



Key Considerations for Magnetically Actuated Valves for HF Alkylation Units by Ned Davis, PhD Maui Innovation Group Inc.





What is Alkylation

- Chemistry: Converts isobutanes and similar short chain molecules from the cracking unit into high octane gasoline components that are comprised of longer chain molecules using an acid as a catalyst
- Boosts the Value of the Outputs of a Given Refinery
 - Enables higher octane gasolines and aviation gas than could otherwise be produced
 - Cleaner Burning Resulting Product Better for the Environment
- Not all Refineries do Alkylation though In part because it is so dangerous
- Two main types of Alkylation: HF or Sulfuric Acid
 - HF is arguably much more efficient (uses far less acid for a given output), but is also more dangerous

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• And some other Alkylation processes are in R&D



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HF Units Surrounded

by Safety Curbs

HF Alkylation is Particularly Dangerous

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- Hydrofluoric Acid Penetrates Thru Living Tissue All the way to the bone
- My analogy is that contact with Hydrofluoric Acid is akin to a venomous snake bite:
 - Surface Damage / Contact Poison
 - Necrosis of Surrounding Tissue

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- Systemic Electrolytic Imbalances Potentially Even Fatal
- Clouds of Vapor from Fugitive Emissions are difficult to dissipate and can damage lungs, eyes & cause fatalities
- And the hydrocarbons being processed are explosive
- Bellows are tough to implement in this application because they are thin and the acids are so corrosive
- Carbon Steel is often employed, but then any water in the system matters much more – Enables corrosion
- Exotic alloys such as Monel are also often utilized



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Photo Courtesy of Wiki Commons

SUMMIT Magnetically Actuated Valves Can Help

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- Magnetic Valves Eliminate External Leaks and Fugitive Emissions – Bonnet can be welded shut
 - Regardless of welding, there is no moving gland seal
- Previous Incarnations of Magnetic Valves weren't suitable for HF because the magnets were inside and suitable encapsulation was difficult
- A new external magnet circuit architecture can ensure that everything touching the working fluid is made from Monel (or any desired alloy)
- Can offer extreme Reliability SIL3 in a system manner

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Our Valve Utilizes a Magnetic Circuit 2022



Employs a Flux Path from External Magnets through the Bonnet to Magnetizable Metal Core Generating Extremely High Actuation Torques or Forces on it



Return Flux Path

Magnetically Actuated Gate Valve Photo by Maui Innovation Group

- Completes a magnetic circuit much akin to an electrical circuit
- Magnets can now be External Only No Magnets Inside Valve / Bonnet to corrode, degrade, or fail
 - Everything inside the valve casing is metal!
- High Temperature Operation Now Possible As is welding the bonnet closed and welded / soldered / brazed port connections
 - Works with most existing valve topologies such as Gate, Globe, Plug, Ball, Butterfly, etc.
- Lower Cost than previous / competing magnetic valve approaches





Traditional Stem Seals Leak

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- Most Valve Leaks Occur at the Stem Seal because:
 - Inherent Differences in hardness and CTE between different materials
 - Entrained dirt, sand, grit from the surrounding environment
 - Repetitive Rotating or Sliding Motion
 - Can't control environment where the end user employs the valve or even how it is shipped
- Typically leaks at the stem seal are more serious because they lead out to the surrounding environment and people – Especially with HF

Stem Seals have been around a long time – Perhaps it's time to try a new approach...



Photo from Wiki-Commons by liz dawson / 20" gate valve - Calf Hey dam 1856 / <u>CC BY-SA 2.0</u>





Bellows Can't Eliminate Leaks



- Bellows are a path to sealed enclosures, but bellows:
 - Suffer from metal fatigue
 - Are especially problematic for larger valves with greater stem travel
 - Are expensive Often 3 10x the price of an equivalent regular valve
 - Have Pressure and Stroke Limitations
 - Have a Micro weld that has an associated leak spec Bellows are not truly zero emission even when new
 - Leakage rates get worse over time, and then eventually fail
 - Bellows May Suddenly Fail Catastrophically Especially with corrosion For Example from HF – And if the Working Fluid is Explosive too
 - Bellows have often been employed in nuclear applications Simply because there hasn't been a better alternative
 - Even back in 1997 South Korea's Atomic Energy Research Institute tried to develop a magnetic valve instead (Hwang, Choi, Kim, Choi, & Jo)



Photo By Корниенко Виктор Self-photographed, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.p hp?curid=8058215





Monel and Other Exotic Alloys are Often Needed for Severe Service such as HF Alky

- What we are able to do is to Encapsulate a Ferromagnetically Susceptible Metal Inside the Monel, Hastelloy, or Other Compatible Materials
 - Couldn't do this with previous magnetic valves because of Internal Magnets
 - Earlier Generations of our Magnetic Circuit Valves were still limited by choice of available magnetically susceptible core materials
 - But just as bonnet can be welded shut, magnetically susceptible cores can be encapsulated inside materials such as Monel.











How we Constructed a Magnetically Actuated Monel Valve



- Started w a COTS Monel Valve
- Removed Legacy Bonnet & Packing
- Enclosed a Ferromagnetic 400 series Stainless Core in a Monel Puck Welded it Shut Completely encased in Monel ullet
- Built a Closed Monel Bonnet No Gland Seal
- Held it in Place with an External Metal Ring
- Hence Everything that Contacts the Working Fluid is Monel. •
- External Magnets Now Actuate the Valve No dynamic seal / valve packing to leak















SUMMIT Other Types of HF Valves & Approaches **2022**

• Plug Valves are Often Employed in HF Alkylation

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- Existing Bonnet and Packing can be Encapsulated within a Closed Bonnet and Magnetic Actuator – Preserving all the Original Certifications of the Valve
- Internal Gland Seal Leaks will be Contained, Detected, and Mitigated within the Closed Bonnet without endangering Personnel or the Surrounding Environment







High Reliability/System Integrity Levels Now Possible **2022**

Levels such as SIL 3 and Six Sigma Now Possible – Only Our Architecture enables this type of reliability!

- Once the possibility of stem leaks is completely eliminated, multiple valves can be placed in a network to achieve any desired reliability, which could be a game changer in severe service applications such as HF!
- Traditional valves are more likely to leak if placed in series
- Bellows Valves have a micro-weld and suffer fatigue, hence would be ineffective in series
 More
 likely to fail as they cycle & age



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Magnetic Valve Position Sensors





- Valve Position can also be detected magnetically without penetrating the valve body or bonnet
 - Same high temperature performance as our magnetic actuators – Can be Welded inside if so desired







Continuous Monitoring

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- Valves Can Remotely Report their Status
 - Contain any Leaks Indefinitely Within a Secondary Bonnet
 - Notify that Repairs are ultimately needed
 - Warn service personnel of any interstitial build up of working fluid Especially in hazardous or lethal service applications like HF
 - Rotork has a gearbox with an outer packing and rupture disk already on the market
 - With magnetic actuation, working fluid could be contained indefinitely









Linear Actuation

- Seals on Sliding Stem Valves are potentially even more prone to entrainment, damage, and leakage than rotary seals
- Horizontal Mounting, Transport, & Actuator Installation Damaging
- Bellows suffer from fatigue & leaks
- Most pertinent prior linear magnetic valve is shown in Heard, Fernbaugh, & Nobles 1991 Patent 5,039,061
- We can support far higher forces than previous approaches
- We Have Patent #62/653,963 Pending for an improved Higher Force Sliding Stem / Linear Actuation Mechanism



Photo from Maui Innovation Group

Both Drawings from Heard, Fernbaugh, & Nobles' 1991 Patent 5.039,061





Large Valves Requiring Very High Actuation Forces are Addressable



While our magnetic actuator architecture scales up quite well, extremely large magnets (for example the size of bricks) tend to be expensive – Luckily there are other approaches that can be used to actuate larger valves:

Travelling Nuts, Worm Gears, and Finer Lead Screws are all potential solutions for larger valves and are covered by our patent applications

Actuators can be geared up to accomplish the same amount of work on the valve element for a given torque by rotating the coupling itself faster

We can optimize across a trade space of actuator size, cost, torque, rotational speed, and ohmic damping (wasted induced electrical energy)





Patented Asymmetric Actuation



Able to back out of the seat if valve gets stuck – for example after being closed a long time or with a sticky working fluid:

- Forward torque is limited by design to the specified seating torque of the valve
- Reverse torque is allowed to exceed forward seating torque by a specified percentage – Typically 20%





Cheater Handles



Customers in some applications like to employ cheater handles when valves are badly stuck:

- Since our magnets are only located in the external portion of the actuator, a "Super Handle" can be made with larger / stronger / more expensive magnets
- If all else fails, a cheater handle port can be utilized if incorporated:
 - Ordinarily a Static Sealed port is kept closed or could even be brazed shut / or contained under a punch-out cap until needed
 - The access port is only opened when needed for the Cheater Handle Dynamic Seal not exposed under normal operating conditions (like in John Oliver's 1994 Patent)







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Legacy Valve Magnetic Actuation Upgrade Option / Retrofit Kit



- Upgrades legacy valves to magnetic actuation without altering original design certifications
- Could be offered as a zero leak option or upgrade for new valve sales
- Can Repair / Convert Existing Valves to Leakproof Magnetic Actuation Even While in Operation / Without Shutting Down a Process Line
- Encloses original Bonnet and Gland Seal resulting in Zero Emissions without any further maintenance, repacking, tightening, or testing required
- Cost Effective \$60 worth of parts can keep a whole process line running
- Works with existing valve topologies such as Gate, Globe, Plug, Ball, Butterfly, etc.





Magnetic Actuation Can Improve Control Valve Operation too

- Stem Friction causes Dead Band in Control Valves
- Teflon Seals have low dynamic friction, but still exhibit high static breakaway friction
- Magnetic Actuation Offers:
 - Extremely low break away friction
 - Predictable, consistent, repeatable ohmic damping in place of dynamic friction
 - Zero leaks Much Safer and better the environment
 - Extremely broad temperature range
 - Essentially unlimited operational life
 - Zero maintenance



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Solid Model by Maui Innovation Group





History of Magnetic Valves

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Allure of Magnetic Valves Goes Way Back:

- Patents date from1942! And reappear every decade in between 1940's, 50's, 60's, 70's, 80's, 90's, and continue to the present day:
 - All previous magnetic valves had magnets inside the bonnet Limiting them to low temperature benign applications and precluding welding, brazing or soldering bonnet or ports
 - Magnets prior to the advent of Neodymium Iron Boron generally not powerful enough or too exotic / expensive / brittle to be practical for most valve applications
 - Some relied on very expensive, exotic, and brittle High Temperature Samarium Cobalt magnets to meet temperature specs once those were available
 - Neodymium magnets have temperature limitations
 - And all need access to the magnets for installation and servicing hence static seals are still required
 - Our Patents are Unique and Better than all Previous Approaches!
 - Enables high temperature operation and welded, brazed, or soldered bonnet and ports
 - And prevents stuck valves



July 14, 1942. R. G. CARLEO Filed June 19, 194 Jig.1 JE9.2. RalphG. Carlso

Image from Ralph Carlson's 1942 Patent at Crane Valves US Patent #2,289,574



What's New – Our Patents:

- Magnetic Flux Actuator US Patent 9,797,521 Issued October 2017
- Asymmetric Actuator US Patent 10,151,403 Issued December 2018
- High Speed Actuation Mechanism US Patent 10,221,959 Issued March 2019
- Manual Override Patent US Patent 10,487,959 Issued November 2019
- Valve Actuation Conversion Kit US Patent 11,047,499 Issued June 2021
- Sliding Stem / Linear Actuation US Patent 11,067,190 Issued July 2021
- Magnetic Valve Position Sensor & Indicator System US Patent Pending
- Lethal and Severe Service Magnetic Valve US Patent Pending
- Additional patents pending that we can discuss in more depth privately



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- Other Lethal Service Applications: Sour Gas H₂S, Semiconductors, etc.
- Steam Valves: Steam leaks may not be visible near source Can be fatal
- Nuclear Valves: Usually Bellows Now But they have Fatigue Life Issues
- Cryogenic Valves: Often also benefit from autoclave cleaning
- Eliminate Fugitive Emissions: Reduces pollution & compliance issues
 - Equivalent to 72 Million Tons of CO₂ Released into the Atmosphere Every Year!
- Reduced Maintenance: Permanently sealed / No stem seal maintenance
- Higher Reliability / Availability Enables Six-Sigma / SIL3 Valve Networks
- Rotary Couplings for Pumps and Compressors: No Shaft Seals, Higher Temperatures & Better Material Compatibility than previous couplings

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- Sweat / soldered, Threaded, Flanged, and other connections
- Gate, Globe, Plug, Ball, Butterfly... Valves
- Stainless, Brass, Copper, Plastic
- Hermetically Sealed / Welded Bonnets
 - Or Statically Sealed Bonnet (access for service)
- Handles, Actuators, Motors, Levers...
- Pareto's Principle likely applies 80% of the value lies with 20% of the values
- All have No Stem Seal to Leak!
 - 80% of leaks are at Stem Seal







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Magnetic Valves Can Now Succeed! 2022

- Modern Neodymium Iron Boron Magnets are Extremely Powerful and Affordable – Very Cost Effective
 - Magnets are Strong Enough that they can now be used just on the outside
- Novel Architecture No Magnets Inside the Valve
 - This approach employs a smaller quantity (half as many) of more affordable, less exotic, magnets –outside the bonnet
 - Nothing inside valve casing to corrode, degrade, or fail Can Address HF!
- High Temperature Operation Now Possible
- Enables Welded / Soldered / Brazed Bonnet & Port Connections
 - Production handle could even be pyrolytic carbon for API 607 rated valves
- Asymmetric Operation and Cheater Handles Prevent Stuck Valves
- Performance is Better and Cost is lower than previous magnetic valve approaches





Magnetically Actuated Gate Valve by Maui Innovation Group







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