WEST AFRICAN CASE STUDY IN APPLYING WORLD-CLASS PRINCIPLES IN EXISITING SOLAR SALT OPERATIONS

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Introduction

There are hundreds of solar salt operations around the world. Some of them employ the best technologies available for salt production. Most, however, fall short of their economic potential by allowing a low total production volume or producing poor quality salt. Many salt winning operations which are very labor intensive, either harvesting by hand or using other primitive technologies.

With an understanding of state-of-the-art principles and the application of a few proven methodologies, most existing operations could see significant improvements in yield and quality. Most of the changes required are procedural or systemic and don't require large capital investments.

Most under-producing facilities struggle with what seems to be conflicting objectives: improve throughput efficiency and product quality without impacting current production or requiring large capital investments. Knowing how to efficiently migrate from existing solar salt operations to world-class technologies and processes is as important as knowing what to do. This presents the operations manager with the problem of solving one objective without violating the other.

The dictionary defines a problem as a "difficult, perplexing situation." Allen Newell and Herbert Simon, two experts in problem solving, wrote, "A person is confronted with a *problem* when he wants something and does not know immediately what series of actions he can perform to get it." In other words, what makes a problem a problem is uncertainty regarding action; having a goal and not knowing how to achieve it. This means that a key area of focus is the goal or solved state.

Approach

One of the biggest challenges to overcome in improving operations is that because solar salt frequently forms from natural processes, operators perceive that improvements are neither necessary nor justified. Therefore, implementing world-class technologies at a solar salt facility requires an understanding of the potential benefits that are possible. Many management and board-level executives may have the attitude that "It's just salt!" and won't allocate the appropriate capital or manpower needed to make the changes that a simple cost-benefit analysis can reveal.

There is, however, some validity in the claims that "It's just salt!" Production of solar salt has been around for centuries and although advances in technology have made it possible to measure concentrations more accurately, monitor flow rates with greater precision and monitor weather conditions with greater predictability; it is still the same basic process.

Although solar salt production has been around for a long time, there have been relatively few cases where people have been successful at implementing highly efficient practices from the beginning to the end of the processing facility. Some sites may have successfully implemented a highly efficient pond management system, but lack the available resources necessary to efficiently process the finished product.

Making changes to an existing solar salt facility is as much a business problem as it is a technical problem. A upgrade approach requires an integrated implementation of improvements in all of the three basic business components; Organization, Data Systems and Technology.

Organizational items are those items typically thought of as management issues. Financial allocations for capital and operational budgets, business forecasts for shareholder and industry reporting, etc. Each planned change has to show a positive return on investment to satisfy the organizational component of the business.

For example, a seemingly simple change may result in improved yields, but it may also require 12 months for change to be fully realized throughout the upgraded system and will negatively impact yield rates until the end of that period. The available budget and operating requirements for the facility may not be able to bear the short term impact to production. Unless a way can be found to implement the upgrade in a phased approach that reduces the impact to production, the change may have to be removed from consideration.

Business systems deal with the policies and procedures of the processing facility. How is data gathered and shared? What is the basis for decision making regarding process quality? How is productivity measured? It has been said that information is knowledge and knowledge is power. This is very true when applied to the implementation of new solar salt processing technologies and procedures.

For example, a planned processing change may require measurements to be taken at prescribed intervals and charted over time. If a computer system or other mechanism is not available for collection, storage and presentation of the data, the benefit gained from collecting the data may be so minimal that it doesn't justify the cost.

Technology is often the driver for change when improving the efficiency of a solar salt processing plant. However, the optimal technical solution may not always be the right solution for a specific plant. For example, mechanical harvesting may be justified by increased throughput in an under-served market, but hand harvesting may be the appropriate response if the area suffers from unemployment.

Ultimately the decision of what changes to implement and in what order to implement those changes requires a full understanding of the integrated results of the three components of business – Organization, Systems and Technology.

Specific tools for decision making tasks

Decision making is best performed using the proper perspective and tools. In many cases, tools shape and define how we approach a problem. Decision make us need to be wary of making all decisions using the same tool. It has been said that if the only tool you have is a hammer, all problems look like a nail. For optimal decision making, the tool or method must fit the situation, data available and goals of the operator. The choice of a decision making method should be based on the same principle that underlies the selection of any tool: choose one appropriate for the task at hand. Using the wrong tool changes task performance and ultimately the outcome of the project.

Tool: Technical troubleshooting

First place to start when evaluating how to implement changes to a solar salt facility is by looking for things that are broken. The "repair" approach is appropriate when things have been observed to go wrong. Typically, this approach is needed when some unwanted change, event, or circumstance produces a deterioration in results or performance. A part fails, an unforeseen circumstance crops up, or a procedure isn't followed. The objective in such cases is to discover the true "root cause" and correct it or at minimum, put things back the way they were.

The appropriate problem-solving tools for a repair job consist primarily of fault isolation techniques. Identify the conditions that should or should not exist and then narrow the search for the fault or malfunction by focusing on where and when the problem appears or doesn't appear. The failed component can be corrected or a suitable workaround identified[i].

Tools: Kaizen, continuous improvement, TQM, and Re-engineering

This tool is used when things are going reasonably well at the facility and nothing is obviously broken and in need of repair. The objective is to improve current levels of performance. The improvement sought might be incremental and continuous or radical and discontinuous. Several characteristics distinguish this approach from the repair approach. All changes in operations must be justified by appropriate "cost / benefit" analysis.

When process improvement is the goal, the causes that are sought are those factors that account for current performance levels. Generally these are the same factors that, if changed, would lead to improved performance. The objective is to identify bottlenecks, obstacles or improvement opportunities in current operations.

Successful improvement depends on being able to reliably and correctly explain and account for performance in complex systems. Simple visual inspections are not adequate. Frequent, thorough, painstaking, disciplined, and scientific work is required. Control charts, scatter plots, cause-and-effect diagrams, and other tools and techniques commonly associated with total quality management (TQM) and continuous improvement can be used. Solutions are data driven. These are the tools most often associated with optimal or "world-class" operations.

In some cases the best solution might be to re-engineer the current facility. This often leads to the use of different systems and / or processes. Existing systems and processes are usually replaced by new systems and processes which are designed and built from scratch. The causes of performance problems in the old systems and processes are of interest only to ensure that the same problem factors aren't included in the new systems and processes.[ii]

Tool: Solution Engineering

The notion of replacing existing systems and processes with newly engineered ones gives rise to a third problem-solving approach, one that centers on design or "solution engineering." To engineer means to plan, construct, or manage in the manner of an engineer. But there is another, more pervasive meaning of engineer: to arrange or bring about through skillful, artful contrivance, as in, "She engineered a remarkable turnaround in the performance of her company. "Substantive changes to the physical aspects of a process or facility requires the involvement of a licensed chemical, mechanical, electrical, or civil engineer, and skilled managers are still expected to engineer solutions to the problems they encounter.[iii]

Not all problems are tied to existing systems and processes. The goal is often to attain a result never before achieved—or to achieve it in a brand new way. There is no cause that can be found or fixed, no root cause to discover, no existing system or process to redesign or re-engineer. There is only a goal and the means of its attainment to be considered. In these cases, solutions must be engineered. World-class enterprises exemplify this perspective when they strive for continuous improvement, lean manufacturing and total quality control part of their learning organization.

Data Gathering and Analysis

In the shift from an under-productive salt facility to one which utilizes world class techniques and principles, the focus is often turned to physical layout and technical knowledge limitations rather than determining what is already known. Seemingly basic and overlooked data can be very valuable as a part of the upgrade process.

Organizational Data

Before any plant or engineering data is gathered it is essential to know the organizational and business constraints and opportunities that exist, as they may greatly impact the outcome of the upgrade process. The decision makers must be identified. Often, there will be multiple decision makers, each with their own level of interest and influence in specific areas. These areas of influence may not necessarily align with job title.

In our emerging market case study, there is a hierarchal organization led by a CEO who is very concerned with overall production numbers and profit. Under his direction are the production, financial, maintenance and QA departments, amongst others. When intake pumps were procured not only was the production manager involved, but the head of maintenance, finance, and even the board of directors representative all had strong opinions on what size and type of pumps should be installed.

Without a clear understanding of who had influence over pump decisions, even amongst the managers themselves, the process of procuring pumps was very slow, despite the immediate need for new pumps. It was simply impossible to obtain all the correct information when that information originated and differed from manager to manager. Once again, it is critical for the company to identify the decision makers and their specific areas of influence/responsibility.

Not only did different departments have different opinions on the same topics, they also had their own background and influences. In the above example the maintenance manager was very concerned with obtaining pumps that would not break down, he was less knowledgeable when it came to the flow rates required at the ponds. Meanwhile the board representative had noticed the large amount of downtime and demanded that the pumps had a local vendor that could perform on-site maintenance in a timely manner.

If knowing who makes what decisions is valuable, then understanding *why* those decisions are made is invaluable. Nowhere will this understanding be of as much use as it is with regards to budget and schedule.

In a project of any type, including a salt facility upgrade, three factors define and measure the project outcome: Scope, Schedule, and Budget. Just as with a three legged chair or tripod, as one fixes any two of these factors, the third is determined by needs of the other two. Since the implementation schedule in a developing salt facility is governed by market and weather, and the budget is usually less flexible, it follows that the scope will require a definition and careful balance between engineering opportunity and capital restraints.

Thus, three pieces of information must be obtained before a clear picture can be painted of business constrains and opportunities. First: planned capital budget. What amount of money can the company set aside or obtain through financing in order to support the upgrades? Second: operations budget. Is this budget sufficient after upgrades take place, or will design have to take into consideration a reduction of personnel? Third: upgrade schedule. What impact does the market have on the urgency for upgrade? Will the construction be limited to a short rainy season? How available will key personnel be during the design and construction phases?

The answers to these and other related questions on the organizational structure of the salt facility decision making group may seem obvious, well established, and unnecessary, but just as building a salt floor is critical in order to upgrade to mechanized harvesters, so is a solid and agreed-upon understanding of the organization essential as a framework on which to work with systems and technical data.

Systems Data

There are many systems in a salt facility, some recognized as important, some merely dealt with, but all have important pieces of data associated with them, relevant to the upgrade process. These systems include, but are not limited to: Preventive Maintenance, Pond design, Salinity control, Weather and seasons, Intake system, and Tidal action. As can be seen, some of these are under human control, others can only be measured, but all directly affect facility performance.

The majority of these systems are addressed in the worksheet in Appendix 1, where basic location information such as rainfall, soil quality, and tidal information can be filled in quickly and easily.[iv]

Accompanying this information is a site layout with pond flow details and survey data. It is important to know what exists before beginning to address how to upgrade the facility. This includes not only physical arrangement of ponds etc, but also details regarding of how water in the ponds flows through the system (if at all) and what equipment or process units exist and their current location.

Also, if a facility is suspected to be underutilizing its salt production capacity, it is extremely likely that it is also under-productive when it comes to preventive maintenance. Lack of a comprehensive and efficient maintenance program can cause financial losses that amount to more than those due to an inefficient operation. A detailed description of an existing preventive maintenance program should be provided with input from multiple sources, including, but not limited to, the CEO, business and operations managers, engineering, head of maintenance and maintenance staff.

In our case study in an equatorial emerging market; we can see the impact of a maintenance program on the financial stability of a salt facility. First and most obviously, many ponds in the system were found to be dry, thus impacting the evaporative area and effective ability of the sun. This was due partially to aborted upgrade project, weather and mis-management of brine, but was mostly due to the consistent failure of five pump engines and insufficient backup / spares. Each time an engine went down, it took days or weeks to find the parts in town and get the engines returned to operation. Second, there was a flooding situation which caused the breach of levies and contaminated the system with fresh water. Though it was less obvious that this was the affect of inadequate preventive maintenance, it was an extremely costly problem, effectively reducing the annual production by 50%.

Finally, it is important to know the material balance of the facility. First, the intake flow rates, pumping hours, and a description of operation. Second, any consistent or known losses in the system should be described and quantified. Finally, the production rates and market need should be listed and quantified, separated by product type.

Once all organizational and systems data has been collected, the time for analysis begins. A salt expert can quickly and accurately predict a theoretical capacity for the facility based on salt evaporation formulas. This predicted capacity is then to be carefully compared to the information previously gathered.

Technical Analysis

A solid understanding of the principles of salt production is required to determine where improvements can and should be made. With this knowledge theoretical calculations can be made and analysis performed. Comparing data that has been collected from the site to theoretical optimal values can be a daunting task, even for an experienced salt expert. Thus, it is critical for a knowledgeable and unbiased individual or team to reconcile the two realities in the field. Though all the information described above may have been gathered and found complete, additional information that cannot be easily quantified or described must be obtained through on-site study and observation. One way this is done is through discussions with operators. Often it is beneficial to have assistance by an independent, experienced and qualified individual or group.

Challenges

Once all the data and background information has been gathered and analyzed, upgrade ideas and solutions will begin to solidify. As they do, however, many challenges arise. Returning to the case study it was noted that these challenges are not only technical, but relate to organizational and data systems.

The obvious goal of an upgrade is to improve the revenue stream of the facility. However, this long-term goal may directly conflict the short-term revenue stream. For example in our case study, when it was found that certain ponds would necessarily be drained in order to perform construction for a redesign of the ponds there was great resistance from management because they did not want to interrupt the ongoing salt production which would negatively affect current revenue.

Another challenge associated with revenue stream is the return on investment. For any group, be it investors, owners, or even employee's, a large change can bring fear. Fear that the technology might not be a good fit for the specific site, fear that rain or other natural occurrences may negate the benefits of any possible upgrades, fear that the investment may cost too much or the return may be too little, or just a general fear of change. These fears may be valid and are often disabling.

A third organizational challenge faced in the case study was group dynamics. When decisions are made that affect everyone in the facility directly, especially on such a large scale, individuals must be able to work as a team to create solutions. Also, as discussed previously, in order to have a functional and productive analysis of the upgrade situation it is important for all parties to have a firm understanding of who makes what decisions.

Systems challenges are another category of struggles that will show through as the upgrade transitions between data collection and the design phase. The first challenge will be that all the data required to complete the analysis and design will simply not be readily available. Some data will be difficult to find, other data will be difficult to extract from personnel in a usable format and still other data will have to be obtained through measurement in the field.

Even after all the data is obtained, it is likely that a significant portion will be suspect. Whether due to mishandling of data or improper measurements, it is difficult to know which data can be relied upon and which must be verified.

Finally, the ultimate challenge involves selecting an upgrade plan and developing the implementation strategy associated with that plan. This challenge combines both the organizational and systems difficulties and adds the technical difficulties as well. At this point it may feel like there are more questions than answers. What *can* be done to improve the facility? What *should* be done in light of the collected financial and site data? *When* should *which* steps be implemented? And possibly most importantly, *how* should those steps be implemented?

Overcoming Challenges

Considering the challenges faced by small salt facilities looking at an operations upgrade, it is no wonder that many just continue with business as usual, operating in a less-productive state, unsure or unable to move forward. The challenge is especially daunting for smaller operations when magnitudes of scale conflict with revenue streams and capital costs to upgrade.

The solution lies not in addressing each individual concern as a battle between current production and upgrade, but rather through a general approach which allows each employee, from mechanic to CEO, to contribute to a dynamic and effective upgrade strategy. This begins with education. Almost all the organizational and business challenges described previously can be met with a solid understanding of how the upgrade process can work for a given facility and how each employee fits into that process.

Each under-productive facility has its own difficulties and particular issues, but all have the same basics: they produce salt, are currently unable to produce more and would like to make more money. Though a detailed plan and training really needs to be site-specific, there are a few principles that apply generally to under-productive operations and will be briefly discussed here.

Upgrade Principles

The first principle: More and/or Better Salt Equals More Money. A rather obvious statement, but this is, after all, the entire reason a facility wants to upgrade in the first place. Thus it is important to remember from conception to construction that though an upgrade means more capital investment, it almost always means more revenue with a short pay-back period.

Second principle: More salt does not necessarily mean less salt in the short term. As discussed previously, the African facility management had great concerns about interrupting the salt production by redesigning concentrating ponds. Once they understood that some simple but novel techniques allowed minimal construction which could take place while brine was still in the pond, their fears subsided and the project was back on track.

Third principle: Technology allows world salt experts to offer specific advice even for small facilities. Economies of scale have in the past prevented the smaller operations, in any industry, from receiving the same expert consultations as larger operations. However, today with the ability to duplicate and share information quickly and efficiently, as well as travel quickly and for relatively low costs, the few seasoned salt experts in the world can train an entire company with general information and offer specific recommendations at affordable rates.

Fourth principle: Every salt facility is special, just not *that* special. It's all just salt after all. That said, each location will have different site conditions, maintenance problems, system layout configurations and personnel with varying levels of technical capabilities. These differences *must* be addressed or the application of expert knowledge will compete, rather than work with the local situation. It is key however to note that these differences are an *opportunity* for improvement not an impediment.

Fifth principle: Every employee is valuable, but only if they can collaborate. Each individual involved in the operation of a salt facility has knowledge and ability that no one else does. Pump mechanics know better than anyone which parts fail and why. The finance department understands why less money came in despite higher production. But if the different groups never speak to each other nor to the upgrade team about the high cost of repeated maintenance on the same part, the expert that knows which part is better suited for the environment will never be able to offer that advice.

A clear understanding of these principles creates a framework for overcoming organizational and business challenges. A clear understanding of a sixth principle will act as the glue to hold the other principles together as a foundation.

Principle six: Data is important and can be accurately kept at ANY facility. Most improvements at existing salt operations are subtle and fine-tuning of the system can result in a large increase in production. This also means that the problems and losses are subtle and can usually only be detected through analyzed data. In the computer age we live in with cheap and accurate measurement devices there is no excuse for the lack of a centralized, accurate and complete data system capable of tracking weather, production, pond salinity and losses.

Even with this last principle, personnel are still not well prepared for the large task ahead. They still lack the tools to create and implement an upgrade plan. These tools also come through education and training, primarily in the form of technical understanding and consensus building.

Technical Training

The production of salt has evolved through the ages, with new techniques that have been developed in the last decades. [v] Unfortunately these techniques have not been passed on from large world-class operations to more primitive ones, and even when they have, they often have not been properly understood or followed.

It can take years for a staff to obtain all the technical training available and applicable to their facility. This paper does not attempt to summarize or address this immense repertoire of knowledge. It does, however, recommend that an intensive training session occur before the upgrade plan is started. This training should be led by an outside facilitator and should address the following basic solar salt topics:

Principles and Theory of Brine Evaporation

Pond Design

Rainwater Control

Harvest Technique

Salt Washing and Refining

Data Systems & Measurement

Tricks of the Trade

Question & Answer Session

All employees should be present and sufficient time allocated for thorough comprehension.

Consensus Building

Technical know-how is essential, but not the only important factor in designing the upgrade of a salt facility. Often, finding solutions to the upgrade challenge can be greatly enhanced if the vision of the staff is open and synergistic. Consensus building is the term used by REDD Engineering to make this happen.[vi]

Returning to the case study, the ability to create an upgrade plan was severely hampered by the different opinions and sensitivities of individual employees. For example, one operations staff member was insistent that the old way of salt production was most effective and that any new ideas would only hurt the company. Other production staff did not necessarily agree (and overwhelmingly wanted to see improvement), but did not know enough technically to prove otherwise, nor did they have the opportunity or skills to address the conflict.

After some initial technical training in the field, all interested parties were called to a meeting. The 'Picture Card Design Method' was preliminarily introduced and individuals were asked to create a comprehensive layout of the plant using post-it notes.[vii] Written on each post-it was either a task, a person responsible for a task, or the information needed to perform a task. This turned out to be a rather difficult undertaking.

Additional training was then offered on upgrade design, teamwork, and consensus building. This allowed everyone to share a common vision for how the process could work from a high level. This had an incredible effect on the staff as they were then asked to return to the post-it note plant layout and complete it. This time, with new vision and understanding of how each person fit into the process, the post-it plant began to take shape with numerous tasks and names appearing everywhere.

Another impressive thing then occurred. As the previously mentioned individual expressed his concerns about the upgrade process as a whole, and other specific concerns, others in the group felt more confident and spoke up to defend the new process. They utilized the technical knowledge and consensus building skills they had learned to help him understand what improvements were possible and conveyed that his input was needed to make them successful. The individual felt more respected and new ideas began to come forth. The upgrade development is still underway in West Africa. Though not complete, the project continues as work is coordinated between salt experts and all levels of staff to improve operations.

Conclusion

The implementation of world-class technologies and processes is within reach for all solar salt production operations, no matter how small. The key is to understand the full business scope required to properly identify, plan and implement. Technology alone is not the answer. It must be adapted to the specific requirements and conditions of each site.

The process needs to be conducted in such a way that current personnel feel part of the solution and not victims of a change in procedures. As the case study showed, group consensus can be achieved around sound technical principles without unnecessary bureaucracy. As demonstrated in this paper a balance in Organization, Data Systems, and Technology can form the framework with which to implement a successful solar salt operations upgrade.

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Appendix 1

Annual Evaporation Rate (and records):
Annual Rainfall (and records):
Wind Velocity and Direction:
Seasonal Min and Max Temperatures:
Soil Conditions (sandy, clay, rocky, etc.):
Flat Acreage as evaporation ponds:
Flat acreage as crystallizer ponds:
Unused flat acreage:
Sub-surface conditions-water table, salinity:
Salinity of seawater:
Availability of Fresh Water, its Source, Location:
Tidal Variation (Tide charts):
Availability and Cost of Power:
Availability of Labor, Rates of Pay:
Susceptibility of plant site and salt storage pile to flooding:
Type of Construction required (protection from elements, temperature, wind conditions etc):
Potential contamination of salt pile from dust: