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1 INTRO

Crude oil and inflammable liquid storage tank owners are required to inspect them at scheduled intervals according to legal regulations or standards. All tanks (Fig.1) must be cleaned before they are inspected. It is not so difficult to clean small-capacity storage tanks containing light oils and little sludge. In contrast, it is very difficult to clean large-capacity storage tanks, with a diameter of 90 to 100 meters or more, containing a large amount of sludge, such as crude oil storage tanks.

Our S.R.S. (Sludge Recovery System), based on the C.O.W. (Crude Oil Washing) method, is an automated, mobile and modular, non-manned oil tank cleaning system.

Compared to manual cleaning techniques, S.R.S. cleans tanks much more safely and quickly. A distinctive feature of the S.R.S. is its closed loop cleaning system, which heavily reduces the impact of tank cleaning on the environment and provides near 100% hydrocarbon recovery. Based on its years of experience in storage tank cleaning, about 20 years ago NUOVA SAIMAR S.r.l developed the S.R.S. to clean large-capacity storage tanks while meeting the requirements listed above. Our systems stems from oil-tanker cleaning methods and it has been adapted and perfected to clean above-ground storage tanks.

The S.R.S. (Sludge Recovery System) fluidises the hydrocarbon phase of the sludge, by injecting the same fluids that generated or, as it often happens in refineries, using cuts compatible with the sludge to be cleaned.

Sludge fluidisation is determined by the chemical action of fresh oil, and by the mechanical action of Jet Washers that, properly installed on the tank roof, eject the fresh oil stream at a pressure of 6 bar approx.

This way the hydrocarbon phase, within the sludge, is dissolved in the fluidising oil, and the inert portion (sand, earth and debris) is left inside the tank. The fresh oil intake and the fluidised phase return can be continuous or discontinuous, according to the cleaning procedure agreed with the Client.
A discontinuous procedure is selected to minimize the use of fluidizing oil, but it requires more time. A fluidized phase is returned to the Client who can process it according to their needs. For instance, in some operations of ours, it was returned:

- to another tank;
- to another tank that was feeding the topping tower;
- to the line feeding the topping tower, at controlled rates (±0.1 m³/h)

In all cases, the stream is filtered by 11 mesh size strainers.

After the oil washing phase, the quantity of residues can be minimized to be disposed to the landfill, through hot-water washing (70-80°C). During this phase, the stream gets through an oil/water separator. The oil stream is returned to the client, and the water stream is returned to the tank.

After water washing, the residue usually has an oil content lower than 20% (by petrol ether extraction 40/70 - IRSA/CNR Q64 N21).

At the end of S.R.S. operations, the tank’s man-holes are opened, natural and forced ventilation is applied, and workers can safely enter the tank to take out the final residues.

## 2 THE SYSTEM

The NUOVA SAIMAR S.R.S. mainly consists of:

1. **A - Unit**
2. **B - Unit**
3. **Separator Tank**
4. **Jet Washers**
5. **O₂ Monitor**
**A – Unit**

The A-Unit is used to suction oil from the tank being cleaned and transfer it to an oil-receiving tank.

The dissolved sludge and the oil are temporarily suctioned into the ejector vessel and transferred to the receiving tank, through a recovery pump (power: 75 kW, 400V @ 50 Hz; flow-rate: 180 m³/h; head: 10 bar).

All inflammable gases suctioned by the vacuum pump are returned to the tank being cleaned. This is to keep the areas surrounding the workplace safe and to hold the internal pressure of the tank being cleaned, at a positive level.

The liquid level and the degree of vacuum are controlled by automatically starting and stopping the vacuum pump at a signal from a level controller and a vacuum pressure sensor/transmitter.

**B – Unit**

The B-Unit is used to feed washing oil to the Nuova Saimar Jet Washers.

The heat exchanger may be used to heat oil or water for tank washing.

When the A-Unit and the B-Unit are connected the following advantages will result:

- Two pumps are available for oil transfer operations.
- When dismantling the temporary piping, the oily water left in it can be easily recovered into the ejector vessel.
- Both the recovery and the washing pump can be used for crude oil cleaning operations.

**Separator Tank**

A separator tank is used to separate oil from water during water-washing operations.

The separator tank is equipped with a container with a retractable roof.

The insert includes a weir that creates an intake area between the weir itself and the side wall; an inlet gap to introduce the surface oil into the intake area; wherein the weir is positioned in such a way that it induces the influent liquid to flow in a swirling motion within the intake area.
✓ **Jet Washers**

This is the core of S.R.S.. It is a washing machine that will dissolve and discharge sludge.
Nuova Saimar has devoted much attention to the design and construction of Jet Washer type AM-70.
Nuova Saimar Jet Washer AM-70 is a washing machine with a unique mechanism and an excellent performance standard, it has been developed for the effective cleaning of oil tanks.
The washing liquid passes from 3-inch flange outside the pipe and is injected from the tip of nozzle.
Orbital rotation and axial rotation of nozzles are obtained by the rotation force of air motor and gear mechanisms.

Some data about Jet Washer:
- Maximum Outer Diameter: 70 mm (allows installation inside the support guide)
- Dispensing Volume: 90 m³/h @ 7 kg/cm²
- Driving Force: air motor, maximum pressure 6.1 kg/cm²
- Repeat Angle: [45-105-45] or [105-140-105] degrees
- Main Material: ASTM304; ASTM316; aluminum alloys
- Actual Length: 1'950 mm
- Weight: 45 kg

✓ **O₂ Monitor**

Oxygen concentration within the cleaning tank is held below 8% (vol).
Using an automatic monitoring unit, oxygen concentration is constantly monitored at six locations inside the Tank.

3 **FEATURES OF THE SYSTEM**

The reasons why our clients prefer to select S.R.S. tank cleaning are the following:
- a. maximum recovery of hydrocarbon phase contained in the sludge, (up to 98%) whose value often pays the overall cleaning operation;
- b. minimum quantity of material to be disposed of, just the inert portion saturated by water and HC (its dry residue, at 600°C, is approx 35%);
- c. minimum tank downtime, the cleaning operation fluidises from 200 to 400 t/day of sludge, depending on sludge quality;
- d. minimum overall cost of tank cleaning operations;
- e. best cost/benefits ratio;
- f. highest possible safety level of operations, according to the most recent CE regulations;
- g. elimination of Health and Safety risks run by the operators; their access, into the tank, is restricted to the final phase, when the tank internal atmosphere is neither flammable nor hazardous;
- h. environmental risks off; the System operates through a closed cycle.
4 WHERE S.R.S. WORKS

The S.R.S. can be used to clean whatever type of tank, best results are obtained with:

1) crude oil tanks;
2) fuel oil tanks:
   a. intermediate cuts (topping and vacuum bottoms);
   b. heavy oil;
   c. light oil;
   d. oil emulsion;
3) tar and bitumen tanks.

5 OPERATION

✓ Flow Scheme
✓ **Mobilisation**

Cleaning plans, drawings of temporary piping, schedules, lists of outgoing materials, manpower mobilization schedules, procurement plans, and transportation plans are prepared. The S.R.S. is installed according to the mobilisation plan approved by the customer. The mobilisation process involves the installation of A-Unit, B-Unit, Separator Tank and Jet Washers. The time required for mobilisation of the S.R.S and the auxiliary equipment varies depending on the complexity of the job, but usually it does not take longer than a week.

The auxiliary equipment are set up in accordance with prevailing regulations regarding potentially hazardous zones. The zones are set up to meet the highest international safety standards and directives when working in potentially hazardous environments. Depending on the diameter of the tank, the required number of nozzles are installed in the roof. This is either done through existing openings or new, cold-tapped openings safely made with the certified safetap tool. The nozzles are key to ensuring an optimal cleaning result. Their unique indexed washing pattern fully covers the tank’s complete surface.

✓ **Outline of S.R.S**

The S.R.S. is connected both to the Tank and to a sister tank for the supply of cleaning oil and receipt of dissolved oil. The two are connected by temporary piping. Temporary piping is connected. Leakage tests are carried out so as to ensure complete connection.

✓ **Tank Blanketing**

For the purpose of disaster prevention due to static electricity that may arise from Jet Washer operations, an inert gas (normally nitrogen) is fed into the space. The purpose is to reduce the oxygen level to below 8 per cent, eliminating by so doing the risk of explosion. This oxygen level is held for the entire cleaning process. When S.R.S is employed for the cleaning of floating-roof storage tanks, the probability for the system to discharge ignitable electrostatic sparks is extremely low. However, in order to ensure safety in the event of emergency, explosion-proof measures are taken.
This device measures oxygen density thanks to an automatic changeover mechanism through both indications and records. It is composed of an O2 sampler and an O2 density monitor. A mixture of inflammable gas and oxygen (air) causes an explosive combustion whenever the mixing ratio of gas to oxygen reaches a certain level. No explosive combustion occurs when the mixing ratio is outside the explosive combustion limits. Our gas sampler is explosion proof.

**Desludging & Cleaning**

NUOVA SAIMAR Jet Washers are installed on the roof (floating or fixed) of the tank and play a basic role in the cleaning process. Generally Jet Washers are assembled in the centre of some roof supports, therefore avoiding the need to cut through the roof. Clean crude oil is used as cleaning oil. The cleaning oil is ejected through NUOVA SAIMAR Jet Washers toward the sludge deposited within the Tank in order to break, dissolve, disperse and fluidize the sludge. The fluidized sludge is then flushed out of the Tank. Desludging is the first process of tank cleaning and it is also where most of the oily sludge from the tank is removed. The desludging process may begin after the oxygen level has fallen below 8 per cent. The nozzles are operated alternately. Since the sludge may contain solids, water and trapped liquefied oil it may be necessary to add cutter stock to re-liquefy the sludge.

The cleaning process consists basically of oil wash. The nozzles use recirculated oil as their primary cleaning media and their effectiveness is due to their far-reaching, low pressure high impact jets. The nozzles are compressed air driven and they can be operated two at a time.

After oil cleaning, there are cases in which the Tank is further cleaned with hot water. Such cleaning operation removes almost all oil components from inside the Tank facilitating therefore the manual finish-cleaning. The nozzles can be programmed to focus on areas that require more intensive desludging.
**Control**

The system is easily operated and monitored by a few trained operators via user-friendly control panels. In addition to this, personnel must undergo a comprehensive training programme to operate the NUOVA SAIMAR S.R.S. as well as a safety-procedure training.

The panels, provided with explosion-proof start and stop switches, are used to control pumps and air compressor.

Nuova Saimar Research & Development department is planning and testing an S.R.S. remote monitoring; the following picture shows a prototype of the Digital Monitoring System’s “Front Panel”. Such system is implemented at Labview® by our Engineers and it will process data from (ATEX) sensors in strategic positions on all S.R.S. machines.

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**Oil Transfer**

Before NUOVA SAIMAR’s Jet Washers are started, all fluidic oil remaining in the Tank is transferred through the drain nozzle at the bottom of the Tank to a receiving tank.

After the floating roof deck support reaches the tank bottom, space is formed inside the Tank.

NUOVA SAIMAR’s S.R.S. operations remove almost all the deposited sludge. However, in order to ensure complete removal of oil, there are cases when hot-water cleaning is performed after S.R.S. operations.

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**Hot-Water Cleaning**

The Tank is filled with a quantity of hot water, which is made to circulate through an oil separating tank to recover oil.

Hot-water cleaning is more effective in the removal of greasy matter but it is likely to emulsify the remaining sludge and form moisture-containing sludge as by-product.
✓ **Internal Finish-Cleaning**
The portions of the tank that are not completely cleaned and rusty are scraped and brushed. All mud, sand and rust deposits, solid matter and sludge, within the Tank, are removed. All the work is done manually. The Tank is required to be finish-cleaned to the extent that the use of fire is allowed inside it. When a Tank is to be cleaned for the storage of a different kind of oil, then it will require a cleaning based on different standards.

✓ **Dismantling of Temporary Installation**
Finally demobilisation and de-installation of the tank cleaning system takes place. As soon as the tank atmosphere has been approved by a safety officer, personnel will be free to enter. Temporary piping is disconnected, and all materials are removed from the location of the cleaned Tank. To facilitate transportation NUOVA SAIMAR’s S.R.S. is built into standard 20’ flat rack containers.

6 **BENEFITS OF S.R.S.**
✓ **Value of Recovered Oil**
The hydrocarbon recovered through an S.R.S. cleaning, is 95% of hydrocarbon in the sludge. These will be dissolved in the fluidising oil and carried to the production, thus becoming a true recovery. The hydrocarbon recovered through manual cleaning is "zero", because hydrocarbons transferred by the manual cleaning to the receiving tank, will settle inside it, and will never go back to production. This situation will generate a further cost when the receiving tank will need to be cleaned.
If we clean a tank with 3,000 m³ of sludge, we can return a true value as high as **500,000 USD** (depending on the market value of crude oil).
Health and Safety
The non-manned concept of NUOVA SAIMAR’s S.R.S. means that nobody needs to enter the tank during cleaning operations ensuring this way the utmost personnel safety. S.R.S. is a non-manned cleaning system, since there is no need for personnel to enter the tank during the process. Every component of NUOVA SAIMAR’s S.R.S has been designed with safety and human health in mind. S.R.S. operations are conducted without people entering the tank, exception made for the final cleaning. In this last phase, considering that the water-washing phase has eliminated HC e H₂S from the tank’s internal atmosphere, people may enter the tank without any breathing apparatuses. In any case, before people enter the tank, the tank’s internal atmosphere is checked for oxygen and hydrocarbons content. On the contrary, during manual operations, people are compelled to work in flammable and hazardous atmospheres. In addition to that, a big quantity of hydrocarbons dissolves in the atmosphere thru the open man-holes; such phenomenon is excited by the redundant steam used during manual operations. Some times the amount of sludge is so high, more than 2m, that the roof cannot land. We have solved many situations like that. The S.R.S. guarantees safe roof landing: operations start with the roof floating on the liquid phase, and the S.R.S. unit operates by reducing sludge peaks that impede the roof from landing. We can achieve such results whatever shape and quantity prevent of sludge. The Jet Washers are installed on the roof using the roof support legs. Not to compromise roof stability, max 25% of the legs are used. This guarantees the necessary roof support. Supports are then put back into place before people enter the tank for final cleaning. When support legs can not be used, Jet Washers are installed thanks to special sleeves that are installed on the roof under a specific safety procedure. During the S.R.S. washing the atmosphere within the tank is continuously monitored to guarantee that it does not become flammable, and nitrogen is used to control it. To this end the unit is equipped with O₂ monitoring system and alarm. Safety instruments are new and subject to maintenance control procedures. People managing and supervising operations are very experienced and high qualified.

Environmental Protection
During the fluidisation phase, all the apertures, that may connect the tank’s inner atmosphere to the external atmosphere, are purposely sealed in order to avoid any HC loss. During S.R.S. operations no chemicals are used.

Treatment Efficiency
When asphaltenes and paraffins are melt and then they go back to room temperature they are more compact than before, i.e. they require a higher temperature to be melt again (1). To eliminate this problem, the S.R.S. operates a soft heating, just enough to achieve the solution of sludge in the fresh oil, this way the solution will remain stable for a very long time.

Cost Savings
The S.R.S. recovers more than 95% of the hydrocarbon phase contained within the sludge, which is returned to the client together with the fresh oil used to fluidise it. The subsequent hot water washing leaves inside the tank a residue, to be disposed of, whose average composition is 1/3 inert, 1/3 water, 1/3 solid hydrocarbon. No other system gives better recovery, and minor quantities to be disposed of. Such result generates a significant cost saving that is evidenced only by evaluating the entire cleaning project.

Schedule
A S.R.S. operation lasts much less than any manual cleaning:

a. During the washing phase the sludge is treated at a speed of approx 250/350 m³/day depending on the technique used and in the type of sludge;

b. At the end of S.R.S. washing, the residue to be taken out manually ranges between 5 and 10% of the original sludge, depending on the quantity of inert phase within it;

c. The hot water washing phase facilitates the final manual cleaning operations.

---

1 Let us note that this effect is typical of manual cleaning where steam is used to melt the sludge, when the melted sludge reaches the receiving tank, it will precipitates in a more stable structure. It is possible to say that the S.R.S. recovers the sludge to production, while the manual system transfers the sludge from one tank to another.
Reduction of Tank Down-Time

S.R.S. operations last much less than manual cleanings and the time reduction becomes more significant as operations become more complex. To take a tank out of service for a manual cleaning, the sludge must be height below the man-hole levels. Sometimes, to reach this level, the client has to carry on special, long lasting and costing procedures. S.R.S. operations do not need such work.

Minimum Overall Cost of Tank Cleaning

Sometimes comparing the offer for manual cleaning with the offer for S.R.S. operations, it might appear that S.R.S. is more expensive. A more complete cost analysis however, also leaving out the value of safety that for the present European regulations equals “infinite”, by just considering the recovery of valuable material and the subsequent saving for not treatment/disposal of the material recovered, will show how S.R.S. costs are actually cheaper. Recorded data of previous operations and their results are available for analysis.

Autonomy and flexibility of the S.R.S. unit

The S.R.S. unit has been designed for the best flexibility and autonomy. Concerning some utilities as Power and Steam, we always consider the possibility to make use of the Site utilities in order to minimise the cost to the Client.

A brief summary of S.R.S. benefits:

Reduced Time
- Drainage ratio 250/350 m³/day
- Up to 80% reduction of tank cleaning time (compared to manual)
- Shorter overall tank down-time

Minimal Environmental Impact
- Near 100% recovery of hydrocarbons
- Minimal waste disposal
- Minimal hydrocarbon emission to atmosphere due to closed-loop cleaning
- Lower consumption of water, electricity and air

Cleaning Result
- Unique indexed washing pattern covers complete tank interior surface area
- Re-circulation of cleaning substance during desluding

Safe Cleaning Process
- Continuous monitoring and automatic shutdown features
- No risk of explosion
- System complies with CE & ATEX

Personal Safety
- No staff inside tank during cleaning process (non-manned system)
- Minimal health and safety risks to staff, no HC and H₂S
- Thorough safety training of operators

Easy Maintenance
- Easier tank maintenance after cleaning

Compliance with Regulations
- Designed for present and future environmental, health and safety regulations

Highly Flexible
- Modular system can be tailored to customer needs
- Expandable, as from customers needs

Low Costs
- Overall tank cleaning costs reduced - see Cost/Benefit Analysis
7 S.R.S. Vs MANUAL OPERATIONS

✓ Safety

<table>
<thead>
<tr>
<th>S.R.S.</th>
<th>Manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>It complies with CE safety regulations, for which an equipment must: <strong>reduce the risk at the origin</strong>. The S.R.S. eliminates all risks, as operators are not exposed to flammable atmospheres and toxic gases, which happens when the sludge is not treated with S.R.S.; substitute a dangerous system with a not, or less, dangerous system by a general protection system; The S.R.S. eliminates the need to use personal protection apparatuses that are prescribed by technical specifications in case of manual operations; <strong>reduce to a minimum the operators that may be exposed to risks</strong>; The S.R.S. reduces such number to zero Operators enter the tank when there is no risk inside, as the internal atmosphere can be breathed; There is no fire risk.</td>
<td>It does not comply within CE safety regulations Due to the availability of more efficient technologies, the Clients who select the manual system may be subject to civil and/or penal responsibilities <strong>Operators must enter the tank from the very beginning when</strong>: the internal atmosphere is toxic; flammable/explosive conditions are easily generated; operators must use breathing apparatuses or air-feeding-system masks (from outside); working inside the tank is difficult and safety is drastically reduced due to the need of air-feeding masks. Fire risks are always there until operations have been completed.</td>
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</table>

✓ Environment

<table>
<thead>
<tr>
<th>S.R.S.</th>
<th>Manual</th>
</tr>
</thead>
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<tr>
<td>No emission to the atmosphere as the system operates on a closed cycle; Disposal is limited to the inert portion with a reduced quantity of hydrocarbon and water; A reduced amount of water is used.</td>
<td>Emission of hydrocarbon vapours is continuous during the whole operation; The part to be disposed is always more then 20% of the original sludge; Large quantities of water are used, that must be treated afterward.</td>
</tr>
</tbody>
</table>

✓ Costs

<table>
<thead>
<tr>
<th>S.R.S.</th>
<th>Manual</th>
</tr>
</thead>
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<tr>
<td>Operations last half the time of manual operations; The high hydrocarbon recovery (&gt;95%) means a cost recovery higher than with any other system; Cost of solid material disposal is minimised; Cost for water treatment is negligible; Thanks to the cost recovery, the total cost of operations becomes <strong>INCOME</strong>.</td>
<td>Operations last double the time of S.R.S. operations; Whatever treatment is used after the sludge is taken out, hydrocarbon recovery is lower than 70%; Quantity and cost, of solid material treatment and disposal, are very high; Cost of water and relevant treatment may be very high; Due to the poor recovery, manual operations are always a <strong>COST</strong>.</td>
</tr>
</tbody>
</table>

8 REFERENCES

Attached is the list of the operations that have been designed, and successfully managed by our company since 2005.
9 S.R.S CERTIFICATIONS

NUOVA SAIMAR S.r.l. declares that the S.R.S system has been designed and manufactured in compliance with:

- 98/37/CEE
- 89/336/CEE
- 73/23/CEE
- ATEX 94/9/CE (TUV declaration)
- PED 97/23/CE
- 93/68/CEE

10 NUOVA SAIMAR S.r.l. CERTIFICATIONS

- Certificate OHSAS 18001:2007 of RINA, for certified occupational health and safety management system.
- SOA Attestation for categories:
  - OG12 Works and cleaning systems and environmental protection
  - OS21 Special structural Works
  - OS22 Water treatment plants and sewage treatment
  - OS23 Industrial Demolitions.
- National Register Environmental Managers for categories:
  - 4F collection and transport of special non-hazardous waste
  - 5F collection and transportation of hazardous waste
  - 8E brokerage and trade waste without holding
  - 9B remediation of contaminated sites
  - 10B reclamation activities of goods containing asbestos
## 11 REFERENCES

<table>
<thead>
<tr>
<th>No.</th>
<th>Customer</th>
<th>Place</th>
<th>Tag</th>
<th>Year</th>
<th>Size</th>
<th>Diameter</th>
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<th>Service</th>
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<th>Final q'ty sludge</th>
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<td>FLOATING</td>
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<td>2100</td>
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<td>H₂S &amp; HC reduction + sulphides hydration &amp; neutralization</td>
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<td>210</td>
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</table>

NUOVA SAIMAR S.r.l.

C.E.O. Gianfranco Lucchi

Gianfranco Lucchi