distribution, and dimming with the colour temperature remaining stable are explored.

30 Computational Fluid Dynamics are used in order to compare and evaluate existing and proposed M.S.L. designs in relation to their disruption to L.A.F. systems. It is shown that the proposed light-guide system causes negligible disturbance to laminar flow when compared with current designs, therefore further reducing rates of post-operative infection.