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Topic

MODERN MECHANIZED SALT HARVESTING IN SOUTHERN AFRICA

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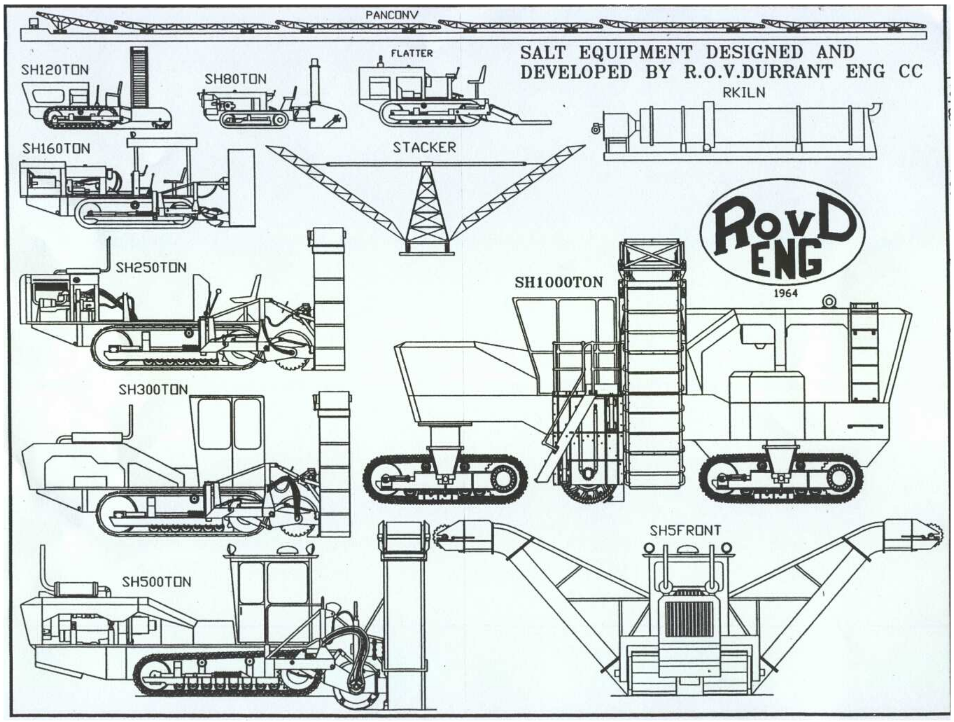
1. INTRODUCTION

ROV Durrant Engineering is situated on the south coast of South Africa in the small city of Port Elizabeth. ROV Durrant Engineering has been involved in the salt industry since 1964. Having been asked to design and build a variety of special purpose equipment such as sea water pumps, salt wash plants, iodide mixers to salt harvesters. Over the years we increased the output (tph) of the harvesting machines as illustrated in the sketch below.



Although the machines are labeled with certain output rates these are dependent upon many factors, usually unique to each geographical location. Factors which will be discussed later, such as permissible ground pressure, crystal structure and properties, crystal age et cetera. In the late sixty's outputs of 100 tph were common, however today's customer expectations are at a minimum of 400 tph.

Over the years RovD has refined certain processes through end user feedback to improve longevity and performance of the machines in daily production. Some of the major developments which will be discussed in the latter chapters include the scraping of the stainless steel chassis due to excessive cracking, metal spraying techniques and carbide tipped cutters.

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2. THE HARVESTING MACHINE

The major areas of interest on the harvesting machine are as follows :

- cutter drum (pick roll)
- elevator
- chassis
- cab
- control system

Output considerations and ground loading factors are discussed separately.

2.1 Cutter drum

The cutter drum also referred to as the pick roll is the business end of the machine. Here the mass, stability and power of the machine are brought to bare on the crystal structure. The construction of this drum is a series of pick holders welded in place in a very particular pattern for the design parameters given, these pick holders are fitted with the carbide tipped cutters just prior to commissioning. The cutters are easily replaceable since they are held in place with a retainer clip only, however salt can re-crystallize around the cutter to make this task more difficult. The cutting process is always a trade-off between available power and particle size. Simply put within limits a smaller particle size requires more cutters per drum area and subsequently consumes more power. As the engine size is fixed for a certain machine the total output may be reduced by inserting additional picks however the particle size could be reduced.

The other function of the pick roll is to convey the salt to the centre of the drum with the use of scroll plates. These plates are bolted to the pick holders, and act as a large diameter screw conveyor. When the salt gets to the middle of the drum a series of horizontal plates fling the salt into an elevator section mounted behind the pick roll drum. The pick roll drum is conventionally driven by two hydraulic motors via variable speed closed loop pumps. During commissioning we adjust the speed of the drum as low as possible to keep maximum output and minimum particle size. If the pick roll is rotating too fast there is a tendency for salt to stay in the drum which is then carried around two or three times before it is deposited into the elevator section. This 'windage' type phenomena absorbs large amounts of power and is of no benefit to reduce particle size.

In order to optimize the cutting power, a feed-back loop is established to control cutting pressure by varying forward speed. A pressure transducer is installed on the pressure side of the hydraulic motors driving the pick roll. This pressure sensor emits an electrical signal which is fed into a load controller which in turn controls the speed of the track motors. As the pressure reaches the optimum pre-set pressure, the voltage feed to the track pumps is reduced and is therefore automatically increased when the hydraulic load is reduced. This process can be manually controlled by monitoring the cutting pressure and adjusting the forward speed as required, however the hysteresis effect is too great.

As the cutting outputs have increased over the years it has now become necessary to protect the hydraulic motor bearings of the pick roll. On current versions of the harvester machines a pair of self aligning spherical roller bearings which carries the weight of the pick roll as well as the cutting forces is mounted in parallel with the hydraulic motors. The bearings run in an oil bath with standard oil seals. The standard oil seals are protected from the salt and brine via a ‘Du-cone’ seal which also has a separate oil bath. A mechanical seal is used to reduce salt particles from attacking the ‘Du-cone’ seal. The mechanical seal requires to be greased at the start of each shift. This bearing/seal combination ensures smooth running of the pick roll while exerting a ‘zero’ load onto the hydraulic motor bearings. The hydraulic motor only applies torque to the pick roll drum. In the past we have used the hydraulic motor bearings to support the pick roll but as production rates have increased over the years we have had several failures of motor bearings resulting in very costly repairs and have now opted for separate bearings to support the pick roll.

2.2 Elevator

The purpose of the elevator is to convey the cut salt to a position where it can fall into a trailer or truck to be transported to the stock pile. The elevator concept on most large machines is the ‘chain and bucket’ type. A standard chain is modified by installing a series of bucket attachment bolts. Buckets are bolted to the chain at 600mm to 800mm centres. The chain slides between hardened wear bars bolted to the elevator frame. The elevator is hydraulically driven with variable speed in two directions, allowing discharge of cut salt on either side of the machine. This allows the truck/trailer to remain on the firmer uncut layer for easier transportation to the stock pile. The elevator chain speed is set to be as slow as possible with the maximum capacity of the machine achieved. This gives the longest chain life. In most cases an elevator chain will last for approximately 500 000 tons of salt loaded afterwhich chain breakages become frequent, the old chain is pulled out and the old buckets are transferred to a new chain. The buckets usually last 2 to 3 chains before they require replacement.

The elevator frame is manufactured of a corrosion resistant stainless steel called 3CR12. This material has very good corrosion resistance as well as abrasion resistance properties and usually only has to be replaced once in the life of the harvester machine. On smaller machines with outputs up to 80 tons per hour we use conventional screw conveyors which feeds to one side of the Harvester only. This means that the harvest has to be done in circular pattern unless the salt pan base is firm enough for trailers to run on the cut surface.

2.3 Chassis

The purpose of the chassis is to provide a platform for the mounting of all the machine components required as well as being the fluid tanks for the operation of the machine, that is diesel fuel and hydraulic oil. The chassis is a compromise between corrosion resistance and strength. In past attempts to manufacture a chassis from stainless steel it became clear that the structural integrity was too compromised for longevity. Today the chassis is manufactured using mild steel and a tried and tested process. This method and regular maintenance has seen a chassis doubling its life expectancy. The steel components are first shot blast to a specific blast profile. Within one hour of blasting the surface is coated with aluminium, 500 microns. Once the steel has been coated with aluminium, the manufacturer applies a 75 to 100 microns coating of a barrier primer to avoid a galvanic reaction between the aluminium and the subsequent zinc layers. This primer is followed by two other epoxy primers after which the colour topcoat of polyurethane is applied. The total paint application is between 750 – 900 microns. If undamaged the steel chassis is good for 7 to 9 years service. Under favourable conditions life expectancy is doubled.
It is recommended within the machine's documentation that at major service intervals the chassis is thoroughly cleaned and a fresh coat of paint be applied. The thinner sections on the Harvester, that is the cab and bonnet covers et cetera are manufactured from stainless steel and 3CR12 sheets.

2.4 Cab

The operators cab, dependent upon specification, is totally enclosed with tinted safety glass, air conditioned, forward facing work lights, as well as side facing working lights to give good visibility during evening/night shifts. The sound level within the cab when the door is closed is normally within 85 db which is acceptable without additional hearing protection. The cab is equipped with a series of pressure gauges to monitor hydraulic filter condition, pump boost pressures as well as service pressures. In the case of an electronic engine we will have a digital display giving engine operating parameters, engine load, pressures, temperatures et cetera as well as keeping a record of any faults. We usually equip the cab with radio/CD player as well as two way radio if required. The harvester machines are equipped with fire extinguishers in the cab as well as two dry powder units, one at the front and the other mounted at the rear of the machine.

2.5 Control system

The control system used can vary from relay logic control to programmable logic controllers (plc). The relay logic is commonly used due to most end users being concerned about the additional electronics of the plc operation in the corrosive environment. A shift towards the plc system is slowly being realized since this allows greater data logging and information flow in real time. A more recent machine has seen the end user opting for real time Ethernet networking and data logging in the maintenance and production offices to monitor the harvesting process and performance. Either system works well if control cabinets and junction boxes are resealed after every opening. Both systems employ the laser leveling system which monitors a signal sent from the trailer mounted base station. Within the adjustable range (300 mm) the machine will automatically lift and lower the pick roll to maintain a level cut profile.

3. OUTPUT TERMINOLOGY

When considering the terminology, **output rate** of the harvesting machine the following considerations are required. The output of the harvesting process is a continuous process, therefore the slowest process dictates the output rate. In the harvesting machine as considered, the slowest process is the cutting process. Therefore the output rate referred to, will refer to the cutting rate. This rate is measured off the end of the elevator and is averaged over several loads. Usually a few trailers are loaded during the commissioning process and weighed, the time taken to load these trailers is recorded in seconds from the time the elevator starts to run until the elevator stops loading. The idle time taken to position the trailer or any stoppages are not included, therefore you can consider this to be an instantaneous rate usually measured in metric tons per hours. Some assumptions include the density (S_g) of the salt to be 1.3, the particle size to be between 1mm and 10mm in diameter and the strength of the layer to be less than 3 MPa. Another consideration in output is the constitution and the age of the crystal layer, the harvesting machine is designed to cut year on year and therefore layers older than one year could result in decreased output rates.

The harvesting process should be considered in individual steps. From harvesting the crystal layer to delivering on the stock pile prior to entering a wash plant or further processing. An instantaneous output rate at the harvesting machine will be subject to a process or plant efficiency (η_{plant}), caused by steps such as turn-around times at the end of each run, waiting for trailers to arrive, operator breaks, et cetera. As an example a typical Southern African operation will harvest at 400 tph for 16 hours to stock pile sufficient product to feed the further process plant at 125 tph for 22 hours per day. Therefore we can assume the process efficiency to be between 40% and 50% (43%), which is typical for Southern African operations.

4. HARVESTING METHOD

The **method** of harvesting depends largely on the output required for the operation, permissible ground pressure, distance of the stock piles from the pans, road conditions, road width, ease of tipping (conventional or bottom dumping). If ground pressure permits, the most efficient method is the harvester machine. Secondly, consideration regarding the cut area's permissible ground pressure is required. Usually the cut area becomes to unstable to drive wheeled machines on, therefore the reversible elevator allows the trucks and trailers to remain on the firmer uncut side of the harvester machine. Truck and trailer loads of 20 tons payload is common and where ground pressures allow, double trailer configurations are used.

In conditions where the permissible ground pressure is very low, it is possible to use a harvester machine with very low ground pressure discharging onto mobile conveyors with very low ground pressure and convey the product to the edge of the pan where it is discharged directly into the trailer for transportation to the stock pile. As an example in such conditions, once the crystal layer is cut it would not be able to support a person's foot pressure without sinking into the substrate.

In very small operations another method to remove salt is to use a harvester machine which is trailed behind a conventional tractor and is powered via the 'power take off' shaft entirely. It should be noted that the tractor needs a specific crawl gear ratio to achieve this method.

5. CONCLUSION

It is clear that every operation is unique in the design parameters required, from outputs required to distances between the source and the plant. The harvesting machine and process to the stock pile should be carefully considered and simulated to achieve the desired result from the capital investment required. The design parameters of the harvesting machine, size and power, the requirements for production information and machine parameter monitoring are all aspects to be discussed to enable the manufacturer to deliver a machine to suit the end users needs.