

CONSIDERATIONS FOR USING SURPLUS EQUIPMENT In LOW SULFUR GASOLINE AND DIESEL PROJECTS

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INTRODUCTION

The low sulfur fuel regulations mandated by the federal government's Environmental Protection Agency are approaching. January 1, 2004 for gasoline and January 1, 2006 for diesel. The economics of adding new Hydro-Processing Facilities to remove sulfur from existing gasoline blend streams for most refiners has a negative rate of return irrespective of the chosen technology. While refinery margins have been good in late 2000 and through the first half of 2001, managers and decision-makers are looking for ways to minimize the capital expenditures needed to meet these regulations. Revamps of existing units is being evaluated against new grass roots facilities and the use of surplus equipment is being considered to reduce the cost and enhance the project schedule. Surplus equipment is being considered not only in the revamp units but also in the new grass roots facilities as well. This paper addresses the economics, schedule impact, design, fit-for-service analysis, and maintenance considerations in using surplus equipment as a part of these projects.

ECONOMIC CONSIDERATIONS

Purchase Price

How do you determine the purchase price of surplus equipment? The first step in this process is to know what that same piece of equipment will cost new. The new price can be established by asking your favorite vendor for a price and delivery. The required information to provide the vendor is the equipment data sheets and your company's standards and specifications for that piece of equipment. Alternately there are equipment costs estimating programs that can provide a plus or minus 20 percent or better price for new equipment.

If the cost of the surplus equipment is the only consideration, then try to negotiate the lowest percentage of new equipment price as possible. Typically this will be in the range of 20 to 50 percent of the new equipment price. Factors that can have an affect on the price that can be justified for the project include; the current equipment owner, rehab and modification costs, how well the equipment fits into the process, dismantling and shipping, re-engineering, and the project schedule.

Ownership

The next step is to establish who owns the equipment. This is important not only for obtaining title to the equipment, but it can speed up the negotiations if you can deal directly with the owner or an equipment broker that has been given contractual authorization to sell the equipment. Dealing with a broker that does not have the authority to negotiate can be very frustrating and time consuming. It is a lot like buying a used car “on consignment,” the owner has to approve the final sales price. If your company owns the equipment, then consulting your company’s accountant should allow you to determine the value remaining on the books for that piece of equipment.

The new price has been established and you know who owns the equipment and presumably the asking price. Before you buy or start to negotiate, there other economic factors that must be address before you can determine what the equipment is worth to your project. These include:

- Rehabilitation and Modifications
- Process Configuration
- Shipping Cost
- Re-engineering

Rehabilitation and Modification Cost

Several questions must be answered in order to determine the rehab and modification cost.

1. What is the current condition of the equipment, internal and external?
2. What is the age of the equipment?
3. What inspections and tests need to be conducted?
4. What are the jurisdictional requirements?
5. Does the equipment meet the process and mechanical design requirements?

Establishing rehab cost starts with knowing the current condition of the equipment including how the equipment was taken out of service and stored. This usually starts with a visual inspection and obtaining the operating and inspection records. This “kick the tires” approach by a qualified inspector will provide you enough information to determine if the equipment is worth spending serious money on further inspection and tests. The cost for this initial look is usually a few hundred dollars or less if the equipment is near by and basically nothing if your company owns the equipment. Many times the owner will provide the operating history and inspection records for review at little or no costs. With a digital camera, pictures of the equipment can be sent to you for your review. This does not take the place of a visual inspection, but it can help to get monies approved for further inspections and tests.

The age of the equipment is very important for several reasons. First, it can help established the number of operating cycles the equipment has seen. Second, the year the equipment was manufactured will determine what revision of the code was governing at that time. The year of manufacture can be important if there have been significant changes to the design codes. Most codes have had changes in the last twenty to thirty years and while some of these changes will

not affect the equipment design, some changes like “allowable stress values” for the metallurgy can affect your intended use of the equipment. For example, in the case of a vessel it is possible that it will meet your design conditions under its original design code, but will not under the current code. It is possible to still use the vessel but the amount of inspections, test on the equipment, and calculations that will need to be completed may prove to be too costly in both time and money. If this situation arises the best approach is to let an experienced vessel design engineer review the information and provide a recommendation. There are some guidelines stipulated in the National Board Inspection Code (NBIC) where current allowable stress values can be used in the repairs and alterations of pressure vessels.

Questions one and two have been addressed, you have the inspection records and operating history and the equipment is still viable for use in the project. Now what test need to be conducted to prove that the equipment is fit for the intended service and how much will this cost. The previous service will influence and provide direction for the type of inspections and metallurgical tests to be performed. Input from inspection, maintenance, and an equipment engineer should provide a list of required inspections and tests. A good rule of thumb to use for the cost of these inspections and tests is one to three percent of the new equipment costs. However, if these costs are estimated to be higher than three percent, continue with the cost analysis for you may find you can afford to spend more than three percent.

Jurisdictional requirements can play a large role in the acceptance of pressure vessels, boilers and exchangers, mainly when the equipment is being relocated from one Jurisdiction to another. It is recommended that the new Jurisdiction be contacted prior to purchase of any surplus equipment so that these costs can be included in the economic evaluation. For a complete listing of the Jurisdictions and an overview of their laws, the National Board of Boiler and Pressure Vessel Inspectors can be contacted in Columbus, Ohio. The National Board also has a Website, www.nationalboard.org/codes/jurisdiction.html, which provides an overview of the Jurisdictional Laws, Code Stamping and National Board Registration requirements by Jurisdiction. Another source of information is to obtain a current copy of the “Synopsis of Boiler & Pressure Vessel Laws, Rules & Regulations”, published by the “Uniform Boiler and Pressure Vessel Laws Society, Inc., Louisville, Kentucky. Rotating equipment is usually not covered under these laws unless it has ancillary pressure vessels or exchangers installed as part of the equipment package.

The next step is to establish the modifications and their cost required for the new service. This is not just the design pressure and temperature, but all of the nozzles, man-ways, and flange rating requirements, including their location and size. A process and mechanical data sheet with a sketch of the new equipment is needed. A comparison of the new equipment requirements with the existing equipment will provide you a scope of work for these modifications and a basis for estimating cost. Sometimes this exercise will let you know early that this equipment is going to cost more to modify than a new piece of equipment. This can easily be the case for small carbon steel vessels that require new nozzles and man-ways.

Some guidelines to use for the amount to be expended on rehabilitation and modification cost including inspection cost are:

	<u>Percent of New Equipment Cost For Rehab and Modifications, %</u>	
	<u>Typical</u>	<u>Max.</u>
Vessels: Towers	25	50
Drums	20	40
Shell & Tube Exchangers	15	50
Air Cooled Exchanger	15	40
Pumps with driver	15	50
Compressors with driver	20	50
Reactors	20	50

Spending more than the maximum will usually require schedule drivers to justify the additional cost. If the equipment is a good fit with the project requirements, then these costs will likely be less than the typical percentages shown.

Process Configuration

The ideal time to incorporate surplus equipment into the unit is when the process design is complete; i.e. you have approved Process Flow Diagrams (PFDs) and a Heat and Material Balance. At this point the process and mechanical data sheets are being developed and issued for inquiry and the Piping and Instrument Flow Diagrams (P&IDs) are being developed but not yet ready for review. During this period surplus equipment can be evaluated and incorporated into the design with minimum or no disruption in the engineering workflow process. Later than this will likely cause re-cycle of engineering and design work and earlier than this can cause the unit to be designed around one or a few pieces of equipment that could prove later to be costly. For example, if you find three compressors that are in good condition and can be purchased and modified for a lot less than new cost of two compressors, that still may not be the most economic answer. By using three compressors instead of two, the cost of engineering and design, field materials and construction will increase. Maintenance and operating cost will also increased. The important thing to remember is to know the process configuration before you commit to using any surplus equipment.

Preparation for Shipment and Transportation

The first thought might be to use the typical three to five percent of new equipment cost for freight, which is a common allowance when estimating domestic projects. There are other cost factors that must be considered with surplus equipment such as dismantling and preparation for shipping. This cost can be more than five percent depending on the location of the surplus equipment. If the purchase price can be negotiated FOB equipment site and free and clear of route obstructions, then this concern is removed. The owner and or equipment dealer can usually provide this service. Whether this can be included in the price or not, it is still better to contract

this work to a local contractor. It is usually easy to get transportation cost from one site to another and unloading cost for the equipment at the new location.

If the equipment to be dismantled and shipped has several pieces, then a dismantling and piece-marking procedure is necessary and will pay off when it comes time to re-erect the equipment. This is especially true of large compressors with lube oil systems, and also for air-cooled heat exchangers. Make sure that all of the pieces being shipped will be used when the equipment is to be re-erected. Small valves and piping connecting a lube oil skid with the compressor are often stainless steel and worth shipping. But if the configuration has to be changed for the new location, these valves and piping may become scrape.

Some things to remember about preparations and shipping are:

1. Do not ship anything loose such as valves, instruments, or pipe. It probably will not arrive at the new site. Make sure small items are either in a container or tied down to a pallet.
2. Make sure the equipment is clean with all fluids removed. The Federal and State Departments of Transportation provide these regulations and rules.
3. Support and brace all internals especially refractory in vessels and heaters. These can be successfully shipped when properly braced.

A cost guideline to use for dismantling, preparations and shipping is seven (7) to fifteen (15) percent of new equipment cost. If the cost estimate is higher than 15% for dismantling and shipping, then this equipment may have too many problems associated with relocation.

Re-Engineering Cost

The optimum timing for incorporating surplus equipment into the project was previously stated as being when P&IDs are being developed. But what if the project has progress further; do you just forget the surplus equipment? If you have already let a purchase order for the equipment, the answer is usually always YES! Cancellation charges will likely eat up any savings and then some. If you have not let the purchase order then you can evaluate the re-engineering cost based on where you are in detail design. The P&IDs, Plot Plans, and Equipment data Sheets can be revised for a piece of equipment at a relatively small cost, but if you have progressed into foundation and piping design then usually it will not pay to re-engineer around a surplus piece of equipment.

The maximum amount to allow for re-engineering cost of using surplus equipment can be determined if you subscribe to the idea that you should not spend more to re-engineer than the engineering cost associated with that piece of new equipment. If the new piece of equipment is 30 % of the Total Installed Cost (TIC) of that equipment and engineering is 12 to 15 percent of the TIC, then the re-engineering cost should not exceed 3.6 to 4.5 percent of that equipment's new cost.

Potential Cost Savings

The cost savings depends on all of these factors.

	<u>Percentage of New Cost</u>		
	<u>Low, %</u>	<u>Typical, %</u>	<u>Max. %</u>
Purchase Price	10	30	50
Rehab & Modifications	10	20	50
Process Configuration	0	0	10
Preparations & Shipping	7	11	15
Reengineering	<u>0</u>	<u>2</u>	<u>5</u>
TOTAL EQUIPMENT COST	27	63	130
Savings (as percent of new cost)	73	37	-30

As indicated, the potential savings can range from 73 % of new equipment cost, to actually costing more at 130% of new equipment cost, i. e., no savings. More than likely the savings will fall in the typical range of 37 % of new equipment cost. The purchase price is certainly a big factor in the economic analysis and it is the one area where the buyer is in control. Once the equipment is purchased, there will not be any surprises if the necessary work was done prior to final negotiations of the purchase price. Develop a checklist and make sure all of the above factors are considered prior to making a decision to purchase and use surplus equipment.

A project executed in the late 1980's that considered all of these factors and determined their cost prior to commitment provided an equipment savings of about \$2.5 million. This chemical plant was relocated to the Gulf Coast. The equipment was inspected, refurbished, and had minor modifications made to meet the new service conditions. The process configuration was not changed significantly and by making the decision to use surplus equipment at the correct time, re-engineering was avoided. The new equipment cost had previously been estimated at about \$6.5 million. The actual refurbished cost was about \$3.5 million for a savings of about 46%.

PROJECT SCHEDULE

The use of surplus equipment can often provide significant schedule savings, especially if a piece of equipment is on the critical path for project completion. If a piece of equipment like a compressor or a fractionation column can be located, purchased, and placed in service for a cost less than or equal to the new equipment price, then the savings to the project can be enormous compared to the cost of that piece of equipment. The increase in profits and Net Present Value (NPV) of the project can be significantly improved by placing the unit in operation one to three months early. This can be the justification for paying new equipment price or even higher than

new for a critical path equipment item even though the project savings for this piece of equipment may be zero or negative.

Currently equipment fabrication shops have good delivery schedules, but the forecast is for deliveries to extend as the push to execute projects to meet low sulfur fuel requirements intensifies. Delaying the expenditure of capital as long as possible can also have a positive affect on corporate earnings. Since these regulation driven projects have a negative NPV, the project economics can also be improved by not spending capital until necessary. This can only be accomplished if you have your project well planned with all of the equipment purchases secured. Surplus equipment can have a significant role in achieving this goal.

The following provides two examples of surplus equipment providing project savings due to schedule improvement. First; A gas turbine powered electrical generator was dismantled, refurbished to OEM specifications in an OEM repair shop. The equipment savings was about \$2.5 million but the real savings came when the unit was brought on line 6 months sooner than if a new turbine generator had been ordered.

The next example involved modifying an existing fractionation tower including adding new product draws. A new column could have been purchased for \$3.5 million. The cost to modify the existing column was about \$4.2 million. By utilizing the existing equipment, the project was completed as scheduled in 12 months. If the new column had been purchased to replace the existing column the schedule would have been extended by two months and the unit would have been down for 70 days instead of 30 days. The savings was estimated at \$3.0 million even though the modifications cost \$700,000 more than a new fractionation tower.

DESIGN CONSIDERATIONS

Equipment Selection Criteria

Before starting to consider different options for using surplus equipment, a sized equipment list should be prepared based on using all new equipment. Information on the list (equipment shopping list) should include: sizing and performance information, design pressure and temperature, corrosion allowance, and metallurgy requirements. If there are options for size, performance, and metallurgy, these should also be indicated on the equipment list. One unique area of hydrotreaters is the multitude of considerations in selecting a metallurgy that is fit for the intended service. The primary causes of corrosion and equipment failures in hydrotreater units include:

- Hydrogen stress cracking (HSC) of carbon steel at relatively low temperatures.
- High temperature hydrogen attack of carbon and low alloy steels.
- High temperature hydrogen sulfide corrosion.

- High temperature sulfidation.
- Stress corrosion cracking of austenitic steels.

All of these types of corrosion and equipment failures are well documented and should be taken into consideration when analyzing the use of surplus used equipment. These should also guide in the development of an inspection plan prior to purchase. The metallurgy type and previous service conditions are very important in determining if the proper procedures, care, and maintenance were used in removing the equipment from service and placing it in storage. For example: if the equipment was fabricated from austenitic stainless steel, was it correctly washed with a chloride inhibiting solution, insulation removed, properly dried, and stored under a slight nitrogen pressure. If these procedures were not followed the chances for successfully placing this equipment back into a new service are greatly reduced.

Available Documentation

Documentation considerations when purchasing surplus equipment include:

1. **Does the equipment have the Original Manufacturer's Nameplate?** If the nameplate is missing, the Original Equipment Manufacturer (OEM) is the only source of replacement. The OEM and their ASME Authorized Inspector (AI) must be able to exactly identify the equipment and verify to the Jurisdiction that it is in fact traceable back to the OEM's Serial Number or National Board Number. The original steel stamping on the equipment can verify this identification but this often is not available. It is in the control of the AI and the Jurisdiction. The National Board Inspection Code (NBIC) provides rules for replacement or duplicate nameplates. If the State or Jurisdiction has no law or specific requirements, then generally the owner can use API-510 code for inspection and assurance that the equipment is suitable for continued safe operation.² If the OEM is still in business then obtaining a new nameplate is achievable, but if the OEM is out of business then getting a new nameplate is virtually impossible.
- **Is the OEM Equipment Data available?** This information is valuable in determining, if the equipment meets the present code requirements, provides confirmation of detail metallurgy and manufacturing procedures, and information to support detail engineering. When equipment, like a pressure vessel is registered, the OEM sends the original and a copy of the ASME Manufacturer's Data Report to the National Board. The National Board keeps the Data Reports on file, so even if the OEM is out of business, a copy of the Data Report can be obtained for a small fee. This is especially important to owners in meeting the requirements of their Process Safety Management and Mechanical Integrity Programs.

General Specifications and Standards

Seldom will surplus equipment meet all of the purchaser's general specifications and standards, unless the purchaser's corporation owns the equipment. Even then the equipment may not meet the current standards, since as codes change so do a corporation's specifications and standards.

This issue must be analyzed as part of the initial equipment inspection to determine if the equipment can be accepted. Safety is the first consideration and any risk would need to be mitigated prior to acceptance.

FIT-FOR-SERVICE

Okay, the purchase of the equipment is justified based on the economic analysis. By utilizing this equipment the schedule can be improved by two months. The next step is to perform a fit-for-service analysis. API 579 provides fitness-for-service assessment techniques for pressurized equipment in the refining industry. This publication augments the requirements provided in API 510 for pressure vessels. As stated API 579 “reflects the best practices know in the industry, but is not a mandatory standard or code”.¹ An individual that is familiar with the manufacturing design codes and standards should perform the fit-for-service analysis. A licensed engineer should perform or supervise this analysis.

The first step is to do an inspection of the equipment. For pressure vessels, API 510 provides the requirements for inspection and testing.² The requirements for exchangers and rotating equipment can be developed using the appropriate ASME and API Codes as guidelines. The resulting inspection reports and records will be the basis and provide direction for the next step, which is the fitness analysis. If the inspection reports conclude that there are no flaws in the equipment, then the analysis will not be necessary. The inspection report then becomes part of the documentation needed to place the equipment in the new service. If there are flaws, then API 579, Section 2 provides an eight-step procedure for the fit-for-service assessment.¹

Documentation

All of these eight steps are important, but after a complete visual inspection and non-destructive examination of the equipment, the next most important step is to obtain the required data. Without the equipment data the fit-for-service analysis will be time consuming and costly at best and perhaps impossible. The list of data requirements for this analysis is common and should be available along with the equipment. The list generally includes:

- Manufactures Data Report
- Fabrication Drawings
- Original or Updated Design Calculations
- Inspection records at the time of fabrication
- Design Specifications
- Material test Reports
- Record of the original Hydro-test
- Maintenance and Operating History
- Process and Mechanical Data Sheets

Physical measurements and inspections can be made if some of the above data is not available. Complete data will insure that an analysis can be made. When the analysis is correctly completed, the equipment can be placed in service with confidence that it can be safely operated at its intended operating conditions.

Equipment Storage

If the equipment has been decommissioned and placed in storage, the first question becomes, “What is the current condition of the equipment and how is it stored”? Once taken out of service, the best way to maintain the equipment is to first remove any external insulation and clean it inside and out. Next place the inside under an inert environment such as nitrogen. Removal of the external insulation is usually an expense the owner does not wish to incur. An alternative is to regularly inspect and repair the insulation. This will also become cost prohibitive in time but should be considered if the equipment is likely to be placed back in service within one to two years. Properly stored and maintained equipment with the documentation to support this effort can bring value to the owner in the form of a higher sales price. The buyer can also benefit with a resulting higher remaining useful life expectancy.

The shutdown and storage records that include periodic inspections can provide useful information in determining if any deterioration has occurred. Some amount of non-destructive tests and inspections will need to be performed prior to purchase, however with good and complete records for shutdown and storage, this inspection time and expense can be minimal.

MAINTENANCE CONSIDERATIONS

A maintenance plan for the surplus equipment should be developed prior to placing the equipment in service. The first step in developing this plan is to determine the difference in the previous and new design and operating conditions. Most equipment scenarios will fall into one of the following four categories.

1. New service conditions and new design conditions.
 2. New service conditions and same design conditions.
 3. Same service conditions and new design conditions.
 4. Same service conditions and same design conditions.
- Service conditions means process fluid and operating pressure and temperature.
 - Design conditions means design pressure and temperature.

The maintenance plans will vary depending on which of the four categories the equipment falls under. Categories 3 and 4 generally will allow the same maintenance program both for the previous and new service. This assumes that for category 3 the new design conditions meet the applicable code requirements and the new design calculations allow a corrosion allowance equivalent to a new manufactured piece of equipment. If the maintenance records and plans are obtained with the equipment, then this becomes a simple review, edit and approval exercise. If these plans are not available, then the use of maintenance plans from similar services can be used as a guideline in developing an equipment specific maintenance program.

If the equipment falls into categories 1 or 2, then a maintenance program will need to be developed based on the new service. The information needed to develop this program includes:

- Maintenance and operating history from the previous service.
- Inspections reports from the equipment evaluation prior to purchase.
- Inspection, repair, and modification reports developed after purchase.
- Maintenance plans from similar equipment in similar service.

The remaining life of the equipment will determine to a large extent the maintenance plans. The procedure for the “remaining life assessment” provided in Section 2 of API 579 can be used to establish the inspection frequency and an in-service monitoring plan, if deemed necessary. In-service monitoring is very important when placing surplus equipment in service and design conditions that falls into categories 1 and 2. It may be difficult to precisely predict the future equipment deterioration rate in new service and design conditions and thus in-service monitoring becomes essential. The in-service monitoring methods discussed in API 579 typically include:¹

- Hydrogen Probes
- Corrosion Probes
- Ultrasonic Examination
- Acoustic Emission Testing
- Measurement of Process Variation

Some or all of these methods can and will be used in the maintenance plans and can provide confidence in establishing the equipment’s remaining life.¹

A Hydrocracker Unit was relocated to the Gulf Coast from another country. All of the pressure vessels and exchangers had to be certified through a new set of calculations for the new design conditions. The equipment was proven fit-for-service through calculations, metal thickness measurements, and re-habilitation as required by the inspection report. There was some concern involving the corrosion rate of some exchangers since the hydrogen partial pressure was increased for the new design. An acceptable corrosion rate had been determined by calculation. The exchangers were installed in parallel with corrosion probes and isolation valves so they could be taken out of service. After two checks of the actual corrosion rate via the probes over an eighteen-month period, the calculations and expected equipment life were verified.

When placing surplus equipment back into service, it is important that the maintenance plans are developed based on an “ongoing mechanical integrity” philosophy rather than a “breakdown maintenance” philosophy. As discussed in OSHA 1910.119, section 9, the elements of a mechanical integrity program include:³

- Proper identification and categorization of equipment.
- Inspection and testing.
- Development of maintenance procedures.
- Training of maintenance personnel.
- Establishment of criteria for acceptable test results.
- Documentation of test, inspection results, and manufacturer’s recommendations, if available.

Summary

Surplus equipment can be re-commissioned into new or same service cost effectively and with confidence. The key elements for successfully accomplishing this goal include:

- Develop a complete evaluation of the equipment to establish cost and schedule affects prior to commitment.
- Make certain the design conditions can be meet cost effectively.
- Develop a “fit-for-service analysis” that will provide the basis for the beginning of the equipment’s new life.
- Develop a pro-active maintenance program with a mechanical integrity philosophy.
- Operate the equipment within the new service and design conditions.

Literature Cited

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2. Pressure Vessel Inspection code: Maintenance Inspection, Rating, Repair, and Alteration, American Petroleum Institute (API) 510, Eight Edition, June 1997, Addendum 1, December 1998.
3. Occupational Safety Hazard Association, OSHA, 29XFR1910.119 Appendix C – Compliance Guidelines and Recommendations for Process Safety Management (Non-mandatory), Section 9. Mechanical Integrity.