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An economic case for an ammonia plant relocation

DALLAS ROBINSON
BD Energy Systems
Houston, TX, USA

Relocation of a thoroughly investigated existing facility has some unique challenges. There is a significantly lower risk of using a known and proven process design and a cost and time savings versus a new facility. Best laid plans – rarely happen in the real world.

The paper and presentation would focus on tasks, time-frames, approximate costs and lessons learned.

Summary of PRO's and CON's on a relocated versus new chemical plant

ISSUE

With the increased exploration and fracking techniques in the last ten years, there has been an increased supply and lower cost of natural gas in some parts of the world. This favorable shift in raw material cost has encouraged investors and chemical plant operators to evaluate additional capacity.

The conventional routes to increased capacity has been to upgrade existing facilities by removing chokepoints to attain their maximum rates and/or to evaluate new larger and more efficient facilities. Three new ammonia plants have been completed and started up in the USA between 2016 and 2017. The total added new capacity of these three plants is expected to be in the 3 million tons of ammonia per year range or about 12% of North American Ammonia production (based on a list of 50 operating ammonia plants in North America).

The cost and time to construct a new facility have proven to be greater than original estimates and has caused "sticker shock" and a re-evaluation of any future new facilities. There have been several recent cases of greenfield new ammonia plants that have taken 36 to 48 months for mechanical completion and have cost in the billions. While full cost reports are not in, the expected final costs are in the $1,500 to $2,200 per annualized ton range (Total capital cost divided by the expected total annual tons).

A PLANT RELOCATION SOLUTION

Another concept for consideration is to identify older and proven facilities that have recently been shut down and evaluate relocating them from a high cost of gas geolocation to a new low gas cost location.

A recent relocation example is where a 1,000 ton per day Kellogg Design was removed, relocated, rebuilt and upgraded. This project was in the range of $500 million and took 25 months to mechanically complete from the groundbreaking (after an environmental permit was issued). The ground breaking occurred in December 2013 and the first drop of ammonia was in April 2016. The full costs were less than $1,100 per annualized ton. This restart of a legacy ammonia plant will return approximately 470,000 tons per year to the market.

This paper will look at concept of evaluating an existing facility and rebuilding it to today's codes and emission standards and upgrading its reliability, efficiency and capacity. In addition, a review of tasks, timeframes, approximate costs and lessons learned will be covered.

The relocation of an "experienced" facility has some unique advantages and challenges. There is a significantly lower risk of using a known and proven process design and a cost and time savings versus a new facility. There is usually a set of operations and maintenance history to provide a good insight on reliability, efficiency and capacity. There can be many potential unknowns on equipment conditions and the future site location condition and layout.

Best laid plans – rarely happen in the real world. You can have most of your plans meet all expectations, but the entire project can be delayed, and costs dramatically creep upwards if a few task execution steps are flawed.

PLANT RELOCATION PHASES

In a well laid out plant relocation plan, there are at least 6 to 8 Phases:

1. Phase I – Due Diligence
2. Phase II – Process Study
3. Phase III – Process Frontend Engineering Design [FEED]
4. Phase IV – Detailed Engineering
5. Phase V – Procurement
6. Phase VI-A – Construction – Dismantling and Transport
7. Phase VI-B – Construction – Rebuild and/or Upgrade
8. Phase VI-C – Construction – Pre-Commissioning and Commissioning (Start-Up)

Phase I - Due Diligence

A Due Diligence site visit and a Process Study of potential plant is needed for a plant evaluation and selection.

Origin Site

A typical Due Diligence consists of:

- A careful and diligent original site investigation.
- Several walk downs – front-to-back and back-to-front should be conducted.
- Each piece of equipment should be photographed and labeled.
- Surveys and 3-D Laser Mapping should be performed for a true "as built" reference.
- Utilization of high resolution drones that photograph plants vertically and top-down (for a virtual plot plan) should be considered.
- Engineering, Operations and Maintenance - Records need to be
  - Found
  - Secured

  - Scanned
  - Cataloged and Organized

If any previous operations, maintenance or engineering personnel are available – they should be interviewed on the previous and current condition of the plant. If there is a language difference between the origin site and the destination site, plan on finding and third party technical interpreter.

As part of the investigation, safety and environmental issues must be reviewed. Inquires and confirmations on any contaminants should be made. An example list consists of:

- Radioactive materials (Instrumentation, Phosphate rock derivatives, catalyst)
- Biological (Water treatment and circulation systems)
- Asbestos (Insulation, gaskets)
- Lead (and/or other toxic metals)
- Hydrocarbons
- Solvents (CO2 or otherwise)
- Ammonia
- Catalysts

A baseline Heat and Material Balance is needed to define the existing plant efficiency and capacity.

A Pre-Inspection can provide a short list of what equipment needs to keep. A strategic equipment list should define increment costs to either use, repair or replace. If large long lead-time and costly pieces are deemed to be replaced, they will need priority for specifications and ordering.

Examples of what to leave:

- If local destination site purchase is less costly than dismantling and transportation – leave old – buy new
- If the equipment is obsolete, or spare parts are not available of the cost to install is greater than new – leave and scrap the old.
- An example was a decision to use all 3" and above piping. However, the disassembly timeframe was cut short and sections that may have two welds – now required 4 to 8 welds to reinstall. The labor, re-fit, welds, and QC cost more than if new pipe with fewer welds had been used.

A typical origin site Due Diligence visit can span a week or two. The report development can take a month to prepare, if good origin site records and personnel have been made available.

Destination Site

The destination site should be considered as part of the Due Diligence as well. It is important for the owner/operator to evaluate the area for:

- Environmental permitting and surroundings. Meeting emissions at the "fence line" may dictate a balance on how large the site needs to be, where the "fence line" is placed and having to add point source emission controls.
- Raw Materials
  - Natural gas – Pipeline, Pressure, & Composition
  - Water – Surface, Wells, Municipal
- Energy
  - Electricity
  - Steam
- Transportation
  - Truck (i.e., Typical 200-mile supply radius)
  - Rail (i.e., Typical 500-mile supply radius)

- Barge – location and access to navigable water
- Pipeline

- Size – acres and "fence line" (Important for environmental modeling and determining sound mitigation)
- Seismic, Soils and Underground Impediments
  - Soil borings
  - Previous site use
  - Cases where previous foundations, piping and cabling have been encountered and can delay the construction time and add cost to mitigate
- Neighbors, wind direction and buffer zones. Consider how emissions from one plant that could affect adjacent internal plants intakes, neighboring chemical plant, commercial or residential locations. Examples:
  - Do not locate the ammonia plant air machine intake in line with a prevailing downwind from a sulfuric acid plant.
  - Consider Cooling Towers as both scrubbers and emitters. If you have an ammonia or urea plant vent upwind – you can scrub ammonia into your cooling tower. Cooling tower drift can be a detriment to electric switch gear.

Phase II – Process Study

A rebuild "as is" can be accomplished, but not recommended. The plant should be studied, and improvements made for reliability, efficiency and capacity based on incremental and justified costs. From the Due Diligence baseline and applying experience from the last 40 years of plant improvements, a Phase II Process Study can model, identify, remove and upgrade any bottlenecks in equipment.

A set of baseline and improved efficiency and capacity Proformas can show simplified tables with production, efficiency variable and fixed costs and product pricings leading to margin and capital payback (IRR and years).

With this information, a client can see various cases and make decisions on financing and plan of the begin of payback cycles.

Phase III – Process Frontend Engineering Design [FEED]

Once a decision is made to move forward, develop reasonable project timelines and refine costs to within +/- 10%, a FEED study can begin.

Frontend Engineering Design [FEED] on the run

- New plants can take two years or more to conduct a FEED
- An existing plant has the advantage of a known process that can be quickly evaluated and enhanced.
- However, an existing plant will most likely need new
  - Foundations and superstructure due to modern design codes
  - New instrumentation and controls due to obsolescence and spare parts

Elements of the FEED are:

  - Detailed material baseline balances are performed within the plants and between plants
  - Regulatory Codes are reviewed
    - Environmental Permit Emissions and Operating limits are defined
      - New and evolving regulations
        - In the US – some greenfield plants have set new low emission targets by allowing state and federal regulators to use "similar" technology Best Available Control Technologies and apply them to New and

Relocated ammonia plants. This has caused quite a challenge to design and meet the standards. Some new plants have taken the attitude that they would agree to the new lower standard – then test and adjudicate their permit after up and running. This is a poor management decision and sets a de facto standard for everyone else.

- Evolution from Construction to Operating Permit = a moving target

  - Mechanical Equipment specifications are reviewed or developed
- Equipment
  - Inspections are defined
  - Equipment to be kept, inspected and refurbished is defined
  - Equipment to be replaced/upgraded is defined
- Bids are secured with suppliers to better define costs
- Another round of Proformas are run with costs

Phase IV – Detailed Engineering (The "E' of EPC)

To prepare for construction, detailed designs and drawings need to be developed that meet today's standards and will be used by contractors to bid and install components.

Some of the main elements of detailed engineering for ISBL and OSBL areas are:

- 3-D CAD of entire plant
- Civil (Including foundations and superstructures)
- Piping
- Instrumentation & Electrical

An example of an Ammonia Plant Inside Battery Limits [ISBL] versus Outside Battery Limits [OSBL]

ISBL – Inside Battery Limits = The production plant boundaries would be the Reforming through Synthesis Loop. This would Include:

- Lube Oil Systems – new safety and insurance requirements have increased the size of these units and require a location away from the machine it supplies.
- Hydrogen Recovery – larger and more efficient units are available that provide better operation and quicker payback.
- Start-up Heaters – newer codes require improved safety systems
- Fire Protection Systems
- Demineralized water and Condensate Polishing, Stripping or Recovery
- Electrical and Motor Control Centers

OSBL – Outside Battery Limits = Support systems. These may include:

- Raw and Demineralized water supply systems
- Cooling Towers – new FRP towers can be erected in modules more cost effectively, are more efficient, have better service lives and do not require fire protection systems.
- Natural Gas Supply Systems
- Ammonia Storage Tanks – single and dual wall systems can be evaluated against the available space, cost of containment systems and future expansions and inspection cycles.
- Shipping and export systems
- Package Boilers

Phase V – Procurement (The "P" of EPC)

Procurement is an important role in getting equipment and labor in place at planned costs at the right time to maintain a project schedule and performance. Issuing specifications, setting up bidders lists and responses, issuing Purchase Orders, receiving and reviewing invoices and making payments on-time is a value-added service. Some companies may have these internal services in place, but they are rarely setup to handle a large and time sensitive capital project of the magnitude of a plant relocation.

Phase VI – Construction (The "C" of EPC)

Phase VI-A – Construction – Dismantling and Transportation

The Dismantling/Disassembly planning is a process to intelligently balance size and weight removal of plant elements to meet transportation limits and simplify and minimize assembly.

Transportation - A transportation review on trucking, rail and barge/ship options should be investigated and optimized for cost and time. If importing – have an experienced transporter and importer (for customs forms and fees) on the project team.

Phase VI-B – Construction – Rebuild and Upgrade

Having current and up-to-date sub-contractor contacts is very important. There have been cases where an EPC bid out the job and awarded the contract to the low bidder. This resulted in poor efficiency and quality and led to firing the sub-contractor.

Piping – Lesson Learned - This is one of the major areas of construction that all four of the recent North American new and relocation plants went over on time and costs. A low-cost piping contractor was selected in each case. Piping (new and reused) standards for productivity, quality, quality control (X-Rays and Hydrotests) were neither up-to-date or accurate from the EPC and the subcontractor. In all four cases, the piping contractor that started the job was either replaced of highly supplemented to complete the job. The initial poor productivity and quality led to time delays, extended number and time of piping labor on-site and dramatically escalated costs – for not only piping but cascaded to crane time, scaffolding, and delaying other crafts like I&E, insulation and painting.

Bottom line = Additional time and cost impacts occur when having to change contractors in mid-job. Pick a well-known contractor with the right crew size for high productivity.

High Productivity –

- In a conventional new plant construction – sometimes referred to as "stick built", tasks and timelines are geared to out-of-date construction timelines and standards. When an existing plant goes into a planned turnaround, the reduction of downtime is planned in. Applying a "turnaround plan and mentality" to relocating and rebuilding an existing plant can and has been done.
- The concept of "Modularization" can also be applied. By taking sections apart in modules or building new sections in modules can save reassembly field time.
- 3-D Modeling can aid in supplying take off data and prevent field interference. The virtual drawing can be a valuable training and maintenance aid.
- Mapping and installing field instrumentation into satellite areas reduce cabling costs as compared with the older technique of "home running" field to control systems – without sacrificing reliability.
- Reducing a mechanical completion cycle by 12-months can add a years' worth of production and shorten the payback time.

POSITIVE PROJECT "TO DO'S":

- Safety
  - Have contractors pre-vetted and pre-trained. This will save time of the project start and place an appropriate amount responsibility on your contractor.
  - Layers of Protection – Have your contractors provide safety supervision. In addition, consider having a third-party safety company to supplement any on-site operations or construction

management. Having a safety plan for "day ahead" permits or confined space work will save time and costs.
  - Training – Having you contractors provide training records and matrices – showing that basic safety training and craft modules to do the work have been conducted are up-to-date
  - PPE – Make sure site polices are clearly communicated. Get commitments from management and labor representatives that policies are firm and appropriate use is a condition of employment.
  - Safety Supervision and Support – Begin each day and meeting with an emphasis on safety. Empower anyone to call a job stop if a safety event could cause harm to people, the environment or equipment.
  - Safety Audits – Consider having each supervisor and manager perform a safety audit as part of their field visits.
  - Behaviors – Safety behavior (or lack thereof) is a key to prevent accidents and injuries.
  - Supervision – Make safety performance part of management's job description, performance review and any merit consideration.
- Look at Span of Control closely - The number of subordinates that a manager or supervisor can directly control. This number varies with the type of work:
  - Complex or Variable Work may require one supervisor to a range of six to eight workers, whereas routine
  - Fixed Work may increase it to a ratio of one supervisor to twenty or more.
  - Piping Field Supervision - typically, a maximum of 8 workers per field supervisor
- Work Tracking – How do you know what is the plan and if you are on schedule? Areas such as Piping and I&E can layout an "Earned Hours" set of measures.

As an example, how much time does it take to install "X" linear feet of piping based on:

  - Piping Size (Diameter)
  - The number of Welds

The contractor should know, based on his crew size, craft/skill make-up and experience what to expect for a Weld Failure Rate and time to conduct QA/QC. At the supervisor level, earned hours actual accomplishment versus planned goals should be reviewed daily. If the ratio is one or greater you are on track. If the ratio is less than one, there should be a reason identified and corrected. Project summaries should be provided to Project Managers at least weekly.

REASSEMBLY & REFURBISHMENT

A unique characteristic of a plant relocation is that the equipment has been designed and placed in service for the intended set of conditions over time. When equipment is initially designed and fabricated, it was done so in the past and with fabrication codes (i.e., ASME, NFPA, etc.) in existence at that time. When equipment is decommissioned, moved and set in place, it must undergo inspections and evaluations and consider any fabrication codes changes, and API Fitness for Service and End of Life assessments.

The destination site may require a code review and a "pedigree" of documentation to license or recertify for use. Examples:

- ASME design basis documentation
- U-1 Form
- National Board Registration
- Equipment tag (physically on the unit)

Varying levels of FFS are required.

- FFS Level 1 - For equipment with all the 4-part pedigree available. This level of inspection and review is the easiest. An inspection report would detail potential internal repairs and document no significant shell or nozzle defects. Any noted areas of thinning or surface anomalies would be listed as to what and when to re-examine on the next turnaround period.

- FFS Level 2 – This level would be the same as a FFS level 1, except for a situation with significant shell or nozzle defects. These repairs would require a contractor and AI with code stamps and authority. Any noted areas of thinning or surface anomalies would be listed as to what and when to re-examine on the next turnaround period.
- FFS Level 3 - For equipment with MISSING a part or all the 4-part pedigree. A full reverse engineering exercise would be required and then require state approval to be placed into service.

REPLACEMENT

- The project planning should expect some pieces of equipment may not pass inspection – nor be repairable.
- Based on the size and expected replacement time, high cost and long-lead equipment should be inspected 1st.
- Consider pre-emptively preparing replacement specifications and have RFP on time and cost – to cut down on the replacement timeframe.
- Some equipment may be repairable – but will require replacement by the 1st turnaround

UPGRADE

- As part of the Phase II evaluation, the Owner and Project Team will have an idea of the Original Efficiency and Capacity. Incremental improvements will have been reviewed, justified and approved
- Ammonia Plant Examples:
  - Primary Reformer System
    - Burners – Based on environmental requirements, there are options to install optimized Ultra-Low NOx burners or use high efficiency burners with the SCR or SNCR depending on the NOx permits allowed in the destination site zone requirement.
    - Catalyst Tubes – Catalyst tube designs can be optimized with improved metallurgy, diameter and wall thickness. To improve safety and reliability and reduce the potential for catastrophic failures, an online Thermal Growth Measurement [TGM] and Monitoring system should be considered.
    - Tunnels - New and improved designs now incorporate customized precision refractory shaped blocks (like a LEGO concept). These systems are design for reliability with integral spacing and tolerances built-in. Tunnel Optimal Performance [TOP] – Is a patented enhancement to tunnel walls. The addition of improved near-perfect uniform flow is achieved with strategically placed orifices
    - Convection Section – When rebuilding the convection section, an improved design and heat recovery system can be incorporated. Some units have been retrofitted with coil changes over time, the result can be a “Frankenstein” arrangement. A redesign and rebuild provides an opportunity to optimize:
      - Process Gas Saturation for heat recovery, fuel efficiency and condensate recovery in place of a fixed air preheat system
      - To add SCR or SNCR and use high efficient burners instead of hard to adjust and maintain ultra-low NOx burners
        - SCR (Selective Catalytic Reduction) – by a module in the convection section. Ammonia is sprayed into the SCR to reduce NOx by 90 to 95% - in the range of 30 to 10 ppm.
        - SNCR – Selective NON-Catalytic Reduction – Reduce NOx by injecting ammonia into the system at the most optimum reaction location considering sufficient residence time.

PRE-COMMISSIONING

A good Pre-Commissioning Plan and Team can help to drive mechanical completion. The steps to take ownership from the construction phase when mechanically complete and prepare for start-up include:

- Witnessing and signing off on hydrotests
- Buttoning up (flange, gasket, bolt checks) systems for start-up
- Charging catalyst vessels – but leaving under low nitrogen pressure blanket
- Cleaning, filling, and circulating:
  - Air systems
  - Water system
  - Oil systems
  - CO2 solvents

OPERATIONS STAFFING AND TRAINING

Some projects who are driven by investors may not have an operations group. Some projects who have operations group are challenged to grow their organization. There can be a challenge of building an ammonia plant on a site where no one has had previous ammonia operation experience. A team of experienced supervisors and managers can be recruited to conduct training and pre-commissioning. Operator training simulation systems can be evaluated. A system that can take existing design heat and material balances and add actual control valve response times should be selected. The system should also be able to overlay onto the DCS system and integrate "what if" real world upset cases. This system needs to be in place and new operators begin to train on starting up, running, and shutting down the approximately 6 months in advance of the actual plant commissioning.

Commissioning and Start-up (synonymous) – The process of charging systems with water and gas, firing and heating systems, circulating CO2 systems, reducing catalyst and making product.

SUMMARY OF PRO'S AND CON'S ON A RELOCATED VERSUS NEW CHEMICAL PLANT

- RELOCATION
  - PRO's
    - In the range of 40% of the cost of a new plant.
    - No original design license fee needed
    - Demonstrated and proven production capacity
    - Potential 24-month installation and mechanically complete timeframe – after regulatory permit issuance.
    - 12 to 24 months of "being in production" over waiting on new plant completion.
    - Approximately 50% of the cost will be from Field Erection company
    - Spare Parts - typical life and spare availability is known.
  - CON's
    - Additional inspections required on experienced equipment
      - To provide ASME and other code pedigrees. If documentation missing – Level III Fitness for Service [FFS] reverse engineering can be applied.
      - to ensure adequate remaining life
    - Potential to replace worn out equipment

Schedule Example

- Gantt Chart - Planning is the key to any project. A typical task and timeline chart is provided in Table 1.
- Many Pre-Construction tasks can begin before an environmental permit is issued. However, beginning of construction (breaking ground) cannot begin before an environmental air permit is issued. Recent projects have shown a new environmental permit development and issuance taking approximately one year.

Table 1 – Task and Timeline Chart

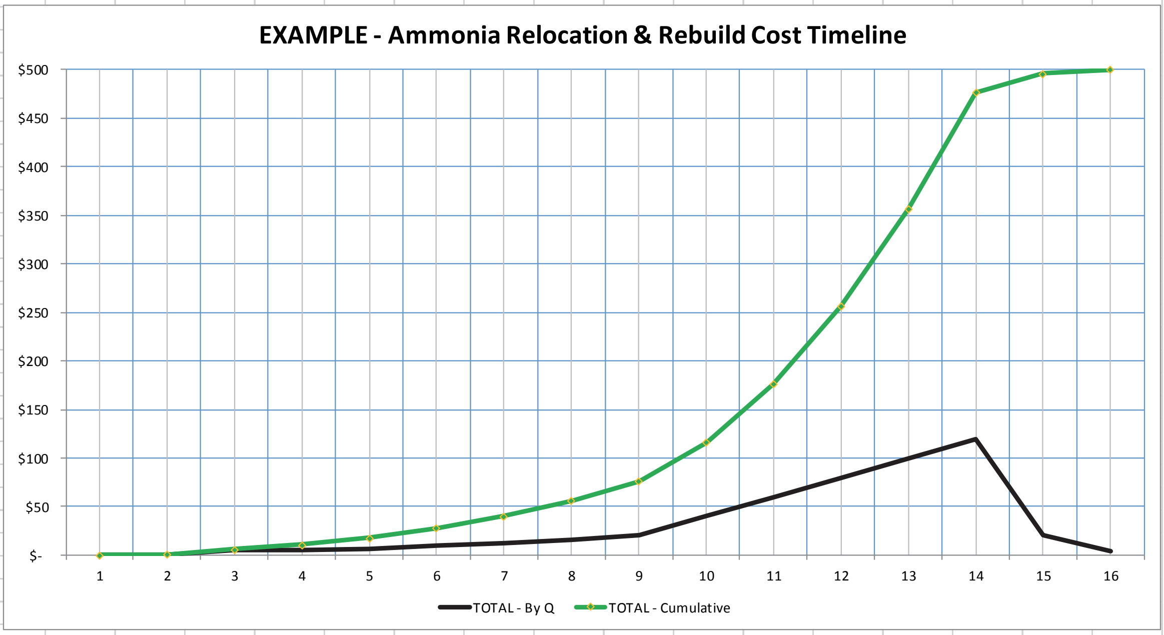
NH3 Relocation and Rebuild	QUARTERS (3 MO)															
Project Elements	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dismantle/Move Plant																
Environmental Permit (Air)																
Frontend Engineering Design [FEED], (Foundations, Underground Piping, Structural Steel, Above Ground Piping, Instrumentation, Electrical)																
Inspections of base equipment and use, rebuild, or replace																
Inspections of Rotating Equipment and Rebuild to Manufacturer's specification																
Foundations & Concrete Base																
Underground Piping																
Setting Equipment																
Structural Steel																
Aboveground Piping																
Instrumentation & Electrical																
Pre-Commissioning																
Staffing & Training																
Initial Start-up																

Cash Flow Schedule Example

- In addition to a task chart, it is very important to develop an accurate estimate of costs over time. A typical cost chart is provided in Table 2.
- The elements of equipment and labor costs should be laid out on the project calendar.
- The peek in costs will generally occur when the labor (headcount) peeks.

Table 2 – Cash Flow Task and Timeline Chart

	QUARTERS (3 MO)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
TOTAL	$ -	$ 1	$ 5	$ 5	$ 7	$ 10	$ 12	$ 16	$ 20	$ 40	$ 60	$ 80	$ 100	$ 120	$ 20	$ 4
Cumulative	$ -	$ 1	$ 6	$ 11	$ 18	$ 28	$ 40	$ 56	$ 76	$ 116	$ 176	$ 256	$ 356	$ 476	$ 496	$ 500



- NEW PLANT
  - PRO's
    - All new equipment.
    - Approximately 50% of the cost will be from Field Erection company
  - CON's
    - Recent new plants have taken 36 to 48-month engineer, procure and construct timeframe after regulatory permit issuance
    - Recent new plants have shown to be 3 to 4 times the cost of a relocated plant
    - Recent new plants have reported 2 to 3 times longer to per-commission and start-up to work out "bugs".
    - Buying a new set of spare parts and establishing a new history of use and repair.