Gaseous Chlorine & Its Alternatives
Webcast 1-3 pm eastern time
June 19, 2007

Welcome and Introduction
Diane VanDe Hei
AMWA Executive Director
Housekeeping

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- To ask a question of a speaker/panelist, press the chat icon at the top left corner of the webcast screen and type in the “message” box and send. Responses will be provided verbally as time allows and in writing after the webcast.

- Please indicate whom your question is for. All webcast participants will be able to see these questions.

- The moderator will review the submitted questions and pose them to the speakers/panelists. Most questions will be posed after the presentations are complete during the panel discussion.
Polling Q&A, AMWA Website Postings & Other Background Information

- Polling questions throughout the webcast - Please answer them quickly with your “best” choice.
- Polling and Q&A responses compiled (with no utility identifiers) after the webcast.
- Copies of slides and speaker bios with contact information are posted on AMWA website.
- May contact speakers or AMWA for additional background materials and references.
Polling A. & B.
Who’s attending today?

Acknowledgments & Disclaimers
Information from a variety of sources has been built upon for this webcast and background materials.

Mention of specific utilities is not meant to represent any one entity as the sole, or predominant, expert in any particular topic area or technology. Opinions expressed are those of the speakers.

Mention, or omission, of vendors or trade names in this presentation does not constitute endorsement, or non-endorsement, of any process or product.

All those considering new technologies, or working to optimize existing applications, can benefit from consulting a variety of sources and references.
Question: What are impacts of conversion from chlorine gas to hypochlorite?

- Increased capital & operations cost, maintenance concerns/complexity, equipment failures (leaks, clogs in lines/tanks/pumps), chemical QC.
- Benefits = Reduced risk, no RMP

Percent of AMWA members:
- Total response (~15%)
- Chlorine (29%)
- Bulk hypo (67%)
- On-site (17%)

Percent of Respondents:

Chlorine Forms, Sources, Volume:

- **Onsite Generated**
  - Gas
  - Liquid ~12%
  - Liquid ~0.8%

- **Commerically produced**
  - Gas
  - Solids
  - Liquid ~12%

*all measured as, and chemically active as, chlorine.*
Chlorine Gas Decision Tool

• Tool developed by National Association of Clean Water Agencies (NACWA) for the Department of Homeland Security.

• Series of Excel spreadsheets and formulas, to identify disinfection priorities (e.g., reliability, safety) and rate disinfection alternatives.

• Provides a cost-benefit analysis for the alternatives based on the agency-specific information such as chemical costs.

• Utility managers may request a CD on NACWA’s website - http://www.nacwa.org/clcd.cfm.

• For additional information on the Tool, please contact NACWA’s Chris Hornback at 202/833-9106 or chornback@nacwa.org.

Polling C-1, C-2. & D.
What chlorine disinfectants do you apply?
What other disinfectants do you apply?
CONVERSION TO SODIUM HYPOCHLORITE: NKWD

Northern Kentucky Water District

Ron Lovan
President and CEO

Bari Joslyn
VP, Water Quality Production

NORTHERN KENTUCKY WATER DISTRICT

- 3 surface water treatment plants
- 44 MGD: Ohio River
- 10 MGD: Ohio River
- 10 MGD: Licking River
- 15 booster pumping stations
- 4 booster chlorine stations
- 19 water storage tanks
- Serves population of > 250,000
Raw Water

River Intake / Pump Station

Reservoirs

Rapid Mix

Basins

Filters

Clearwell

choline

Residuals
WHAT WERE WE DOING?

- Ton chlorine gas cylinders at all 3 treatment plants
- 150 pound cylinders at 3 booster chlorine stations, ton cylinders at 1 station
- Plant effluent of 1.5 - 2.0 mg/L free chlorine
- Maintain system chlorine residual of 1.0 mg/L
WHY CHANGE?

- Plants in residential areas, one next to a school
- 2 of 4 booster chlorine stations in residential areas
- Accidental release at booster chlorine station
- Disaster drills were a disaster
- Avoid use of scrubber systems

WHAT DID WE DO?

- Converted gas chlorine to liquid sodium hypochlorite:
  1998 - 10 MGD plant
  1998 – booster stations
  2000 - 44 MGD
  2003 - 10 MGD plant
ADVANTAGES

• Safer for operators and public: transport, delivery, containment, cleanup
• Readily available in most markets
• Scrubbers not needed
• Our insurance carrier loves it
• Risk Management Program not needed

DISADVANTAGES

• Cannot use Cl₂ feed systems for NaOCl
• More frequent deliveries, more storage area
  (1 ton chlorine cylinder = 2000 gallons sodium hypo)
• Vapor-locking (O₂ production)
• Incompatible with most materials - corrosive
• Ball valves can explode
• Mixing with other chemicals can be catastrophic
• Scaling
• Increased expenses
UNEXPECTED

- pH impact more than anticipated
- Contamination of bulk chemical
- Perception of safety for staff
- Increased maintenance (3X)

ANNUAL CHEMICAL COSTS

10 billion gallons water/year

- Sodium hypo: $0.59/gallon $206,000
- Chlorine (gas): $0.25/pound $87,500
- Caustic soda: $1.132/gallon $85,000

At a 50% decrease in caustic use, sodium hypochlorite increases costs by $33,500 or 13%
SUGGESTIONS FOR STARTING FROM SCRATCH

- Use peristaltic pumps
- Insure feed pumps have degassing valves
- Place feed pumps below tank level
- Use diaphragm valves instead of ball valves
- Install flushing equipment on system
- Minimize number of connections

SUGGESTIONS, CONT’D

- Use CPVC
- Install pH meters for indication of stability (faster decomposition below pH 11)
- Key chemical delivery stations differently
- Do not eliminate gas until sodium hypo is working
- Get references on vendors, require training
- Be prepared to change operating procedures
CONCLUSIONS

• Be prepared for increased maintenance
• We made the right decision

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• or www.nkywater.org

Conversion to Liquid Sodium Hypochlorite - EBMUD

East Bay Municipal Utility District

Richard Sykes
Manager of Maintenance and Construction
Summary

- Public demands elimination of chlorine gas at facilities located in urban areas
- Hypochlorite has higher initial capital and ongoing operation and maintenance costs
- A properly designed hypochlorite system can be operated without difficulty
- Filtered hypochlorite supply eliminates/minimizes many operation and maintenance problems
- Workers feel better protected without chlorine gas being used

East Bay Municipal Utility District

- Water and Wastewater Utility on the East Side of San Francisco Bay
- Six Surface Water Treatment Plants
  - Capacities from 25 to 200 MGD
- Two 300 MGD Aqueduct Disinfection Stations
- One 420 MGD Wastewater Treatment Plant
- 125 Water Pumping Plants
- 170 Water Storage Reservoirs
- Serves Population of over 1.3 million
Gaseous Chlorine Facilities before Conversion

- Aqueduct and water treatment plants use gaseous chlorine in ton cylinders; some plants had chlorine gas containment and scrubbers
- Used pressure and vacuum chlorine gas feed systems
- Wastewater plant used chlorine delivered in 90-ton rail cars
- Never had chlorine gas leak beyond plant ground

Reasons for Conversion

- Increased public aversion to use and storage of toxic chemicals in the community
- EBMUD water treatment plants located in residential neighborhoods
- Worker health and safety
- Increased toxics control and response regulations
- Standardization of facilities and equipment
- Conversion timing triggered by rehabilitation and upgrade projects
Road to Hypochlorite Conversion at Water Plants

- 1986-- Established a capital improvement project, water treatment improvements program to modernize all of the water treatment plants

- Late 1980’s, three water treatment plants were renovated and gas chlorine scrubbers were a part of the improvements

Road to Hypochlorite Conversion (Cont’d)

- 1991– Draft EIR circulated for improvements to our largest water treatment plant
- Draft EIR included construction of chlorine gas containment and gas scrubbers
- Public and neighbors strongly objected to the proposed continued delivery and use of chlorine gas at the plant
- Offsite consequence analysis projected up to 17,000 people potentially affected in a chlorine cylinder leak
- Decision made to select liquid sodium hypochlorite as disinfectant for Orinda plant in the WTIP
Road to Hypochlorite Conversion (Cont’d)

• 1995—A Water Treatment Chlorination Improvements Master Plan was prepared for the remaining raw water chemical feed and water treatment plants to reduce risk of hazardous chemical exposure to public and staff, and minimize regulatory restrictions on storage and use of toxic chemicals.

Road to Hypochlorite Conversion (Cont’d)

• 1995 Master Plan recommended replacement of gaseous chlorine with hypochlorite as the form of chlorine disinfectant

• In 1998 Hypochlorite systems were completed for the aqueducts and all water treatment plants
Conversion at Wastewater Plant

- Process Safety Management Plan for wastewater treatment plant indicated significant offsite consequences of catastrophic leak for 90-ton rail car
- Substantial residential/commercial development downwind
- Decision in 1995 to convert to sodium hypochlorite
- Conversion completed in 1997

Lessons Learned from Conversion to Hypochlorite

- Higher initial capital and recurring replacement costs for hypochlorite storage facility than gaseous chlorine facility
- Higher chemical cost for hypochlorite
- More maintenance intensive
- More chemical truck deliveries
Lessons learned from Conversion

- Hypochlorite degrades during storage (time, temperature). Good bulk chemical inventory needed to manage shelf life and to minimize chlorate formed as a result of the degradation.

- Unfiltered hypochlorite supply had impurities that tended to cause precipitates that plugged pipe, and degassing problem that caused air lock in feed pumps. Problems reduced significantly after improving the material purchasing specifications requiring filtered hypochlorite supply.

Pumps
Polling E & F
Experiences with Hypochlorite Solutions

Self-Generated 12% Sodium Hypochlorite -- DMWW

Des Moines Water Works
Des Moines, Iowa

Dr. L.D. McMullen
CEO and General Manager
Alternatives to Chlorine Gas Feed:

– Rebuild existing feed system.

– Commercial Sodium Hypochlorite (NaOCl).

– On-site generation of Sodium Hypochlorite (NaOCl) – 12.5% or 0.8%.

Why produce sodium hypochlorite on-site?

• Need to upgrade the existing disinfection system – equipment, piping, controls.

• Safety concerns with existing chlorine gas pressure system:
  – Potential leaks – tanks and feed equipment.
  – Storage and handling of chlorine containers.
  – Increased plant security in recent times.

• Increasing cost for chlorine gas – 10% to 33%.
Salt Dissolver (Brine Tank) and Dust Collector

Brine Treatment Unit
DC Rectifiers

Electrolyzer/Membrane Unit
Sodium Hypochlorite Conversion Unit

Sodium Hypochlorite Delivery System
Equipment and Installation Costs

- 1,500 gpd generator in form of parallel 750 gpd generation units.
  - Generation Equipment @ $415k
  - Generation Equipment Install @ $335k
  - Storage/Delivery System Equipment @ $85k
  - Delivery System Install @ $80k

- For this presentation, our total equipment and install costs are $915k.

Start-Up/Commissioning/Oct. ’03

- The Good
  - Generates good disinfectant. As of May of 2007 DMWW has used over 580,000 gallons of the product.
  - We specified several control modes.
  - We specified a high level of automation.
  - We are familiar with several system components.
  - We are still learning and gaining knowledge.
Start-Up/Commissioning/Oct. ’03

• Challenges/Hurdles
  • System endures extreme temperatures; Expansion/contraction within system has brought some nagging leaks.
  • Cold weather required addition of a brine heater.
  • Operation in warmer weather may require some additional cooling.
  • Automation and alarming improvements are still planned.

Maintenance Costs

Recent Water Production Maint. Costs

• 2005 $34,646/yr
• 2006 $23,335/yr
Parting Comments /Questions

- It has been a struggle, but we feel we’ve made it over some critical hurdles in the last half of 2004.
- Goals now are to find ways to increase annual production.
  - Can we use this product at some of our remote sites?
  - Can we find utilities within the area who might want bulk hypochlorite?
  - WP intends to investigate issues related to transportation (permits) and stability of the hypochlorite product (sunlight exposure, temperature, and pH are factors).
- Thank you for your time.

Evaluation of Alternative to Containerized Gaseous Chlorine

Long Beach Water Department
Long Beach, California

Kevin Wattier
General Manager

Dr. Robert Cheng
Deputy GM of Operations
Long Beach Water Department

- California’s 5th most populous city (~500,000 residents)
- 70,000 AF of drinking water per year
- 8,000 AF of reclaimed water per year
- 900+ miles of drinking water lines
- 750+ miles of sewer lines
- Operate largest GW treatment plant in US

Disinfection

Treatment Plant Capacity: 62.5 MGD

- Up to 40 x 1-ton cylinders stored
- Deliveries up to 2X per week
Disinfectant Alternatives Consideration

Water quality (DBP formation not an issue)

Cost of alternatives to containerized chlorine
- Cost depends on factors included
- On a strict $ basis, is still the least-costly disinfectant

Issues associated with chlorine cylinders
- Transport
- Storage/Handling
- Reporting

Safety and Security

Release will affect airport, freeway, businesses, and homes
Disinfection Alternatives

- Gas chlorine (current practice)
- On-site gas generation (NaCl needed)
- On-site hypochlorite generation (high strength, NaCl needed)
- Bulk hypochlorite delivery
- On-site hypochlorite generation (low strength, NaCl needed)
- Chlorine Dioxide (various generation)

Generation Process

**Cl₂ gas generation**

\[ 2\text{NaCl} + 2\text{H}_2\text{O} + \text{power} \Rightarrow \text{Cl}_2(g) + 2\text{NaOH} + \text{H}_2(g) \]

**NaOCl (hypochlorite) generation**

\[ 2\text{NaOH} + \text{Cl}_2 \Rightarrow \text{NaCl} + \text{NaOCl} + \text{H}_2\text{O} \]
Existing Chlorine Application

Using On-Site Chlorine Generation
Evaluation Approach

1. Phase 1 (2004, on-going)
   - Initial Trial of 700 ppd Unit

2. Phase 2 (2007)
   - Trial Test 1,500 ppd unit with improvements from Phase 1

3. Phase 3 (If Phase 2 is successful)
   - Full plant conversion, 6,000 ppd

Phase 1 Trial Test
Evaluation


Operation Period

Total Operating Days 534
Total Days Non-Operational 207

Chemical Production

Chlorine (lbs) 92,950
Caustic (lbs) 104,848
Salt (lbs) (268,540)
Hydrochloric Acid (lbs) (13,442)
Sodium Bisulfite (lbs) (4,544)

Power Consumption (6/22/05 - 8/19/05)
Estimated Long Term Power (kWhr) 38,909
Chlorine Production (lbs) 20,913
Power Used for Ancillary Equipment (manufacturer's est) 13,013
Power to Chlorine Ratio 1.86

Evaluation

Factor Actual
Percentage of Non-Operation 39%
Salt to Chlorine Ratio 2.89
Long Term Power to Chlorine Ratio 1.86

Cost Analysis

Factor Unit Cost Total Cost
Recovered Caustic (dry weight) $ 519.90 Ton $ 21,122.75
Salt $ (159.00) Ton $ (21,348.93)
Hydrochloric Acid $ (0.16) lbs $ (2,150.66)
Sodium Bisulfite $ (2.90) gallon $ (1,187.94)
Power $ (0.14) kWhr $ (25,429.64)

Cost per Ton of Chlorine Produced (2005 $) $ (623.87)
Summary of Experience

On-site gas generation least-cost alternative

Trial shows Cl$_2$ can be generated as needed

System reliability can be improved
- Generation cells reliable
- Ancillary equipment were primary causes of shutdown
- Work needed on limiting moisture in produced gas
- Operation labor minimal when operating, but maintenance may be high due to materials issues

Conclusions

System is promising, additional evaluation is warranted

Further work includes
- Improvements on systems materials
- Cost optimization (reducing salt consumption)

Full-scale implementation will include production and storage of 12.5% hypochlorite in addition to gas (disinfection reliability)
Take Home Message

Technology evaluated provides another alternative to the use of containerized gaseous chlorine.

Tempe, AZ On-Site Generation of 0.8% Sodium Hypochlorite

City of Tempe, Arizona
Don Hawkes, Water Utilities Manager
Brad Fuller, South Tempe Treatment Plant Lead
Goals of Tempe’s Gaseous Cl₂ Alternatives Study

• Meet current and future regulations
• Reduce vulnerability/improve safety
• Select a reasonably cost-effective alternative
• Technology implemented for both WTPs
Selected On-Site Generated NaOCl

**Pros**
- Removes vulnerability of gaseous Cl2
- Low concentration: no degradation or off-gassing
- Allows retrofit of existing chlorine facility

**Cons**
- Hydrogen gas by-product
- Higher O&M costs
NaOCl Design Criteria

• NaOCl Generator Design Dosages
  – Average: 1.8 mg/L for virus and residual
  – Maximum: 4.0 mg/L

• NaOCl Generator Equipment Redundancy: 100%

• One Salt/Brine Tank:
  – 30 day storage @ max dose, max flow

• Two NaOCl Day Tanks:
  – 24 hour storage @ max dose, max flow

• Feed Pumps: One pump/feedpoint & one standby

NaOCl System Set-Up

• STWTP
  – One 40 ton brine tank
  – Two 2,250 ppd generators
  – Two 18,000 gallon NaOCl day tanks
  – Six 6.8 gph metering pumps
  – Six 600 scfm blowers
  – Two chillers
  – Three water softeners

• JGMWTP
  – One 60 ton brine tank
  – Two 3,000 ppd generators
  – Two 22,500 gallon NaOCl day tanks
  – Six 10.4 gph metering pumps
  – Six 600 scfm blowers
  – Two chillers
  – Three water Softeners
NaOCl System Costs

- STWTP
  - Capital cost: $2,725,000
  - Annual O&M: $71,000

- JGMWTP
  - Capital cost: $1,935,000
  - Annual O&M: $111,000
Summary

• Increased O&M cost, but greatly reduced vulnerability, improved safety
• Easily fit each new process on the plant sites
  – Retrofit existing chlorine buildings for NaOCl
• Very reliable and stable systems

QUESTIONS?
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City of Tempe, STWTP Team Lead
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SNWA On-Site Generation of 0.8% Sodium Hypochlorite

Southern Nevada Water Authority
Henderson, Nevada

David J. Rexing
Water Quality Research and Development Manager

Key Points of Webcast Topic

• Infrastructure

• Disinfection Practices

• Chlorination Facilities

• Regulatory, Environmental and Security

• Future Options
Infrastructure

- 900 Million Gallons per Day (MGD) Capacity
- Treatment Facilities
  - Alfred Merritt Smith – Built in 1970, 600 MGD
  - River Mountain – Built in 2002, 300 MGD
- 30 Pumping Facilities
- Distribution
  - 164 Miles of Pipeline
  - 36 Metering Stations

Chemical Feed Systems

- Oxygen Purification
- Ozone Generation
- Ferric Chloride
- Polymers
- Sulfuric Acid
- Caustic (NaOH)
- Hydrofluosilicic Acid
- Zinc Ortho Phosphate
- Chlorination
- Liquid Ammonia
- Calcium Thiosulfate
- Liquid Oxygen
- Salt
Chlorination Systems

• Chlorine Gas System

• On-site Electrolytic Chlorination
  0.85% NaOCL

• Sodium Hypochlorite 12% NaOCL

On-Site Electrolytic Chlorination (OSEC) Major Components

• Salt/Brine Storage Tanks
• Power Supply/Rectifiers
• Electrolyzers
• Local and Master Control Panels
• Sodium Hypochlorite Day Tanks
• Hydrogen Blowers
• Hydrogen Gas Detectors
• Sodium Hypochlorite Feed System (Pumps, Piping, Valves, Meters)
• Water Softening System
• Manufactured Product
<table>
<thead>
<tr>
<th>Sodium Hypochlorite Generation Building</th>
<th>Salt / Brine Storage Pits</th>
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<tr>
<td>Water Softeners</td>
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<tr>
<td>OSEC Power Supply/Rectifiers</td>
<td>Sodium Hypochlorite Electrolyzers</td>
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Chemical Regulatory Requirements

- Process Safety Management (PSM)
- Chemical Action Prevention Program (CAPP)
- Risk Management Plan (RMP)
Security

• Security onsite 24/7, 2-3 Officers per Shift

• 24/7 Camera Surveillance / Security Command Center

• Secured Buildings / Badge Entry

System Information

• Weekly Chemical Delivery
  – 500 MGD Production

• Gas
  – Chlorine 4.0 loads/wk

• OSEC
  – Salt 10 loads/wk

• Cost
  – Cl₂ $0.20/lb
  – OSEC $0.27/lb

• Stats
  – 3.2 lbs salt per lb of chlorine
  – 1.8 KWH per lb of chlorine
  – 15 gal soft water per lb chlorine
## System Evaluation

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<th>Chlorine</th>
<th>OSEC</th>
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<tr>
<td><strong>Positive</strong></td>
<td>• Reliable&lt;br&gt;• Simple&lt;br&gt;• Purchased Product</td>
<td>• Low Risk</td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td>• High Risk&lt;br&gt;• Regulatory Requirements&lt;br&gt;• High Level of Security&lt;br&gt;• Transportation Risks</td>
<td>• Manufactured Product&lt;br&gt;• High Maintenance&lt;br&gt;• Water Treatment System&lt;br&gt;• Process Quality Control&lt;br&gt;• Limited Storage</td>
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## Future Considerations

- Conversion of Chlorine System to OSEC
- Capital Investment $40 - $60 million
- Site Restriction 17 Acres
- Cost Increase $530,000/year
- Park Service Requirement
- Transportation Risks
- Public Input
Mixed Oxidant Research & Applications

• What it is not…
• \((O_3, \text{ClO}_2, \text{H}_2\text{O}_2)\)
• What is it?
  – DHS Research
    Miami University of Ohio
    University of North Carolina
    Montana State University
  – Superior Disinfection
  – Biofilm Control
  – Enhanced Residual
  – Reduced TTHMs
  – Micro-flocculation

Known Benefits
Mixed-Oxidant Advantages

Department of Homeland Security Research

• Four main thrusts to study MIOX as replacement technology for chlorine gas
  – Speciation – Identification of the components in the mixed-oxidant solution (MOS)
    • Dr. Gilbert Gordon, Miami University of Ohio
    • Dr. Howard Weinberg, University of North Carolina
  – Biofilm reduction studies
    • Dr. Anne Camper, Center for Biofilm Engineering at Montana State University
  – \textit{Cryptosporidium parvum} inactivation studies
  – Electrolytic cell coating optimization
Biofilm removal → more durable residual @ 30% Cl dose reduction

Disinfection By-Products
Mixed Oxidants reduce TTHM formation by up to 50%

**DBP Reductions with Mixed Oxidants**

- **MCL for TTHMs**
- **Chlorine THMs**
- **MIOX THMs**

**Prestonsburg**
Kentucky
Installation
1000lb/day
FAC
Mixed Oxidant Solution (MOS)

- Lower % sodium hypo (~0.4%), more power intensive, different electrolytic cell, dose measured as free available chlorine.
- Effective biocide -- kills bacteria, viruses, *Giardia* and *Cryptosporidium* (CT tables expected in near future)
- Hand-held MO disinfection units used by US Military and sold commercially.
- Free chlorine must be present for MO to be present (won’t work/occur with just chloramine—may be an alternative to chloramine, particularly for small to medium sized applications).

Polling G & H
Experiences with Onsite Generation
Panel Q&A

- We will now ask our speakers and panelists to respond to some of your questions.

To ask a question of a speaker/panelist, press the chat icon at the top left corner of the webcast screen. Type your question in the lower message box and hit send. Please indicate whom your question is for. All webcast participants will be able to see these questions.

We will pause to do our summary polling Q&A as we get close to scheduled end time - but our speakers and panelists will be staying online after that to continue answering questions for a while longer as needed.
Polling I, J & K
Chlorine “drivers,” status and plans

Operator Certification
Continuing Education Credit

If attendees want to apply for operator certification credits for this webcast, the materials, here, along with webcast slides, are provided for you to use in requesting approvals from your individual state. You will need arrange approvals and/or methods of documentation of attendance of persons at your site according to your state’s requirements. You may contact AMWA’s Michael Arceneaux at arceneaux@amwa.net or (202)331-2820, if your state needs more information about your site registration or webcast content.
THANK YOU

• Sharing of information between front-end users of technologies, particularly in times of regulatory and technological change, is absolutely necessary for systems to make their best possible applications & operations choices.
• We hope you have found this interesting useful.
• Thanks to all those who have shared information and experiences for this webcast!

Back to Panel Q&A

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THANK YOU

• *Parting wisdom* – using new technology and making changes *(or not)* -- while ensuring safety and security….
  – Know what you want.
  – Say what you want.
  – Get what you want.
  – Do what you do very well.

• Thanks again, to all who have shared information and experiences and thank you for joining!