

OIL SYSTEMS — DESIGN FOR RELIABILITY

by

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ABSTRACT

The speaker will briefly review the type of problems which have been experienced with lubrication and seal oil systems and their impact upon process compressor train reliability. Recommendations for reducing these problems through improved specifications and appraisal of system design will be discussed. Highlights from the new API Standard 614 will also be reviewed.

On our Jersey affiliate plant startups today one of the highest risk items of plant delay is judged to be machinery, principally centrifugal compressor equipment trains. The use of single train compressors in process units has left the process particularly vulnerable to the slightest problem with this equipment. While pumps may seize and reciprocating compressor parts may fail, the process usually continues onstream because we have installed a spare or the machine is only a fractional capacity unit.

That centrifugal compressors are a high risk item is not just a generalization or an industry rumor; our own recent survey of over 50 affiliate plant startups revealed it. Surveys by other companies have also confirmed this fact for their own organizations. For us, machinery startup problems appeared to be so severe in recent years that Esso Engineering undertook a special study of all plant startups since 1964 to identify the nature of the problem. We covered many plant types including refining and chemicals, grass roots facilities, and additions to existing facilities. Nearly 300 trains of compressor equipment were involved.

Lube and seal oil systems clearly stood out in our study as a problem area affecting train reliability. The incidence of oil system problems were the highest of the

type problems encountered, and next to rotor dynamics was the second highest culprit contributing to potential delays per compressor train. Basically, the majority of these problems were attributable to *vendor design errors* and *quality control errors*.

I plan to cover in my talk today, how we can reduce these systems problems at the design stage and achieve an acceptable level of oil system reliability through the:

1. Use of the new API 614 oil system standard.
2. Incorporation of specific options to this oil system specification.
3. Appraisal of specific areas of the vendor's design.

Before going any further, let us briefly examine the type of problems which were affecting oil system reliability to cause 192 days of potential plant delay or about 1½ days of plant delay per compressor casing. Of the oil system problems encountered, dirty systems was our principal single cause of delay. It accounted for approximately 23% of our system problems. Consoles arriving on site were found improperly painted, extremely dirty (full of metal chips and slag), or else were improperly sealed and protected by the vendor to endure abuse at the construction site while waiting to be commissioned. Another problem, probably associated with purchasing unknown makes of components, has been poorly designed oil filters supplied by the compressor vendors. No need to describe the havoc which occurred particularly when the filter elements collapsed in service or permitted internal bypass of dirty oil to the bearings. When caught early, problems of this type did not cause plant process disruption but did result in extended oil system field flushing programs to the detriment of project commissioning schedules. In some instances, system flushing took up to 5 weeks to complete because several of these deficiencies were present and also because poor field flushing procedures were employed!

- UTILIZE NEW API 614 STANDARD
- CONSIDER SPECIFIC DESIGN OPTIONS
- APPRAISE VENDOR'S DESIGN

Figure 1. Improving Oil System Reliability at Design.

% OF PROBLEMS	PROBLEM	DAYS OF
		PLANT DELAY
		POTENTIAL
25	DIRTY SYSTEMS	55
10	CONTROLS	6
5	O/H TANK BLADDER FAILURES	12
60	MISC. NON-REPETITIVE OR UNSPECIFIED PROBLEMS	119
100		192

Figure 2. Oil System Problems.

Approximately 10% of our problems were caused by incorrect pressure switch settings on oil pump controls and another 5% caused by failure of bladders on overhead oil accumulators due to sharp edges on the bladder stop valve.

Approximately 60% of our system problems, however, were due to non-repetitive type items. These included such things as:

1. Reservoir internal baffles which restricted oil flow to the pump suction piping.
2. Pump piping located such as to take suction at the drain portion of the reservoir's sloped bottom which would have brought dirt and water laden oil to the pumps.
3. Piping to oil pumps which permitted vapor pockets or vapor binding, thereby resulting in pump seizures or interruption of oil flow to cause compressor train trip outs.
4. Seal oil traps which failed to function due to incorrect selection of the gas reference pressure. Corrections in this case could only be made after the machine was shut down and the compressor purged to permit gas piping modifications.

We feel that most of these errors could have been caught through closer design review of the vendor's drawings and data sheets. Our inspectors also could have caught some of these if it is true; however, we feel that inspection should serve as our "second line of defense." We also believe that a more detailed oil system specification flagging these areas of concerns or designs, will permit the user and his inspection forces to better monitor the vendor's quality control and reduce the occurrence of these type problems. The end result will be systems having an acceptable level of quality and reliability, at least compatible with that of the compressor train.

The newly adopted API Standard 614, entitled "Lube & Seal Oil Systems for Special Purpose Applications," we believe provides just such a specification. This standard, to be issued before the end of this year, will take precedence over the oil system sections now

covered in several other special purpose machinery API documents. Revisions to API 617 Centrifugal Compressor is currently underway and will reflect this change by complete deletion of those sections dealing with lube and seal oil systems.

In the past, not enough emphasis was placed on system details either during the bid review stage or at the coordination meeting by either the purchaser or vendor. Review was concentrated instead on the compressor or driver itself. Oil systems could be and were often "farmed out" by the compressor vendor to inexperienced fabricators having little appreciation for the criticalness of component selection and installation. Responsibility for the system design was not often clear as to whether it belonged to the compressor vendor or the system fabricator. Oil systems should now get the attention they deserve due to existence of the API 614 industry standard.

This API Standard includes several *noteworthy* additions and updated industry practices compared to presentation on this same subject in the current official "Special Purpose" machinery API standards such as 617, 612, and 613. Over 30 oil and chemical industry firms, about 15 contractors and 15 machinery vendors contributed their input to this new API standard. Therefore, this standard should contain the needed emphasis on system design and reliability. By utilization of this detailed document, certain pitfalls should be eliminated and fewer surprises should be experienced after release of the purchase order regarding the oil system package that was purchased.

Let's review some of the highlights of this new industry standard.

SCOPE

The scope covers the minimum requirements for *lubrication* systems, *oil type shaft sealing* systems, and *control oil supply* systems for "Special Purpose" machinery applications. Thus the API 614 systems may be applied to serve compressors, gears, pumps and/or their drivers. Internal combustion engines would not normally be covered by this standard.

Systems are to be suitable for a minimum of 3 years continuous operation.

- SCOPE
- SCHEMATIC
- RESERVOIR AND DEGASSIFIER
- OIL PUMPS
- FILTRATION
- COOLERS
- SEAL OIL TRAPS AND DEMISTERS
- PIPING, VALVES & ACCUMULATORS
- SHOP TESTS
- PREPARATION FOR SHIPMENT

Figure 3. API 614 Standard Improves Coverage.

Machine coast-down time and block-in time requirements, if any, are to be noted on the oil system data sheets.

SCHEMATICS

Included are over 15 schematics describing in considerable detail:

—Lube and control oil systems.

—Seal oil systems with either overhead tank or a combined lube/seal system without an overhead seal oil tank.

—Required instrumentation, controls and valving.

—Several acceptable arrangements for coolers, filters, and transfer valves.

—Acceptable pump arrangements for centrifugal and positive displacement pumps.

To avoid the problem of “after order” surprises mentioned earlier, this standard stipulates that both purchaser and vendor are to agree to a mutually acceptable system *prior* to release of the purchase order.

RESERVOIR & DEGASIFIERS

Reservoir levels and capacities are better defined as regards maximum run down levels, minimum and maximum operating reservoir levels.

A free oil surface in the reservoir of at least 0.25 ft²/gpm of oil is required so as to enhance air disengagement from the oil.

Special reservoir construction features to neutralize static electricity and details for degassing tank facilities are also described. These are considered optional items.

Fabrication drawings of the oil reservoir, and degassing tank are required for the purchaser's drawing review.

No interior coating or paint is to be applied unless the nature and method of application is approved in advance by purchaser.

Oil system capacity, where sour seal oil is not returned to the system, is to be designed so that *no* oil makeup will be required for at least 3 days of operation.

OIL PUMPS

The sizing criteria for pump capacity is based upon maximum system usage and transients, including allowance for machinery train component normal wear.

The *main* oil pump is specified to be steam turbine driven and the *standby* pump is to be motor driven.

Low flow protection for booster pumps are described including the location of the associated oil filters.

All pumps are to have flooded suction and be arranged to avoid air or gas pockets in the suction piping.

OIL FILTRATION

Oil filtration is now to be 10 microns (nominal) instead of 25 microns. For piston pumps, 5 micron filtration is to be provided.

For continuously lubricated couplings, a 2 micron *secondary* filter is considered optional. A recommended alarm and bypass piping arrangement around this filter is described but is considered an optional feature.

Bypass relief valves are specifically prohibited from oil filters now.

Oil filters are to have a minimum collapsing pressure of at least 50 psi differential pressure.

Control oil is to be filtered to 10 microns. Dual filters and transfer valves are required, if the control oil stream is separate of the unfiltered lube oil flow.

OIL COOLERS

Oil cooler tubing water side velocity, at rated conditions, is to be 5 to 8 ft/sec. A water side fouling factor of 0.002 and a maximum water side Δp of 10 psi are specified.

A bypass arrangement around coolers, for temperature control, is an optional feature.

SEAL OIL TRAPS & DEMISTERS

Automatic seal oil traps are specified for pressures up to 300 psig. Above this, a snap acting level controller and separate control valve is required.

Mist eliminators are required where the process gas vented from the seal oil traps is piped back to compressor suction.

PIPING, VALVES AND ACCUMULATORS

Stainless steel piping is to be furnished downstream of filters. Socket welded fittings in this piping are *not* allowed.

Oil drains are now to have 1/2 in/ft instead of 1/4 in/ft slope.

Continuous flow transfer valves are to be furnished with stainless steel plugs and steel bodies.

A large fabricated bladderless type oil accumulator can be selected as an option instead of the commercial bladder type accumulator.

SHOP TESTS

Optional shop tests for the oil system can include a check of its operation, cleanliness or sound levels. Details of the test procedures are covered, except for the sound level test which must be specified by the purchaser.

An optional shop test which includes running of the major machinery using the purchaser's oil system, is also described.

Oil system shop tests are to be run using oil having the same characteristics as that for site operation. Oil pressure and temperature conditions during test must also simulate those for site operation.

PREPARATION FOR SHIPMENT

Systems are to be suitably prepared for outdoor storage at the job site for at least 3 months protection.

- COMBINED VS. SEPARATE LUBE - SEAL OIL
- DRIVER TYPES FOR MAIN & STANDBY PUMPS
- PURIFIER
- DEGASSING FACILITY
- OIL MIST ELIMINATOR
- RESERVOIR INSULATION
- BLADDERLESS ACCUMULATOR
- STAINLESS STEEL PIPING
- OPERATIONAL SHOP TESTS

Figure 4. Other System Design Features to Consider.

Solid, full face gasketed metal covers ($\frac{1}{4}$ " min. thickness) retained by 4 bolts are to be furnished for all flanged openings. Steel plugs or caps are required on all unpiped threaded openings.

Many of the problem areas experienced with our oil systems, it should be noted, have been covered by this standard. The API 614 Standard can therefore, also serve as a check list for the user and his inspector to ensure that no items are overlooked either at the design stage or prior to oil system shipment from the vendor's shop.

There are several options to which the user needs to address himself and which could affect oil system reliability. We would appreciate your comments on some of these items after my talk.

COMBINED VS. SEPARATE LUBE AND SEAL OIL SYSTEMS

We prefer combined oil systems in all services except where the gas handled by the compressor can cause deterioration of the oil qualities. For example, we have found that gases containing even traces of H_2S can contaminate the so called "sweet" oil or outer seal oil even though the "sour" oil from the traps is not returned to the reservoir. Buffer gas injection at the seals has not always proven to be an effective barrier to oil contamination since a totally reliable source of buffer gas is generally not available at startup. Therefore, we would generally specify separate lube and seal systems in these cases.

DRIVER TYPES FOR MAIN AND STANDBY OIL PUMPS

The majority of API representatives appeared to favor a motor driver for the standby oil pump and a steam turbine for the main pump drive. We would appreciate your comments today regarding the reliability achieved with this arrangement.

PURIFIERS

We have found it necessary to include water removal equipment for lube systems where the main machine is steam turbine driven. We prefer the centrifuge type because of its effectiveness and lower cost.

DEGASSING FACILITY

On more recent units, we have been including degassing facilities when inner seal oil leakage is to be returned from the traps to the oil reservoir, particularly on compressors handling refrigerants or hydrogen-rich gases. Your experiences on the effectiveness of degassing facilities would be of interest to us.

OIL MIST ELIMINATORS

Our practice is to specify oil mist eliminators when refrigeration machines are involved or where seal oil carryover could cause process contamination problems.

RESERVOIR INSULATION

We understand that some users insulate their oil reservoirs to avoid condensation problems and specify reservoir insulation not only for cold climate installations. Perhaps we can hear some comments on this today.

BLADDER VS. BLADDERLESS LUBE OIL ACCUMULATORS

We prefer to use the fabricated bladderless type oil accumulator design where large oil systems are involved (requiring more than say 4 commercial bladder type accumulators). Cost savings are possible and there are certain inherent benefits—it is easier to monitor the operating condition of the accumulator and there are no ruptured bladders to worry about.

STAINLESS STEEL PIPING

Our normal practice is to specify carbon steel slip-on flanges on stainless steel pipe as it is generally a cost saver. Valves in this portion of piping could also be carbon steel with stainless steel trim instead of requiring complete stainless construction, provided that the valves can be removed for cleaning. (Either flanged ends or threaded ends furnished with nipples and flanges will meet this latter requirement.)

OPERATIONAL SHOP TESTS

We feel that these tests are not the most effective or economic method of insuring system cleanliness or validation of system operation. Instrumentation which was tested and calibrated during the test can be damaged either in shipment or during the site construction phase,

- PUSH FOR INFORMATION EARLY
- CHECK SCHEMATICS AND DATA FOR COMPLETENESS AND ACCURACY
- CHECK FOR OPERABILITY, SAFETY AND MAINTAINABILITY
- CHECK RESERVOIR FABRICATION DRAWINGS
- CHECK PIPING LAYOUT
 - VAPOR POCKETS
 - CLEANING AND FLUSHING OPERATIONS
- CONSIDER COMPRESSOR SEALING REQUIREMENTS
 - AIR RUN-IN @ SITE
 - MINIMUM PROCESS SUCTION PRESSURE
 - SETTLING OUT OR BLOCK-IN PRESSURES

Figure 5. Followup with Design Appraisal Effort.

thus negating the advantage of the test. We would also anticipate that there will be difficulty in scheduling all instrumentation and switches for the shop test. Actual heat loads, line routing, elevations, piping slopes, seal oil and gas reference pressures would be difficult and costly to simulate. It is our opinion that combining the oil system test with that for the compressor tests at the vendor's shop also provides little advantage in view of the costs and scheduling problems involved. We would appreciate your comments on this.

Even after developing such a complete oil system specification, our company feels that it is necessary to do one more thing—that is, appraise the contractor's and vendor's design work. Once equipment is purchased for a project, we begin our design appraisal of the system utilizing one of our experienced machinery engineers. His efforts would consist of the following, for example:

Push for quick submittal of completed API oil system data sheets, schematics, bill of materials, and requested drawings from the vendor or contractor.

Perform a detailed check of the system design, including all component sizing and selections. He would review, for example, pressure switch settings and also pressure switch action, including consideration of utility failure. In general, he makes sure the system is operable, safe and maintainable.

Check vendor's fabrication drawings of the oil reservoir and degassing tanks to ensure no problems of the type mentioned earlier and that maintenance access is provided.

Check that flanges or other removable connections have been provided throughout the oil piping system to permit complete removal of piping. This is required for initial system cleaning and inspection during the field flushing operations. Provision to insert felt pads at bearing oil feed points to evaluate the success of system field flushing operations, would also be considered by him.

Check the basis for the compressor vendor's seal reference pressures. He would also ensure that the seal oil system can cope with all conditions of compressor operation—including compressor air run-in operation at site, minimum process suction pressure, settling-out or block-in pressures.

These appraisal efforts appear to be paying-off based on recent plant startup feedback.

In summary, we feel that the user can benefit greatly from utilization of the new API 614 Standard in specifying his oil systems in order to achieve the quality and reliability required of this type equipment. This standard could also serve as a good check list for the *user* and *inspector* to ensure that oil system design and fabrication requirements have been met.