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MINIMIZATION OF INDUSTRIAL OIL WASTES

United States Federal and state controls are expected to result in continued increases in the cost of waste oil disposal. A significant portion of the waste oil generated by industry could be eliminated through management initiatives and technical improvements. Source reduction, recycling and waste oil treatment are the most common approaches for waste oil reduction. Relatively inexpensive off-the-shelf equipment used in conjunction with routine oil analyses can usually result in waste reductions of 50 to 90%. Savings associated with comprehensive oil management programs typically result in a payback of investment costs within 1 to 3 years.

1. INTRODUCTION

Approximately 55% of all used oil in the United States enters a used oil management system, and 45% is disposed as a waste through landfilling, incineration, or dumping. This means that in 1983 nearly 1.5 million m^3 were disposed as a waste [1]. Most industrial waste oils have compositions similar to the virgin oils but with impurities such as fine suspended metal particles, dust, water and oxidation and decomposition products. Contaminants in used oils generally result from normal usage, however, significant quantities may be introduced through poor management practices.

Several states regulate waste oils as hazardous waste. In addition, federal regulations now being considered would mandate more stringent control over industrial waste oils throughout the nation. These regulatory programs are having the impact of significantly increasing the costs of managing waste oils. Many facilities that had grown accustomed to being paid for their waste oils are now faced with disposal and/or pickup fees for the same materials.

This situation is expected to worsen in the United States in coming years as regulatory controls increase while available disposal options are reduced. Waste oil

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minimization represents the most attractive approach to controlling costs and liabilities to reasonable levels.

2. CHARACTERISTICS OF INDUSTRIAL WASTE OILS

Industrial generators use three major types of oil: straight mineral oil, emulsified oils and synthetic oils. Table 1 presents a summary of the major operations which generate waste oil along with information concerning make-up and additives.

Table 1

Types of industrial oils

Oil type	Major constituent	Additives
Hydraulic	Paraffinic base	Rust and oxidation inhibitors
Turbine	Paraffinic base	High temperature oxidation inhibitors
Metalworking		
Cutting & grinding	1. Straight mineral oil	Neat oil
	2. Emulsions	Surface-active emulsifying agent
	3. Synthetic fluids	Water
Metal forming	Straight mineral oil, tallow, lard, palm oil	Wear reduction additives
Quenching	Paraffinic base	Oxidation inhibitors
Transformer	Straight mineral oils paraffinic or naphthenic	None
Refrigeration	Naphthenic	Friction modifiers
Compressor	Paraffinic base	Oxidation inhibitors
Natural gas engine	Paraffinic base	Rust inhibitors, antifoam, antiwear, detergent/dispersant
Railway	Naphthenic	Detergent/inhibitor package
Marine	Napthenic or paraffinic base stack/high additive	Detergent/dispersant, antiwear, rust inhibitors, detergent/dispersant

The primary characteristics of an oil necessary to maintain effectiveness are:

Viscosity sufficient to seal in the presence of internal system pressures.

The ability to rapidly settle and separate insoluble solids.

Stability relative to oxidation to protect against rust and corrosion.

Film strength sufficient to reduce friction and minimize wear.

Even in a completely sealed system, forces combine to contaminate and otherwise compromise the critical operating properties of oils. The causes of oil deterioration and degradation are highly system-specific. They commonly include bacteria, heat, metal particles, oxidation, tramp oils and greases, solvents, dust and water contamination. The impact of this degradation leads to a change in the physical and chemical properties of the oil. The critical properties often altered include:

flash point,
corrosion rates,
foaming,
solids content,
viscosity,
gravity,
water content,
acid number.

Table 2 presents specific causes of oil degradation and their impacts.

Table 2

Causes and impacts of oil degradation

Cause	Effect
Excessive operating temperatures	Promotes oxidation Increases viscosity Causes sludging
Water contamination	Promotes oxidation Promotes rusting Forms oil-water emulsions impairing lubrication
Metal particles from wear	Promote fluid oxidation Accelerates wear
Dirt or other abrasive contamination	Accelerates wear
Air entrainment	Foaming and aeration causes impairing lubricating impaired properties

3. ESTABLISHING AN OIL MANAGEMENT PROGRAM

Many industries have realized extensive benefits from the implementation of waste oil minimization strategies. Recently, minimization efforts have increased due to increased waste disposal and raw material costs, federal legislation and liability exposure associated with use and disposal of hazardous materials.

An initial condition necessary for a successful minimization program involves management initiative. This initiative incorporates a perceptual shift from end-of-pipe disposal approach to a more comprehensive, process-wide strategy of understanding oil requirements and managing the oils to obtain a maximum life expectancy.

The first step to successfully minimizing waste oil is understanding the composition and performance requirements for the oil and the reasons for its removal from service. Minimum acceptable levels for critical oil properties, such as viscosity, water content and acid number, are usually available from the manufactures of the equipment in which the oil is used. These data should be obtained and used as the benchmarks on which the minimization program is based.

Once the required oil properties are known, the critical property (or properties) that control the oil's useful life can be identified. Inexpensive field tests can be performed for many oil properties that will allow plotting of degradation and/or contaminant accumulation rates. These rates will determine the required oil processing rates and allow proper sizing of oil management systems. Often, the periodic careful examination of an oil while in service will identify a previously unsuspected source of degradation that can be readily corrected, such as a failed seal or a system hot spot.

Emulsified oils, such as metalworking fluids, are usually removed from service due to unacceptable levels of bacterial growth resulting in rancidity, bad odors and skin irritations. By evaluating system flow patterns and sources of contamination, management changes or modifications to the fluid handling system can often be identified that will significantly increase fluid life. Removal of "dead spaces" in oil lines that promote bacterial growth also helps to extend fluid life.

Several alternatives to conventional "drain and replace" approaches are available and should be considered:

Source reduction – the most attractive waste management option, focused on on-site changes which reduce or eliminate the generation of waste oils. Source reduction can be divided into three major areas: material substitution, technology modifications and managerial or procedural alternations.

Recycling – to be considered after source reduction, has the goal of recovering oil of a purity similar to the virgin oil for reutilization. Recycling can be divided into three components: direct reuse of the oil, removal of impurities/replenishment of additives to obtain a reusable product and reclamation for a separate use.

Implementation of an effective waste oil minimization program will involve one or more of the above approaches. Unique opportunities for minimization will depend upon factors such as: the type of application, specifications dictated by the application and the characteristics of the virgin and waste oil and their amenability to source reduction and recycle techniques.

4. SOURCE REDUCTION APPROACHES

4.1. MATERIAL SUBSTITUTION

It may be possible to reduce waste generation rates by substituting other materials for the oil currently employed. Industrial oils function under a wide variety of conditions, acting as lubricants, coolants, cleansers and sealants, or a combination of these. There are several opportunities available for minimization through material substitution, including: utilizing a higher grade oil or substituting a synthetic oil or a synthetic petroleum-based blend. Synthetic oils, which maintain essential characteristics such as viscosity for a greater period of time, may be substituted for petroleum-based stock. By maintaining their critical properties, synthetic oils can reduce replacement requirements by a factor of 10. Alternately, petroleum-based stock may be blended with synthetic oil to achieve comparable results.

4.2. TECHNOLOGY MODIFICATIONS

Oil waste minimization may be realized through technological modifications which decrease oil usage or extend its service life. Opportunities include both process and equipment optimization rather than operational changes. Reductions in oil waste generation through technological modifications may be achievable by action such as: equipment modifications to reduce excessive operating temperatures that promote oxidation and increase viscosity or replacing equipment generating large quantities of oil waste with more efficient equipment.

4.3. OPERATIONAL AND MANAGERIAL CHANGES

The procedural and organizational elements of an operation have a great impact on potential waste generation. Waste oil generation may be decreased through the following:

Provide management initiatives to increase awareness of the need and benefits of waste minimization.

Increase employee training to instill good operating practices when working or servicing equipment to decrease waste oil generation rates.

Expand programs involving preventive maintenance to avoid waste generation through equipment failure, spills and leaks.

Increased segregation of waste oils to facilitate recycle and reuse.

These types of steps can easily be implemented and are generally very economical.

Maximum reductions in waste generation rates require implementation of a comprehensive oil management program that includes an oil inventory program and a quality control program. Oil consumption tracking is essential to tailoring a recovery program. Logs recording oil input and removal along with repairs should be maintained for all equipment. Proper scheduling of oil servicing will minimize waste generation. Periodic testing of the oil to determine contaminant levels or critical properties will facilitate oil waste minimization.

5. RECYCLING APPROACHES

There are several avenues open when considering implementation of a waste oil recycling program. Currently, three alternative routes are available: waste oil recycling through on-site physical reprocessing with some chemical replenishment, off-site refining involving distillation and hydrofinishing and blending to formulate either a specification or non-specification fuel.

5.1. REPROCESSING

The feasibility for physical reprocessing must be determined on a case-by-case basis. Properties such as viscosity are altered by fluid or particulate contamination. There are several technologies appropriate to most contaminant control situations:

gravity separation,
filtration,
distillation,
centrifugation,
magnetic separation.

After physical reprocessing, additives depleted during use and/or purification operations may be replenished.

5.2. GRAVITY SEPARATION

Most industrial equipment provides for gravity separation of oil and contaminants in a sump. Gravity settling is only effective in removing undissolved water and large particular matter. Gravity separation may be employed to segregate mixtures of the following types:

liquids–liquids,
liquids–solids.

The principal mechanisms of gravity separation are sedimentation and coalescence. Sedimentation is defined as the removal of suspended solid particles from a liquid stream by gravity setting. The specific gravity of various solid contaminants allows them to settle to the bottom of a settling chamber.

Coalescence is a method of separation of emulsified oils from their water matrix. This operation involves passing waste fluids through a series of coalescing plates to break the emulsion. Oil droplets deposit on the plates and then separate by gravity.

The principal advantage of gravity separation is that it is economical and is a non-skilled operation. The disadvantages are that it will not remove soluble oils, can only provide limited removal of emulsified oils, and required a long time.

5.3. FILTRATION

Filtration is the separation of solids from liquids achieved by passing the liquid through a porous medium. The mechanism by which contaminants are removed distinguishes the various filter types:

Mechanical filtration operates by passing the oil through a medium which retains particles larger than the pore media. Pleated paper, mesh screens and textile "socks" are examples of common mechanical filters.

Adsorbent filtration involves the collection of contaminant molecules on the surface of a porous granular solid. Diatomaceous earth, fuller's earth and activated alumina are typical filter media employed to retain dissolved contaminants such as acids.

Absorbent filtration occurs when free water is assimilated into the fibers of the filter media. Although systems are not commonly designed to achieve contaminant removal by absorbent filtration, its effects need to be considered when utilizing cellulose filters, as the resulting swelling of media tends to reduce void space and increase the pressure drop across the filter.

The advantages of filtration are that it is able to handle high solids and has wide applicability. Its disadvantages are that it requires backwashing, regeneration, or new media.

Other more exotic methods of filtration include membrane separation processes such as ultrafiltration and reverse osmosis. Reverse osmosis employs a semi-permeable membrane and a pressure gradient of 5–10 MPa. Ultrafiltration is used to remove particles of 1 micron or smaller size, and filters are typically porous membranes. Filtering pressures are approximately 1 MPa.

5.4. DISTILLATION

Distillation is an effective method for removing volatile contaminants such as dissolved water, acids and solvents from used oils. Most oil distillation systems function by passing a thin film of heated oil through a vacuum. The contaminants are removed as a condensate stream for disposal. Temperatures of approximately 75°C and vacuums of 136 Pa are commonly employed. Distillation is almost always preceded by mechanical filtration to prevent system fouling. The advantage of distillation is its effectiveness in removing water from petroleum products. Its disadvantages are its cost and energy requirements.

5.5 CENTRIFUGATION

Centrifugation is similar to filtration except that centrifugal force is used instead of a pressure gradient or gravity to separate solids from a liquid. Centrifugation is also used to separate emulsions of two immiscible liquids. For example, it is commonly used to separate both solids and tramp oils from metal working fluid [1]. A centrifuge for this purpose consists of a series of conical disks stacked on top of each other which spin at relatively high velocities. As the centrifuge spins, the solids and oil sludges are propelled toward the outside walls. The clean fluid rises through the holes and is collected midway on the centrifuge by a collection tube. Tramp oil, the lightest component, rises through the middle and is collected on the top of the centrifuge.

5.6. MAGNETIC SEPARATION

A popular technique for clarifying metal-working fluids involves magnetic separation. In this method iron-containing contaminants from cutting oils are separated by means of a magnetic field. The advantages of magnetic separation are that it does **not** remove valuable additives, and it selectively removes ferrous solids from oils. It is, however, limited to ferrous removal.

Selected data from proprietary reports illustrate the magnitude of the cost savings as compared to capital cost for several of the technologies discussed in this section. These cost savings and their payback period are presented in table 3. In addition to physical separation, several other techniques exist, which are chemical separation and blending which are discussed briefly below.

Table 3

Sample economics of oil recovery system

Waste	Technology	Capital cost [$]	Increased annual savings	Payback [years]
Machine coolant waste	a) contracted coolant recovery	40.000	$ 38.500	1.0
	b) chip wringer	233.542	259.500	0.9
	c) coolant analyzer	5.000	7.000	0.7
	d) coolant recovery	84.000	45.400	1.9
	e) ultrafiltration	N/A	N/A	N/A
	f) CNC centrifuge	126.113	41.000	3.7
	g) pump pumps @ CNC	100.423	55.800	1.8
Waste hydraulic oil	a) oil maintenance	30.000	79.200	0.4
	b) off-site recycling	25.000	22.000	1.1

5.7. RE-REFINING

Waste oil re-refining is typically marketed on a custom recycling basis where a customer furnishes waste oil to be re-refined and is returned oil blended to his specifications and needs. Re-refining produces a high quality base stock suitable to compounding and blending to both motor oil and industrial products. The typical re-refining operation involves distillation and hydro-finishing. The acid/clay re-refining process is no longer favored due to costs and the difficulty of disposal of the acid/clay waste products.

5.8. FUEL BLENDING

Waste oil, when properly treated, may be blended to formulate a specification or non-specification fuel. Pretreatment to remove impurities such as metal-containing particulates and other materials is usually necessary. Waste oil is blended with cleaner fuel oils to avoid exceeding source and air quality standards and to minimize heat transfer surface fouling. In 1985, the U.S. EPA issued regulations to control the burning of used oils in nonindustrial boilers. The allowable levels of contaminants are presented in table 4.

Table 4

Used oil fuel specifications

Constituent/property	Allowable level for burning without permit
Arsenic	5 ppm
Cadmium	2 ppm
Chromium	10 ppm
Lead	100 ppm
Total halogens	1000 ppm
Flash point	100 F maximum

In summary, the potential for cleaning up and reusing contaminated oils is very great, and, if done properly, can pay for itself in a few years.

REFERENCES

[1] KOHL J., CURRIER J., *Managing Used Oils*, N. C. Board of Science & Technology, March 1987.

OGRANICZENIE DO MINIMUM PRZEMYSŁOWYCH ODPADÓW OLEJOWYCH

Od federalnych i stanowych kontroli w Stanach Zjednoczonych oczekuje się przeciwdziałania zagrożeniom wynikającym z ciągle wzrastających kosztów usuwania odpadów olejowych. Znaczna część odpadów olejowych pochodzących z przemysłu mogłaby być eliminowana dzięki odgórnym inicjatywom i technicznym ulepszeniom. Ograniczenie zanieczyszczeń źródłowych, zawracanie do obiegu i oczyszczanie odpadów olejowych to najprostsze sposoby ich zmniejszenia. Relatywnie tanie gotowe urządzenia w połączeniu z rutynowymi analizami zawartości odpadów olejowych mogą przyczynić się do zmniej-

szenia tych zanieczyszczeń w zakresie od 50 do 90%. Oszczędności uzyskane dzięki zastosowaniu kompleksowego programu zarządzania zwykle umożliwiają zwrot kosztów inwestycyjnych w ciągu 1–3 lat.

МИНИМИЗАЦИА ПРОМЫШЛЕННЫХ МАСЛЯНЫХ ОТБРОСОВ

От федеральных и штатных контролей в США ожидается противодействия опасностям, вытекающим из все растущих затрат на удаление масляных отбросов. Значительную часть промышленных масляных отбросов можно бы удалять благодаря инициативам и техническим улучшениям сверху. Ограничение загрязнений, происходящих из источников, поворачивание и очистка масляных отбросов — это самые простые способы их минимизации. Относительно дешевые готовые установки в соединении с постоянными анализами содержания масляных отбросов может причиниться к уменьшению этих загрязнений в пределах от 50 до 90%. Полученные благодаря применению комплексной программы управления сбережения обычно способствуют возвращению затрат на инвестиции в теление 1–3 лет.