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Benchmarking Chlorine Safety Practices in the Water and Wastewater Industry

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ABSTRACT

Less than six percent of the total chlorine production in the U.S. is used for disinfecting drinking water and wastewater. However, this segment of the industry is responsible for the operation and maintenance of more than seventy-five percent of the sites exceeding the Risk Management Program (RMP) threshold level of 2,500 pounds for chlorine gas. This group also represents approximately twenty-one percent of the total RMP facilities that are currently listed by the Environmental Protection Agency (EPA).
This paper reports on the development of benchmarks to characterize "best-in-class" operation and management practices for chlorine safety within the water and wastewater industry. A set of "straw man" chlorine safety benchmarks was developed by the author, from a review of more than one hundred water industry RMP narratives and a survey of thirty water and wastewater utilities. Using a Delphi expert panel review procedure the set of "straw man" benchmarks is now being modified and prioritized to identify operational and management practices that should be emphasized within the water industry to reduce community risks associated with chlorine use at more than 5,000 sites in the U.S

Benchmarking Chlorine Safety Practices In the Water and Wastewater Industry

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Abstract

Less than six percent[XX] of the total chlorine production in the U.S. is used for disinfecting drinking water and wastewater. However, this segment of the industry is responsible for the operation and maintenance of more than seventy-five percent of the sites exceeding the Risk Management Program (RMP) threshold level of 2,500 pounds for chlorine gas. This group also represents approximately twenty-one percent of the total RMP facilities that are currently listed by the Environmental Protection Agency (EPA).

This paper reports the development of benchmarks to characterize "best-in-class" operation and management practices for chlorine safety within the water and wastewater industry. A set of "straw man" chlorine safety benchmarks was developed by the author, through a review of more than one hundred water industry RMP narratives and a survey of thirty water and wastewater utilities. Using a Delphi expert panel review procedure, the set of "straw man" benchmarks is now being modified and prioritized to identify operational and management practices that should be emphasized within the water industry to reduce community risks associated with chlorine use at more than 5,000 sites in the U.S.

[X] Unless otherwise noted, all opinions expressed in this paper are those of the author, and do not necessarily represent official positions or policies of the San Antonio Water System or the Bexar County Local Emergency Planning Committee.

[XX] Estimate includes all forms of chlorine disinfectants including gaseous chlorine, sodium hypochlorite, and calcium hypochlorite. In the U.S., about 4.4% of gaseous chlorine is used by the water treatment industry.

Prior to the Environmental Protection Agency's (EPA) implementation of the Risk Management Program (RMP), the water and wastewater treatment industry could be described as the Rodney Dangerfield of the worldwide chlorine economy: "Not getting much respect and largely ignored." On a global and national level the amount of chlorine used by the water industry is small when compared to other industries. Of an estimated 47 million tons of chlorine produced worldwide each year approximately 4 % is used for water and wastewater disinfection.[1] In the U.S., total chlorine production has been estimated at 14 million tons with about 0.6 million tons (4.4%) used by the water industry.[2]

Thanks to EPA and RMP, chlorine use in the water and wastewater industry has begun to receive more attention and get more respect. In communities with few or no chemical processing industries, the local water utility may account for 100 % of the total chlorine gas used. In San Antonio, Texas, about 60 % of the 414,500 lbs of chlorine reported under RMP is managed by the water industry. In comparison, water utilities in College Station, Texas are responsible for managing 100% of the chlorine reported in the local RMP database.

When EPA was first unveiling Section 112 (r) of the Clean Air Act and calling it a "risk management program", some of us in the water and wastewater industry were thinking, "*This sounds like something you only have to worry about if you're in an air pollution non-attainment area*." Boy - were we wrong.[3] Fortunately the San Antonio Water System (SAWS) was invited to participate in a project to develop an RMP guidance manual for the drinking water industry. Roy Weston, Inc., conducted this project, which was sponsored by the American Water Works Association Research Foundation (AWWARF).

At this time, EPA was publishing new RMP implementation guidance nearly every month. Attempting to incorporate the latest regulatory guidelines and interpretations made the RMP guidance manual a moving target. In spite of the ever-changing regulatory environment AWWARF was able to complete the guidance manual prior to the June 21, 1999 RMP deadline. By participating in the AWWARF project, SAWS was able to evaluate all of its chlorinating facilities and meet the RMP deadline ahead of schedule.

If benchmarking can be defined simply as, "*a comparison of an organization's performance to what others are doing*," then RMP has been a continuous benchmarking journey for SAWS. Our first adventures in "RMP benchmarking" could better be described as a "gut-check" to see what other industries were doing.

After reading a 1997 article titled, *Are You Ready for Risk Management Plan*[4], I contacted the author, Hubert Hall, Water Production Superintendent for Corpus Christi, Texas to find out why a Corpus Christi water utility was on the cutting edge of RMP. The answer was simple, the *Nueces County Local Emergency Planning Committee*

(LEPC). Hubert provided copies of chemical safety booklets and a HAZMAT videotape prepared by their LEPC.

Armed with glossy, three-colored RMP leaflets and videotapes, I sought out and found our County LEPC. I didn't find any three-colored glossy leaflets or videotapes. What I did find was a wealth of HAZMAT experts, responders and other local RMP partners such as the HEB grocery chain and Exxon, to name a few. Our first "gut-check" benchmark comparison with other local industries was short and simple:

Early Gut-Check RMP Comparison

- ✓ About 25 local industries are expected to register 50 RMP facilities.
- ✓ We will need to register 15 of our facilities using chlorine.
- ✓ The Nueces County LEPC annual budget is about $100,000.
- ✓ Our Bexar County LEPC annual budget is less than $10,000.

Up until the June 21, 1999 deadline we continued to work with other local industries and the Bexar County LEPC. Our LEPC even formed an RMP subcommittee and created a mascot known as "HAZMAT Bear" to promote community HAZMAT awareness. We also continued to check and compare to see what other members of the water industry were doing.

A 1998 Circa Gut-Check RMP Benchmark Report

- ✓ They have 1 RMP site with 180 tons of chlorine. We have 15 RMP sites with 2 tons of chlorine at each site.
- ✓ They plan to use partial-fill to stay under the 2,500 lb threshold to avoid RMP.
- ✓ They plan to switch from ton containers to 150 lb cylinders to avoid RMP.
- ✓ They plan to switch to sodium hypochlorite (bleach) to avoid RMP.

To compare our chlorine-related operational and maintenance procedures with others in the water industry, we contacted thirty other utilities and requested information on the level of personnel protective equipment (PPE) used and copies of standard operating procedures (SOPs). The majority of facilities contacted had detailed SOPs and required extensive PPE when working on chlorine feed systems. Only two of the facilities contacted did not require operators to use any PPE when connecting containers to chlorine gas feed systems (see Table One).

On June 22, 1999, local RMP industries in Bexar County breathed a sigh of relief - now that the deadline was past, we could take it easy. Our sigh of relief was short-lived. On August 5, 1999, EPA issued the good news for the propane industry, which also included an – *"Oh, by the way"* – *"Other RMP facilities must hold a public meeting (roll-out) to discuss worst-case scenarios and also send a notification letter to the FBI."* [5] Our LEPC RMP subcommittee was quickly revived. A quick gut-check was performed to see what others were doing for their RMP Rollout.

Gut-Check on RMP Roll-Outs

- ✓ Lake Charles RMP roll-out greeted with zeal and enthusiasm.
- ✓ Local meetings to discuss hazardous sparsely attended.
- ✓ Washington DC spends $40,000 for RMP roll-outs –few attend.
- ✓ Chemical roll-out alarms and scares general public.

With lessons learned from this gut-check of RMP rollouts, the Bexar County LEPC began planning a Public Forum and HAZMAT Information Fair. Our LEPC Chairperson recommended using HAZMAT Bear to make the public "*HAZMAT Aware*" instead of "*HAZMAT Scared.*" RMP industries contributed more than $5,000 to promote the HAZMAT Bear Program.

The Bexar County HAZMAT Public Forum and RMP Information Fair was held with *HAZMAT Bear* as the star attraction during February 2000. More than 80 persons representing local elected officials, community groups, HAZMAT responders, regulatory agencies and industries attended. One attendee, representing a local neighborhood group aptly described public concerns, *"It's not the industries who are here that I am worried about – it's the ones who are not here."*

As soon as RMP reports became available for public review, it was apparent that the water industry operated a high percentage of the facilities meeting the reporting threshold. It was also apparent that the water industry was at the top of the list in terms of the number of accidents reported. When the RMP database was queried on July 4, 2001, twenty-two percent (22%) of the total sites were operated by either water or wastewater treatment facilities. In Texas, thirty-two (32%) of the RMP sites were managed by the water industry and on a local level, forty-nine (49%) of the RMP sites in Bexar County were operated by water utilities.

When only those facilities using gaseous chlorine were considered, the percentage operated by the water industry was even greater. Of the 4,327 RMP facilities reporting the use of chlorine, 3,268 (76%) were operated by the water industry. In Texas, water utilities operated 79% of the 564 industries reporting the use of chlorine, while in Bexar County water utilities operated 89% of the total RMP chlorine facilities. This same trend can be observed in nearly every community and state (see Table Two).

Since worst-case accident release scenarios had to be analyzed for RMP, we attempted to find examples for comparison and lessons learned. In 1978, a 50-ton chlorine release during a train derailment in Youngstown, Florida, resulted in 114 injuries requiring hospitalization and 8 fatalities.[6] For gaseous chlorine, Youngstown may represent the worst-case accident in the U.S. in terms of morbidity and mortality.

In terms of the amount of material released, the record may go to a 70-ton chlorine accident at an industrial site in Henderson, Nevada in 1991. Morbidity and mortality statistics were quite different than the Youngstown derailment even though Las Vega, Nevada was located less than ten miles from the accident site. No fatalities occurred, and injuries requiring hospitalization totaled about thirty. [7] In 1996, a train derailment releasing 65 tons of chlorine occurred in Montana. This accident resulted in one fatality due to injuries in the derailment and nine chlorine related injuries requiring hospitalization. Monetary damage for the derailment was reported to have been $3.9 million.[8]

A review of chemical accidents reported in the news media and in various governmental databases also placed chlorine at the top of the list.[9] [10] [11] [12] In terms of the number of facilities reporting chemical accidents, water supply and sewage treatment facilities tend to be at the top of the list, typically in second or third place. Our own gut-check efforts to benchmark chlorine gas accidents prior to RMP indicated that while chlorine "gas" was being reported in a large number of chemical accident reports, gaseous chlorine only accounted for about 30 to 40 percent of the total. Other chlorine products such as commercial sodium hypochlorite (bleach), household sodium hypochlorite, calcium hypochlorite and chlorine dioxide accounted for the other 70 to 60 percent.

Thanks to the efforts of EPA's Chemical Emergency Preparedness and Prevention Office (CEPPO), epidemiological techniques are now being used to analyze the RMP database. This public health approach to analyzing RMP data is helping to better characterize community risk associated with the use of chlorine as well as other hazardous materials.

When reported accidents are viewed in terms of the number of accidents per process year, chlorine gas falls from second on the list to number thirteen. With EPA using a public health approach to analyze RMP reports, water supply facilities were found to experience 0.011 accidents per process year. Sewage treatment facilities were slightly higher experiencing 0.013 accidents per process year. With the application of public health tools, water supply and sewage treatment facilities fell from number 2 and 3 on the list to number 24 and 22, respectively. [13] While a water utility might want to benchmark against the 0.011 accidents per process year, the only acceptable benchmark target for chlorine accidents is zero.

There has been a lot of discussion and debate related to RMP worst-case analysis and "vulnerability zones". It is interesting to note the RMP 40 CFR 68 Final Rule does not specifically define the term "vulnerability zone". Definitions found in the literature range from; "*zone of vulnerability in which people could be hurt or killed*"; "*the area in which people would be at risk of serious injury or death* "; to "*the area that could be impacted by a release of a regulated substance depending upon wind direction and other meteorological conditions*."

There have been some suggestions for using RMP worst-case vulnerability zone information for comparing and even benchmarking chemical risk in a community. Caution should be used when using RMP vulnerability zone information for benchmarking community risk. Given the choice, in which of the following communities would you rather live: community (A) with no RMP vulnerability zones; community (B) with 6 RMP vulnerability zones; or community (C) with 15 RMP vulnerability zones? In this example, community (C) might be your best choice. Community (A) is Youngstown, Florida, the site of the 1978 train derailment; community (B) is Bellingham, Washington, the site of the 1999 pipeline tragedy; and community (C) is Corpus Christi, Texas, with one of the best trained HAZMAT response teams in the country.

Using vulnerability zone benchmarks to compare public facility (schools, health care, theaters) risk within a community should also be used with caution. For example; is school (A) located in an RMP vulnerability zone of a facility using one-ton chlorine gas containers at greater risk that school (B) which is not located in an RMP vulnerability zone? By requesting the LEPC to conduct a "community hazard analysis" we might find that while school (B) is not within an RMP zone of concern; it is located directly adjacent to a swimming pool using two 150-lb chlorine containers. Without additional site-specific information, this type of comparison would not have much meaning.

In the above example, if the one-ton containers of chlorine are equipped with vacuum regulators and the 150-lb cylinders are only equipped with yolk adapters, school (B) might be perceived as being at greater risk. The LEPC's Community Hazard Analysis might also show that school (B) is located near a designated HAZMAT transportation route, or that school (A) has a major natural gas transmission pipeline at the north end of the property and is adjacent to a railroad shipping twelve 90-ton rail cars of chlorine on a monthly basis.

There have been success stories in reducing worst-case vulnerability zones. Surveys of wastewater disinfection practices conducted by the Water Environment Federation (WEF) shows a steady decline in the use of chlorine gas for this segment of the industry. In 1979, WEF reported that 90.4% of the wastewater facilities surveyed were using chlorine gas compared to 4.5% using sodium hypochlorite and none reporting the use of UV. By 1996, only 62.7% of the facilities surveyed reported using chlorine gas compared to 13.8% using sodium hypochlorite and 13.5% using UV.[14] An LEPC in Northeast Ohio has implemented a program to officially recognize wastewater treatment facilities and other industries for their risk reduction efforts.[15]

Reducing chemical inventory or changing processes may not always reduce community risk. Without analyzing "life-cycle-risk, " unanticipated consequences, similar to the current MTBE dilemma, may result. The Chlorine Gas Disinfection Association (CGDA) has reported that some chlorine facilities have used management strategies such as partial filling of ton containers or converting from one-ton containers to 150-lb cylinders to stay below the RMP threshold. Benchmarking chlorine inventories at 2,499 lbs per process to avoid RMP may eliminate a vulnerability zone on a map, but it may also increase the number of times that critical operational procedures must be performed.

Other water utilities have elected to convert from gaseous chlorine to commercial grade sodium hypochlorite (bleach) having 10% to 15% available chlorine. At first glance, this change would appear to reduce community risk. Neglecting life-cycle-risk analysis may result in a community replacing several one-ton containers used by a local water utility with a 90-ton rail car of chlorine gas at a new a commercial bleach manufacturing facility in another part of town. A life-cycle-risk approach might also indicate that transporting chlorine gas in DOT containers twelve times a year is less risk than transporting 50,000 gallons of commercial grade bleach on a weekly basis.

Some utilities have elected to convert to the on-site generation of 0.8% sodium hypochlorite. The typical on-site generation process requires about 3 lbs of salt and 2.5 kWh of electrical power to produce one pound of chlorine for disinfection. To replace gaseous chlorine for a 10 million gallon a day water treatment plant would require more than 91,000 pounds of salt and nearly 76,000 kWh hours of electrical power a year. On-site generation should be seriously considered when life cycle analysis shows that this option will not result in unanticipated water quality problems, energy demand problems or an overall increase in negative environmental impacts.

In making process changes, water utilities should keep in mind that all chemical disinfectants (liquefied gas, sodium hypochlorite and calcium hypochlorite) are hazardous when safety precautions and risk management are neglected. Life-cycle-analysis can help to determine if community risk is actually reduced or simply transferred from one part of town to another part of town. Since the RMP deadline in 1999, the U.S. Chemical Safety Board and other agencies have reported several incidents involving injuries and evacuations by water utilities using sodium hypochlorite and on-site generation. Unfortunately, these facilities are not in the RMP database and may not receive the same level of analysis.

The RMP database can also provide a wealth of other information that can be used for comparing current operational practices to what others are doing in the industry. This summer 100 RMP reports were reviewed to compare chlorine inventories, operational controls and emergency response planning. This "gut-check" comparison with other RMP facilities will be used in making continuous improvements in our current water disinfection practices.

While a lot of attention is now being focused on those facilities in the RPM database, keep in mind that RMP represents only the tip of the iceberg. The RMP database does not include utilities having chlorine inventories under the 2,500-lb threshold. The CGDA has estimated that there are about 10,000 one-ton containers users and up to 90,000 150-lb cylinder users in the U.S. [16] This is quite different than the 3,268 water utilities currently registered under RMP.

In any discussion of water disinfection practices, one set of benchmarks that must be kept in mind is the number of waterborne diseases experienced in this country prior to the use of chlorine. In the early 1900s, the water industry was challenged with reducing morbidity and mortality from waterborne diseases. Since chlorine was first used for disinfection, mortality due to typhoid and other waterborne diseases has fallen to nearly zero. With the recognition of Cryptosporidium and other chlorine resistant agents as valid public health threats we can expect changes in disinfection practices and technology within the water industry. Hopefully, process safety and life-cycle-analysis will be an integral part of engineering designs for these new disinfection technologies.

For now, we can expect chlorine (gas, sodium hypochlorite and calcium hypochlorite) to be the disinfection method of choice for the majority of the water industry. It is somewhat ironic that the same epidemiological techniques, which convinced public policy makers in the early 1900's that chlorine disinfection of public water supplies was a necessity, are now being used to help policy makers to reduce community risk associated with the use of chlorine. In the same manner that the water industry has reduced waterborne diseases in the U.S., we will be able to achieve a zero chlorine accident rate.

A zero chlorine accident rate cannot be achieved by merely complying with the regulations. Even eliminating the use of gaseous chlorine will not guarantee the elimination of all morbidity and mortality associated with the use of chlorine and other disinfectants. Achieving a zero chlorine accident rate within the water industry will require setting management and operational benchmarks above RMP regulatory requirements. As a starter here are ten suggested benchmarks for moving beyond regulatory compliance and establishing a best in class RMP.

Benchmarks for Moving Beyond Compliance

1. Achieve an accident rate of zero per process year.
2. Establish measurable goals and priorities for continuous process improvements through the use of inherently safer disinfection processes.
3. Conduct life cycle risk analysis as part of the engineering design process for all existing and planned disinfection facilities.
4. Establish specific chlorine inventory levels to reduce or eliminate risks associated with chemical transportation, storage and the performance of critical operator tasks.
5. Conduct worst-case analysis and prepare risk management plans for all hazardous chemicals used in the treatment process regardless of inventory or regulatory requirement.
6. $upport the LEPC in establishing specific goals and priorities for increasing HAZMAT awareness and preparedness within the community.
7. Provide 3rd party investigation of all offsite chlorine accidents to identify root cause and lessons learned. Incorporate lessons learned into standard operating procedures.
8. Conduct 3rd party audit and hazard reviews at least every five years and internal audits and hazard reviews annually.
9. Certify operator skills and competency using industry recognized training programs such as the AWWA's Seminar in a Box or the Chlorine Institute's Designated Trainer Program.
10. Prevent in the first place and prepare for the worst case by conducting emergency response exercises with designated first responders and ensuring that first responders are trained and equipped to use "A" and "B" chlorine container repair kits.

These benchmarks are being reviewed and revised (see Table Three) through peer review.

The cost of "*preventing in the first place and preparing for the worst case*" must be recognized by industry as part of the life-cycle-cost associated with the use of any hazardous material. Benchmarking chemical inventories just below RMP thresholds may avoid a few regulatory hassles but will not eliminate an industry's general duty obligations under Section 112 (r). While a lot of attention is being focused on industries in the RMP database, keep in mind the lesson our LEPC learned during it's HAZMAT Community Forum; "*It's not the industries who are here that I am worried about – it's the ones who are not here.*"

The public has a right to know and should know about the chemical hazards within their community. Chlorine gas and other hazardous materials used by the water industry represent only a portion of the total chemical hazards and risk found in any community. The public must not only know about these hazards, but they must be prepared and be able to do the right thing in the event of any chemical emergency no matter if that emergency is caused by a water treatment facility, a train derailment, a pipeline explosion or a household chemical cleaner under the kitchen sink. The application of public health tools in analyzing chemical accident morbidity and mortality data will help to better define community hazards and risks associated with the use of hazardous materials and help policy makers to focus limited federal, state and local resources to get the job done.

Table One
Personnel Protective Equipment (PPE) [①]

Description of PPE Used	Number of Facilities Reported Using
No respiratory protection or other PPE used.[②]	2
Cartridge respirator, eye protection, chemical apron and gloves approved for chlorine used.	19
Self-contained breathing apparatus (SCBA) with full-face mask, chemical apron and gloves used.	8
SCBA with HAZMAT level B PPE.	3
Airline respirator with full-face mask.	1
Thirty-three facilities were surveyed in 1998 to determine level of PPE used by operators when loading and unloading chlorine gas cylinders and containers.	

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① "Loading" and "unloading" refers to connecting and disconnecting chlorine cylinders and containers to gas feed systems.

② One training manual reviewed during the survey recommended that operators, "hold a breath, crack open the container valve to pressure the system".

Table Two

Number of Chlorine RMP Facilities in Selected Counties and States[①]

Where	Total RMP Facilities	Chlorine RMP Facilities	Water & Wastewater Sites With Chlorine
Bexar County, TX	33	18 (55%)	16 ♦ 49% of RMP Sites ♦ 89% of Chlorine
Brazos County, TX	10	7 (70%)	7 ♦ 70% of RMP Sites ♦ 100% of Chlorine
Nuces County, TX	18	8 (44%)	2 ♦ 11% of RMP Sites ♦ 25% of Chlorine
Tarrant County, TX	45	16 (35%)	12 ♦ 27% of RMP Sites ♦ 75% of Chlorine
Texas	1,408	564 (40%)	448 ♦ 32% of RMP Sites ♦ 79% of Chlorine
Alabama	238	128 (54%	93 ♦ 39% of RMP Sites ♦ 76% of Chlorine
Illinois	1063	102 (10%)	60 ♦ 06% of RMP Sites ♦ 59% of Chlorine
California	1012	381 (38%)	273 ♦ 27% of RMP Sites ♦ 72% of Chlorine
Iowa	989	48 (5%)	30 ♦ 03% of RMP Sites ♦ 63% of Chlorine
Kansas	808	59 (7%)	42 ♦ 05% of RMP Sites ♦ 71% of Chlorine
U.S.	15,062	4,327 (29%)	3,268 ♦ 22% of RMP Sites ♦ 76% of Chlorine

[①] Based on review of RMP database during July 2001.

Table Three

Best in Class Benchmarks for Moving Beyond RMP ① ②

Best in Class Facilities	Expert Consensus Review (Use this scale to rate each benchmark statement) Strongly Agree 5	4	Agree 3	Strongly Disagree 2	1
1. Achieve an accident rate of zero per process year.					
2. Establish measurable goals and priorities for continuous process improvements through the use of inherently safer disinfection processes.					
3. Conduct life cycle risk analysis as part of the engineering design process for all existing and planned disinfection facilities.					
4. Establish specific chlorine inventory levels to reduce or eliminate risks associated with chemical transportation, storage and the performance of critical operator tasks.					
5. Conduct worst-case analysis and prepare risk management plans for all hazardous materials used in the treatment process regardless of inventory or regulatory requirement.					
6. Support the LEPC in establishing specific goals and priorities for increasing HAZMAT awareness and preparedness within the community.					
7. Provide 3rd party investigation of all offsite chlorine accidents to identify root cause and lessons learned.					
8. Conduct 3rd party audit and hazard review at least every five years and internal audits and hazard reviews annually.					
9. Certify operator skills and competencies using industry recognized training programs such as the AWWA's Seminar in a Box or the Chlorine Institute's Designated Trainer Program.					
10. Prevent in the first place and prepare for the worst case by conducting emergency response exercises with designated first responders and ensuring that first responders are trained and equipped to use "A" and "B" chlorine container repair kits.					
Comments and recommendations for additions and deletions:					

① Proposed benchmarks were developed from RMP Executive Summaries, National Chemical Safety Program Publications, LEPC Advisors and interviews with water operators and fire department first responders.

② Comments, recommendations and additions to proposed benchmarks are welcome. Email to hemery@SAWS.org.

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