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PUMPS AND PIPES

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Introduction

"The solution to our problems most likely lie in someone else's toolbox.
The challenge is in finding it."

A significant problem in medical technology development, and perhaps the energy business, is that developers are very in-bred — often exposed only to like-minded individuals, which in turn can prevent innovation and maturation of "out-of-the-box" ideas. We believe that great benefit may be gained by exposing cardiovascular and imaging researchers to technology currently available in the oil and gas world. Thus was created the "Pumps and Pipes" symposium, a collaboration between Houston's two most prominent industries. Pumps and Pipes is a problem-focused forum analyzing issues relevant to both the energy and medical worlds. The goal is to stimulate discussion, spark ideas and brainstorm with industry counterparts to explore complementary technologies using common language and terminology, with such themes as "Docs and Rocks," "The Other Guy's Toolkit," and "Better Together, and "No Boundaries."

Background

Cardiovascular medicine and the oil and gas industry share remarkable similarities. Both deal in the business of "pumps and pipes." Both use imaging to identify targets, navigate hollow tubes into those targets, create conduits for delivery of oil or blood, monitor and maintain those conduits, and intervene when they fail. Both consistently seek less expensive, less traumatic methods for achieving their goals. The research tools used to optimize our industries are similar as well: metallurgy, finite element analysis, computational fluid dynamics, stress testing, and search for new durable materials. Blood and oil are both non-Newtonian fluids that have remarkably similar flow characteristics. Computational fluid dynamics, a technique for analyzing how fluids flow, has been largely developed in the oil and gas business and used to optimize pipeline development. It is now emerging as a central tool in understanding the dynamics of how fluid flows in blood vessels in order to optimize device development. Indeed, one of the early Pumps and Pipes participants has evolved their CFD software for cardiovascular diagnosis. Likewise, finite element analysis extensively employed for engineering of critical pump components is now used to predict how and when aneurysms rupture.

Houston is uniquely positioned to benefit from collaboration between petroleum engineers and cardiovascular researchers, mainly because Houston's two leading industries are oil and gas, and medicine. Both industries are national and international leaders. The Texas Medical Center, a consortium of medical schools, hospitals, and universities, is the single largest medical complex in the world. Houston also remains the unequivocal energy capital of the world, housing both Exxon Mobil and Shell's largest research facilities. Although leadership crossover occurs at the board level in many medical and energy enterprises, this has not translated into a meaningful technology exchange. Houston unfortunately has virtually no medical device industry. Therefore, there is a unique opportunity for our community to integrate and leverage the synergy of these industries and technologies.

There is precedent for integrating medical and petroleum know-how with resulting business success and a

Figure 1. Lazar Greenfield, vascular surgeon

Figure 2. Garman Kimmel, oil-industry engineer, suggested an implantable filter for trapping blood clots before they can reach the lungs.

positive impact on patient welfare. One such example is the Kimray-Greenfield inferior vena cava filter that is used clinically to prevent clots passing from the legs to the lungs. Dr. Lazar Greenfield (Figure 1) was prompted by a case of pulmonary embolus in a young trauma patient. After opening the chest and performing a pulmonary embolectomy, the patient died. Dr. Greenfield sought better techniques to prevent pulmonary embolus and asked Garman Kimmell (Figure 2), an entrepreneur-inventor from the oil and gas industry, for his help. Kimmell recognized the similar problem of sludge in oil pipelines and how a conical filter trapped the sludge at its center while still allowing flow around it on the sides. Together they designed a prototype and tested it in animals before implanting it in patients in the early 1970s. The modern descendant is the stainless steel Greenfield filter that has been implanted in more than 200,000 patients to date (Figure 3).

"Great invention is always metaphor," says John Abele, a co-founder of Boston Scientific Corporation, which has manufactured the Greenfield filter since it acquired Kimmell's medical-device company in 1980. "You look at the problem, and then you try to connect it to other areas which may have nothing to do with the problem you're working on."

Figure 3. Greenfield vena cava filter.

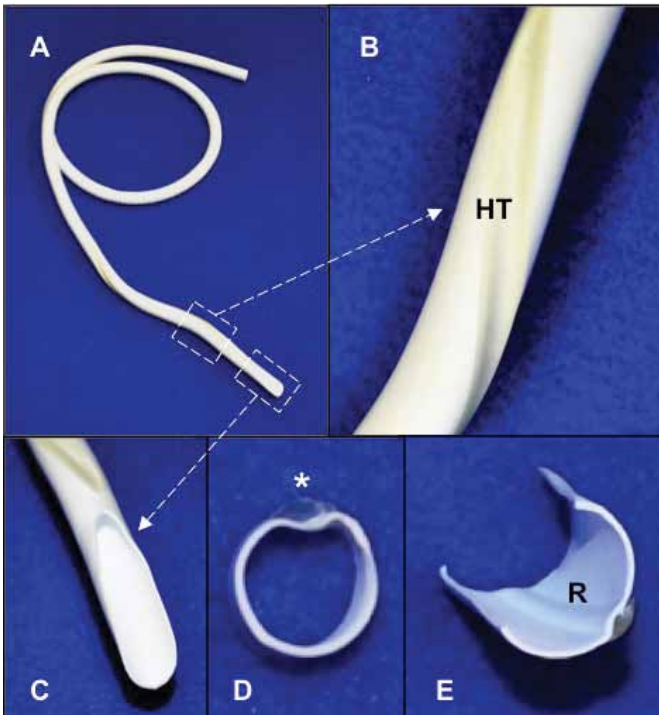

Figure 4. Spiral Flow™ Vascular Access Graft (Tayside Flow Technologies).

A. The novel graft design imparts a spiral laminar flow to the blood delivering less turbulent flow energy to the venous anastomosis site.

B. Spiral Flow Inducer consists of an injection molded polyurethane component that forms one 360° helical turn (HT) running along the outside distal end of the graft.

C. Pre-cut venous anastomosis cuff.

D. Cross-section view of Spiral Flow Inducer showing injection molded component (*).

E. Inside view of Spiral Flow Inducer showing ePTFE ridge (R) on the graft lumen that imparts a rotational force on the blood exiting the graft resulting in spiral laminar flow at the venous anastomosis site.

A Synergy of Industries

Tayside Flow Technologies, a small Scottish start-up company and participant in the Pumps and Pipes 3 Conference, has developed an artificial blood vessel that mimics naturally occurring spiral flow patterns (Figure 4), thereby improving patency of bypass grafts. The same technology is being studied to move oil through pipelines with less frictional energy loss, thereby improving efficiency. Indeed, pipeline engineers have long understood the benefits of spiral flow patterns. There are other crossovers as well. Remote monitoring, remote visualization, 3-D reconstruction of imaging data, automated data analyses, use of simulators, robotics, and quality improvement processes are all techniques common to both industries, where opportunities exist for accelerated learning.

The public was recently amazed at the clarity of visualization and the dexterity of remote-controlled robots in severing and capping the leaking blowout preventer

one mile below the ocean surface following the Deepwater Horizon disaster. Visualization, remote control, and tactile feedback are all key concepts in medical robotics. Partly as a result of Pumps and Pipes interactions, we have established the Cardiovascular Robotics Consortium at the Methodist DeBakey Heart & Vascular Center where the principles of robot-assisted surgery can be studied and developed to treat cardiovascular diseases.

The goals then of Pumps and Pipes 1, 2, 3 and 4 were to expose medical researchers and oil and gas engineers to similar technologies existing in the cardiovascular medicine and energy industries and to explore opportunities for developing "leap frog" technologies between these like industries. To do this, we provided an interdisciplinary platform to explore a series of topics of similar innovations and challenges. Each topic had a discussant from both the field of cardiovascular medicine and from numerous companies within the energy sector followed by an open discussion. Conference participants have included engineers from medical and imaging manufacturers, researchers and cardiovascular disease specialists from within the Texas Medical Center, and invited faculty with expertise in computational sciences and bioengineering from the University of Houston, Rice University, and Texas A&M University. The topics covered in the Pumps and Pipes Symposia are listed in Tables 1-3. The Pumps and Pipes conference, previously held at the University of Houston, was moved to the auditorium of the new The Methodist Hospital Research Institute building for conference 4. The conference will become international in scope and will be held next in Qatar in April 2011.

Summary

The oil and gas industry is the world's largest, with a demand for capital in excess of $150 billion each year. By collaborating with inventors, engineers, and other scientists in the oil and gas industry, medicine stands to gain from potential crossover ideas. One of the most tangible and useful outcomes of the Pumps and Pipes initiative was the widening of the researcher's collaborative network for problem solving. Like the development of the Greenfield filter, some of our medical conundrums already have solutions discovered by others. However, many of the problems medical researchers face will not have ready-made transference from the oil and gas industry. The wealth of talent in different industries can trigger profitable associations and creative solutions. Pumps and Pipes provides the forum for this collaborative brainstorming.

Section 1. Docs and Rocks Introduction and basic concepts. Let's all talk the same language
The Doc: anatomy and physiology of the cardiovascular system — Dr. Lumsden (MDHVC)
The Rock: geology and physics of hydrocarbon production — Dr. Kline, Ph.D. (Exxon Mobil)
Section 2. Hydraulics, Conduits, and Pumps Left ventricular assist devices — Dr. George Noon (MDHC) Subsurface pumps — Rodney Bane (Exxon Mobil)
Staples, glues, and stitches — William E. Cohn (Texas Heart Institute) Joints, welds, and cements — Rustom Mody (Baker Hughes Inc)
Atherosclerosis — chemical modification — Dr. Ballantyne (MDHVC) Corrosion and scale management — Gerald Brown PE (Brown Corrosion Services Inc.)
Mechanical repair of blood vessels — Dr. Neil Kleiman (MDHVC) Through tubing workovers — Li GAO, Ph.D. (Halliburton Energy Services)
Endovascular stents and stent grafts — Dr. Michael Silva Expandable casing and liners — Mark Holland (Enventure Global Technologies)
Section 3. Accessing a Target Navigating and viewing — Dr. Lumsden (MDHVC) Geo-steering a drill bit — (Schlumberger)
Atherectomy and plaque analysis — Eric Peden (MDHVC) Down hole coring and sampling — Fred Palumbo Jr. (Core Laboratories)
Section 4. Imaging and Monitoring Medical imaging — Kin Li TMH, TMHRI Oil & Gas imaging — Bruce Verwerst (Veritas DGC Inc) Medical Image Computing — Ioannis A. Kakadriadis. Ph.D.(University of Houston)
Patient monitoring online — Faisal Masud (MDHVC) Rapid flow stream analysis — Alan Schilowitz, Ph.D. (Exxon Mobil) Meeting Highlights

Table 1. Topics in Pump and Pipes 1

Welcome Renu Khator, Ph.D. —Chancellor & President (University of Houston)
My Medical Toolkit — Alan B. Lumsden, M.D. (MDHVC)
My Oilfield Toolkit — William E. Kline, Ph.D. (ExxonMobil)
My Engineering Toolkit — Ioannis A. Kakadiaris, Ph.D. (University of Houston)
Oilfield Robotics — Ruston Mody (Baker Hughes)
Pipeline Robotic Connection — Kim Breaux (Quality Connector Systems)
Medical Robotics — Nikolaos Tsekos, Ph.D. (University of Houston)
Robot-Assisted High Throughout Experimentation — Rakesh Jain (Symyx Technologies)
Use of Magnetics for Device Positioning — William Cohn, M.D. (Texas Heart Institute)
Full Field Strain Mapping — John Tyson (Trillion Optical Systems)
Practical Development of Medical Robotics — Fred Moll, M.D. (Hansen Medical)
Inside Wall Imaging — Steven Hansen (Schlumberger Global Geology)
Intravascular Imaging Catheters — Mark Davies, M.D., Ph.D. (The Methodist Hospital)
Mapping Surfaces at the Molecular Level — Dalia Yablon, Ph.D. (ExxonMobil)
(Structural) Health Monitoring Using (Vibration) Signature Changes — Kurt Steffen (ExxonMobil)
Belief Networks in Geosciences — Osama Gabber, M.D. (The Methodist Hospital)
Membranes and Filters — C. Vipulanandan (University of Houston)
Nonmaterial's: Present and Future — Alan Lumsden, M.D. (MDHVC); William E. Kline, Ph.D. (ExxonMobil); Ioannis A. Kakadiaris, Ph.D. (University of Houston)
Vision: Pumps and Pipes III and Beyond

Table 2. Topics in Pump and Pipes 2

Session I. Pumps & Circuits—Tales From The Toolbox
Indestructible Pumps—Here's the Idea… Ideas Everywhere: My P&P Clippings File — William Kline, Ph.D. (ExxonMobi) A New Idea for Supporting the Heart — Basel Ramlawi, M.D. (MDHVC)
Nanotechnology & Robotics — Fantastic Voyage Anything You Can Do, I Can Do Smaller — Li Sun, Ph.D. (University of Houstoni) I, Robot — Going New Places, Doing New Things — Jean Bismuth, M.D. (MDHVC)
Distant Monitoring & Surveillance — Reach Out & Touch Someone You Think Your Long Distance Bill is High? — William Standifird (Halliburton) Sensors: Please Call Homes — Rebecca Seidel & Steven Glinski (Medtronic)
Panel Roundtable: Pumps & Circuits — Billy Cohn, M.D. — Moderator (Texas Heart Institute) Interactive Break-out Workshops
Lunch and Guest Speaker — Joe Cunningham, M.D. (Sante' Ventures)
Session II. Pumps And Pipes — Across the Backyard Fence
Managing Imperfect Conduits — 40 Miles of Bad Roads Stent Technology: Keeping the Road Open — Michael Nilson (Gore Medical Products) Porous Media Flow: When Google Map is Not Enough — Karsten Thompson, Ph. D. (Louisiana State University)
Intelligent Conduits — Where All Conduits are Above Average Field of the Future — Bill Blosser (British Petroleum) From Blood Vessels to Pipelines — Peter Stonebridge, M.D. (Dundee University and Flow Technology, Ltd.)
Advanced Materials — The Devil Wears Prada Designer Materials I — Rustom Mody, Ph.D. (Baker Hughes) Designer Materials II — Ramanan Krishnamoorti, Ph.D. (University of Houston)
Panel Roundtable: Pipes & Fluids — Heitham Hassoun, M.D., Moderator (MDHVC) Interactive Breakout Workshops
Bringing People and Ideas Together: NSFI/UCRC on Pumps and Pipes — Ioannis Kakadiaris, Ph. D. (University of Houston) Closing Remarks — Renu Khator, Ph.D. (University of Houston Chancellor & President) Pumps & Pipes 3 Wrap–Up — William Kline, Ph.D.(ExxonMobil) & Alan Lumsden, M.D. (MDHVC)

Table 3. Topics in Pump and Pipes 3