Costs of Oil Mist Control Installations

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ABSTRACT

The current OSHA oil mist limit of five milligrams per cubic meter has been met in most machining plants by machine enclosures and mist collection only on the worst oil mist producing processes. Employee complaints, proactive employers, and machine builders have greatly increased the number of enclosures and mist collectors in our plants. Most machining plant employees are now exposed to less than 2 mg/m^3 of oil mist. To ensure employee exposures below 0.5 mg/m^3, all processes using any type of oil coolant will require machine enclosures and mist collectors above 99.5% collection efficiencies.

Data from six machining plants, ranging in size from 2 to 3 million square feet, collected over the last five years will be used in this paper to outline costs of:

1. New collector installation on a CFM basis
2. Ductwork on a CFM basis
3. Machine enclosures on new and existing single station machines
4. Machine enclosures on new and existing transfer lines
5. Maintenance and operation of collectors

These costs can be used to determine total costs to bring any plant into compliance with the proposed limits.

INTRODUCTION

Coolants are designed and specified to cool and lubricate tools, chips and parts, but the primary use of coolants in machining operations is to move chips from the points of generation to one central, easily accessible location. This greatly increases the use and volume of coolants. In fact many dry machining operations have high pressure coolants just to move the chips. The coolant is also used to keep rails, probes and locators chip-free.

All process changes are expensive and require long qualification periods. Coolant systems are still considered the "Best in Class" method of handling chips. So process changes are beyond the scope of this paper. Total enclosures with mist collection are a less costly and time consuming method to contain this wide spread use of coolants.

Better than 90% of the machining operations in our plants use coolants. Presently about 40% of machining operations with coolants have mist collection and fewer have total enclosures. Costs of both new and retrofit enclosures will be addressed.

Collector designs have improved greatly over the years but only a few collectors are capable of 99.5% collection efficiency. A collector consisting of a metal mesh screen followed by an envelope bag and a HEPA filter will achieve this efficiency. This type of collector is more expensive to purchase, install, operate and maintain than most collectors in use, but they will be needed to meet the proposed limit of 0.5 mg/m^3. This will be the basis for this paper.

METHODS and RESULTS

Machining equipment and processes are usually changed when a new product is required. Therefore, relatively large numbers of machines are installed at the same time with product timing deadlines. Since mist collection cost, even with total enclosures, is less than 10% of the total machine cost, there is usually an attempt to include everything in the machine vendor contract. Machine enclosures should be furnished by the machine vendor in his original design. This usually gives the most economical and maintainable enclosure. Mist collectors are not part of the machine vendor's design nor expertise, and unless a collector manufacturer and model number are specified, you may get a low-bid, inefficient collector that more than likely will not match other collectors in your plant.

Single machine enclosures from the machine vendor have an average cost of $6,000. Single machine enclosures on existing and operating machines are even more costly because the operation and maintenance requirements of the machine change, and retrofit enclosure designs are usually unique. Costs of these installations have averaged $10,000/machine or more, based on the installation costs of more than 30 machines.

Transfer line enclosures installed by the machine vendor during construction cost about $7,000/station. Transfer line enclosures installed later range from $12,000 to $15,000/station, based on 8 transfer lines with 167 stations.

With parts and tool movement in and out of the machine envelope, no enclosure is completely closed 100% of the time. Air exhaust or CFM per machine or transfer line station requirements are usually determined by the openings and machine access ports needed to feed and remove the part from the enclosure. If coolant splashing occurs near an opening, 400 to 500 FPM (feet per minute) of capture air velocity is needed through the opening. If only oil mist is present, 200 FPM is sufficient capture velocity. Machines with doors that open between cycles need only 50 FPM of capture velocity across the door opening. If opening sizes are unknown for a transfer line, a ‘rule of thumb’ value of 150 CFM per linear foot of transfer line has worked well. Most single machines require from 500 to 1,000 CFM of exhaust. Stations on a transfer line usually require 800 to 1,200 CFM of exhaust. Once the required CFM for a machine / transfer line station is determined, the collector and ductwork can be designed and purchased.

Collector size does affect the cost of a collector on a $/CFM basis. Collector sizes from 500 to 2,000 CFM average about $8/CFM. Collector sizes from 4,000 to 12,000 CFM cost about $4/CFM. Larger collectors cost about $3/CFM. Ductwork costs may offset some of these differences in collector cost. These collector costs are based on the purchase of over 150 collectors, and they do include installation of the collectors.

Ductwork costs are determined by the size and complexity of the system. Collector location can affect ductwork costs and fan horsepower requirements; therefore, collectors should be located as close as possible to the machine. Ductwork costs should average $3.50/CFM.

Maintenance and operating costs must also be considered in the overall costs of collector systems. These costs, like collector costs, are affected by the collector size. The first stage of the collector is usually one metal mesh screen for every 2,000 CFM of capacity. The only maintenance on this screen is a good steam cleaning every six months which will probably take 30 minutes to clean one to six screens. Screens should last the life of the collector. The envelope bag and HEPA filters, which also handle 2,000 CFM per unit, should last six to twelve months. They cost $125 and $225 respectively, and require about 30 minutes to change. The fan, motor, and belts must also be maintained on a regular basis. Total maintenance costs should average $1,000/year for a 2,000 CFM collector. Man-power and filter costs for all smaller collectors will be about the same $1,000/year. Operating costs consist of electrical costs (3 HP/2,000 CFM), the operator's startup, and inspections and shutdown labor (1 hour/week). With labor costs calculated at $15/hour and electricity cost calculated at $0.045/kilowatt-hour, operating costs would be about $1,300/year for a two-shift operation of a 2,000 CFM collector.

CONCLUSIONS

The above costs can now be used to estimate most of the required installation costs in a machining plant. An example for new machine oil mist collection system costs is shown in Table 1.

Table 1: Mist Collection Requirements for **NEW Machines**

	Single Machine with Collector	*8 Single Machines with One Collector*	*15 station Transfer Line with Collector*
CFM Requirements	500	4,000	15,000
Enclosure Costs	$6,000	$48,000	$105,000
Ductwork Costs	$1,750	$14,000	$52,500
Collector Costs	$4,000	$16,000	$45,000
Tot. Installation Costs	$11,750	$78,000	$202,500
Operating Costs/Year	$850	$2,400	$9,000
Maintenance Costs/Year	$1,000	$2,000	$7,500

To get a better idea how these costs will affect existing equipment in our plants, I walked through four of our plants counting the various collectors and enclosures. Table 2 shows the costs involved in retrofitting these four plants.

Table 2: Mist Collection Requirements for **EXISTING Machines**

PLANT	*TRANSMISSION*	*TRANSMISSION*	*CHASSIS*	*TRANS. / CHASSIS*
Area (Million Sq. Ft.)	2	3	3	2
Single Machines	684	993	881	240
Single Machines with Enclosures	94	311	136	120
Enclosure Costs	$5,900,000	$6,820,000	$7,450,000	$1,200,000
Single Machines with HEPAs	14	91	74	106
Collectors with HEPA Costs	$2,167,500	$3,723,750	$3,303,750	$900,000
Transfer Lines (Average 20 Stations)	54	59	41	36
Transfer Lines with Enclosures	5	38	1	14
Enclosure Costs	$11,760,000	$5,040,000	$9,600,000	$5,280,000
Transfer Lines with HEPAs	0	8	1	19
Collectors with HEPA Costs	$7,020,000	$6,630,000	$5,200,000	$2,210,000
PLANT TOTALS	$26,847,500	$22,213,750	$25,553,750	$9,590,000
Costs per Million Sq. Ft.	$13,423,750	$7,404,583	$8,517,917	$4,795,000

The first plant had a major program with a large Japanese input completed about three years ago. The Japanese equipment emphasized low coolant pressure and flow to control oil mist. Their mist collection techniques utilized close capture with minimum CFM. They decided to use U.S. manufactured collectors but no HEPA filters were specified. The oil mist level in that area of the plant is below 2 mg/m^3 but would not meet the proposed limit of 0.5 mg/m^3. The remainder of the plant contains 15 year old equipment and collectors.

The second plant had undergone an upgrade using European equipment designs for the transfer lines. They stressed total enclosure, but here again U.S. manufactured mist collectors were used. Collectors with HEPA filters were used on straight oil operations in this program. This plant also had a large number of 15 year old machines that will be upgraded for future programs.

The third plant had very little new equipment but it also has fewer transfer lines than the first two plants. This makes the cost per square foot less than the other plants.

The fourth plant had just finished a major program that emphasized "Best in Class" for all equipment. The plant management had also made an effort to upgrade the oil mist collection capability in the rest of the plant. Costs listed in Table 2 for this plant (Transmission/Chassis) do not show the monies already spent by that plant.

The wide variations in these plants make them representative of the total machining industry. Total plant areas have been given. This includes assembly, in-plant storage, and maintenance areas. The individual plant installation costs were converted to a 'cost per million square foot' basis so they could be averaged. The average installation cost is \$8,535,313 per million square feet. The average annual operating and maintenance costs would be an additional \$495,688 per million square feet. These average costs can be used to determine what your costs may be, regardless of the size of your plant.

Environmental Control Technologies for Special M/C and Transfermachines

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ABSTRACT

GROB, one of the world's leading transfermachine and systems manufacturers and supplier to the automotive industry, has pioneered the development of "dry floor" and "fully enclosed machining area" guarding systems. This paper will address environmental issues concerning metal cutting machine tools such as coolants, lubricants, hydraulic fluids, noise emission, as well as stricter environmental control regulations and laws, new tool technologies, new trends in component material, and trends toward flexible machining concepts.

This paper shall serve as a brief introduction to what we from the machine tool industry are doing with respect to environmental control issues. When talking about metalcutting machines here, we are talking about high volume production systems for parts like cylinder blocks, cylinder heads, transmission cases etc., often running at cycle times of 20 seconds. When building such systems the following environmental issues have to be addressed:

- *Coolant*: for lubricating the tools and for removing and transporting chips, within the machine and outside the machines
- *Lubricants*
- *Hydraulic fluids*
- *Noise emission*
- *Thermal emission*, and emerging in recent years:
- *Electro smog.*

In this paper we will only address the first four issues since the last two would go beyond this forum. The driving factors for the necessity of better control technologies in machine tools are:

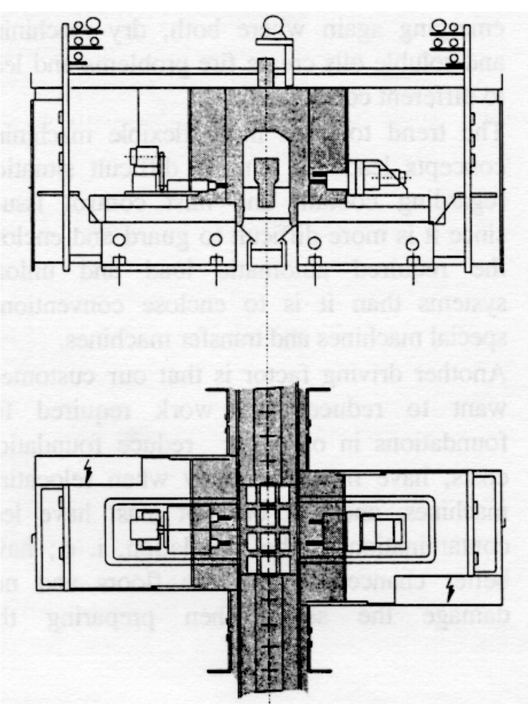
- More strict environmental control regulations enforced today by the governments.
- Closer part print tolerances and new tool technologies (such as carbide tools, diamond tools etc.). These tools allow substantially higher cutting feeds and speeds and thus produce substantially more chips per time unit. These tools also require substantially higher coolant pressures (up to 1,000 psi and more) for coolant through the spindles and the tools, leading to substantial mist emission. These tools and processes also often require mineral oil instead of soluble oils which also leads to more mist. We see more and more mineral oil applications mainly in Europe.
- New trends in component materials also lead to more coolant requirements: for example, more and more aluminum is used to substitute cast iron components in cars. We even see cast iron steering knuckles and suspension parts emerging in Europe. Also magnesium is emerging again where both, dry machining and soluble oils create fire problems and lead to different control issues.
- The trend towards more flexible machining concepts leads to a more difficult situation regarding coolant and mist control issues since it is more difficult to guard and enclose the required automatic load and unload systems than it is to enclose conventional special machines and transfer machines.
- Another driving factor is that our customers want to reduce civil work required for foundations in order to: reduce foundation costs; have more flexibility when relocating machines; and last but not least have less contamination of the foundation, i. e.; have better chances to seal the floors and not damage the seals when preparing the

foundation. Today, we even install machines with a limited number of anchor bolts to avoid anchor bolt holes which also damage the floor seal.

In addressing the control technologies used today in our machines, the most important is the development of what we call "dry floor" and "fully enclosed machining area" guarding systems for transfer machines. GROB as a major supplier of this type of manufacturing equipment for the automotive industry has been pioneering the development of the dry floor guarding for over the past ten years.

It is important that the guarding system is standardized as an integral part of the machine, i. e. designed with the machine and not fitted after a machine is assembled. This is certainly a difficult task for systems integrators. GROB is doing that on the CAD system in engineering, providing data for NC-controlled laser cutting machines, producing the guarding to the required high precision. The guarding is growing with the machine during assembly and is completed when the machine is finished and tryout is started.

Figure 1 shows the principle of a typical transfer machine guarding.



The shaded area is the fully enclosed area containing chips, coolant and mist within this area designed for the connection to a centralized mist extraction system. Sliding doors provide good access for tool change and maintenance as well as taking a part from the station or the adjacent idle stations. The non-shaded area is enclosed to the sides for safety and noise control reasons but is open to the top to allow easy access to the motors and heads which can be removed through the open top. All hydraulic valves are mounted on a central panel at the end of the unit. A drip pan underneath the valves collects all possible leakage or the hydraulic oil dripping down when changing a device.

Paying attention to the detail when designing the guarding is essential to make it really tight, for example:

- precision is important
- no holes to run pipes through the sheet metal
- good seals between the traveling shields on the units
- and the side guarding
- the use of sliding doors instead of swing-out doors to
- avoid coolant dripping on the floor, etc.

This attention to the detail shows in the results. It is part of the reason why some of the machines we delivered to the Ford Motor Company years ago are in the range of 0.5 mg/m^3.

Above floor coolant removal becomes more and more important. The GROB center bases are designed for both in-floor and above-floor chip removal systems. The above-floor removal systems require less civil work on the foundation and leave the sealed floors intact. Chips and coolant are dumped into smaller pits alongside the machine and are pumped from there to the centralized filtration systems, in closed systems.

Noise control is also becoming a more important issue. Machines producing only 75 dB have been built. We see requests going down to as low as 70 dB. We are trying to reduce the noise level at the source by designing adequate clamping fixtures and tools. But this is sometimes very difficult at the high rpm's used, which are often in excess of 15,000 rpm. In some applications we experienced noise emissions up to 100 or 105 dBA without cutting chips, just by running the tool across the part at a distance of a couple of tenths.

The fully enclosed machining area and the fully enclosed machine help to reduce the noise emission. Other measures can be used, such as special belts, helical gears for transmissions etc. If these primary measures are not sufficient, noise damping materials have to be applied to the guarding which leads to additional problems on wet machines. Therefore, we believe the noise emission also has to be addressed when talking about coolant guarding.

Additional measures are required when using mineral oils as a cutting media. Mainly in Europe we see more and more mineral oil applications for aluminum and magnesium components. Automatic pressure release valves in the guarding are required to release the pressure of possible explosions and to immediately shut again after pressure is released to avoid additional oxygen flow into the machining area. Automatic $C0_2$ fire extinguishers controlled by infrared and heat sensors have to be installed.

Certainly the best method is to reduce the amount of coolant used in a machine, but there we have some conflicting issues: on the one side, new tools requiring more and different coolant, and on the other side, stricter environmental control issues. We are trying to combat this by introducing variable coolant flow cycles, such as shutting off coolant for tools when transferring parts etc.

Dry machining certainly is the best method of all. Some parts are more amenable to dry machining techniques than others, for example, we still cannot machine a cylinder head dry with satisfactory tool life, satisfactory quality, and - equally important - with satisfactory chip removal from the machine.

Another important factor is the reduction of the use of lubricants. The new generation of feed units with pre-loaded roller bearing ways instead of box ways with an oil film bearing reduces the lubricant consumption to about 20 to 25 %. The use of electromechanical drives reduces the number of hydraulic cylinders and thus the amount of piping and the possibility of leakages quite drastically. More life-time lubricated bearings are used in boring spindles and also in multi-spindle heads instead of oil and oil mist systems which lead to oil losses and contamination.

CONCLUSION

What do we see for the future? We have to continue to work towards improving the coolant and chip system to contain the coolant and the mist within fully self-contained systems. The industry has to develop better coolants, reducing the mist emission and the associated health problems. We also have to continue to avoid coolants, hydraulic oils and lubricants in the machine shop environment by pursuing dry machining and by electro-mechanizing the machines.

Metalworking Fluid Failure and Disposal - Future Directions

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ABSTRACT

Disposal of spent metalworking fluids continues to be problematic for many manufacturing companies. Controlling metal-working fluid failure not only results in improved metal removal rates, but also results in less material to be waste treated. This paper will discuss factors influencing metalworking fluid failure, and present and future disposal technologies.

INTRODUCTION

Metalworking Fluid Failure

One of the basic assumptions of this research is that metalworking fluids are disposed of due to one or more of the following reasons. First, the fluid becomes rancid, producing foul and intolerable odors. Rust or other forms of corrosion appear on the material being machined or the metalworking machine itself. Similarly, unacceptable residues appear on the part being machined or the metalworking machine. Additionally, the fluid irritates the worker's skin, eyes, nose or throat. And finally, the fluid fails to provide the machining requirements such as rate of tool wear, surface finish, or dimensional tolerances.

Our assumptions continue in that a metalworking fluid will not change significantly until it is exposed to the machining/manufacturing environment. The changes that occur to a metalworking fluid in the machining environment starts the fluid on its progression to failure. The authors further theorize that a metalworking fluid as supplied by the manufacturer, when mixed with water, bears little resemblance to the initial fluid after several weeks of use. To support these assumptions, the study of metalworking fluids has to be done in a machining environment, or a simulation of a machining environment.

These changes to a metalworking fluid are, therefore, caused by a group of reactions called failure mechanisms. These failure mechanisms can be categorized in the following areas; heat, salts from hard water, oxidative and reactive agents, unwanted oils (tramp oils), and biological activity.

It is the intent of this research to understand the significant mechanisms that cause metalworking fluid failure. With this information, by controlling the rate of the action of the failure mechanisms, or eliminating the failure mechanisms completely, the metalworking fluid life can be extended considerably. Furthermore, if the life of these fluids can be extended, then less fluid would have to be purchased and, ultimately, less fluid would require disposal.

The purpose of the initial work was to examine the effect of Zinc Dialkyl DithioPhosphates (ZDDP) on Eaton's cutting fluids in a simulated machining environment. ZDDPs are added to hydraulic fluids as anti-wear, anti-oxidant additives, and find their way into the cooling sumps in a plant setting as tramp oil via leaky machine seals. Over time, tramp oil can comprise a large percentage of a sump's contents, and thus ZDDP. A better understanding of the chemistries and compatibility's of the additives present may help us develop ways to extend the life of these fluids and lower overall disposal costs.

ZDDP's anti-wear properties have been well studied[1,2,3,4,5] since their discovery by Wystrach *et al.* in 1956.[6] Although little has been published on the subject, ZDDPs have been suspected to have detrimental effects on cooling fluid emulsions for some time. The following experiments were devised to study the effects of a commercially available ZDDP product on commercially available basic oil emulsion, and to document scientifically the resulting observations.

Disposal of metalworking fluids:

There exists a similarity to the previously described failure mechanisms in regard to metalworking fluids in use and methods for disposal of metalworking fluids. One of these methods (charge neutralization) involves the use of the addition of various combinations of mineral acids, polyvalent metastable salts, cationic polymers, followed by neutralization with reactive bases, typically sodium or calcium hydroxides. Another popular technique is the use of fixed membrane separation. These membranes are rated in molecular weight cut off - a popular cut off is 50,000 MW.

However, both technologies, charge neutralization and membrane separation, do not fully address all limits of parameters for disposal. Of particular concern is dissolved heavy metals and dissolved organic compounds (DOC) such as measured by biochemical oxygen demand - five day (BOD_5, EPA Method 5210) and chemical oxygen demand (COD, EPA Method 5520 D).

EXPERIMENTAL

Coolant Failure

These experiments were intended to simulate the combination of machining (grinding) of iron in the immediate presence of the basic emulsified oil and the ZDDP reactant. The initial problem to be solved was how to measure the stability of the metalworking fluid under test. In a typical plant, fluid failure is usually measured by its results, i.e. rusting parts, failure or seizure of machine tools. Occasionally, a catastrophic fluid failure is observed with the complete separation of the hydrocarbon components of the emulsion from the water. A simplistic indication of fluid stability can be measured by taking a 75 ml sample of the emulsion and placing it in a 100 ml graduated cylinder and letting it sit, undisturbed, overnight. The next day the cylinder can be observed for the amount of free oil and cream floating on top. A stable fluid should have no visible phase separations. Many plants regularly send a sample of their cooling fluids to their suppliers for laboratory analysis.

For our purposes, we modified an accepted analytical method for hydrocarbons in wastewater, EPA Method 5520 B. This is a partition-gravimetric method using 1,1,2-trichloro-1,2,2-trifluroethane (trifluorotrichloroethane, herein Freon™) to extract the hydrocarbons from the emulsion. The Freon™ is then boiled off and the hydrocarbon residue weighed. The underlying assumption in these experiments is that when the emulsion fails (or breaks), the hydrocarbon portion will rise to the top, leaving less than the original concentration in the remaining emulsion layer. By letting the sample sit overnight and measuring the hydrocarbon content of this layer, we should have an indication of the overall stability of the fluid.

The hydrocarbon results were reported as a % change from the before-grinding sample which was defined as:

(1) [After grinding HC (g) - before grinding HC (g)/ before grinding HC (g)]x 100
or [experimental - actual / actual] x 100

The "After grinding HC" refers to the weight of the hydrocarbon residue left in the flask after the extraction from the "after grinding" sample.

The next experimental concern was how to reproduce the plant's grinding operation in the laboratory in an analytically controlled, reproducible manner. For this we used a variable speed grinder-polisher. This piece of equipment allowed us to control the rpm of the grinding surface and the pressure on the samples. The samples were typical ductile iron (D4512) bar stock received from the foundry that supplies one of the Eaton automotive plants. They were received as 8 inch bars, approximately 1 1/2 inches in diameter. They were machined down to slightly less than 1 1/2 inches in diameter and cut into two 2.5 inch long pieces to fit into the sample fixture. This fixture rotated at 60 RPM with a pressure of 10 psi. The grinding media was a 36 grit adhesive backed cloth disk that rotated at 120 RPM in the opposite direction of the rotation of the sample fixture. The coolant fluid was recirculated continuously through the system during the test. The fluid circulated at a rate of ~ 800 ml/min. The sump was a 2,000 ml glass graduated cylinder, which made it easier to get volume measurements.

It was also important to understand the effect of ZDDP on the cooling fluid without the presence of the iron. In an additional experiment, 4 liters of fresh emulsion was prepared and split into two 2,000 ml beakers. A 100 ml sample was withdrawn for the baseline HC measurement. To one beaker was added 1 % (w/w) of the commercially available ZDDP additive; the other served as the control. The beakers were left, covered, to stir for an extended period of time. Periodically, the stirrers were shut off overnight (identical to the grinding experiment sampling procedure) and a 100 ml fluid sample was taken in the morning from each beaker. They were then compared for any emulsion concentration differences due to the presence of ZDDP.

A set of experiments using $FeCl_2$ (Table 2) as the iron source instead of the grindings were also initiated. These were necessary to see if the end results of the experiments were dependent on the form of the iron, as would be the case if there was a more complex mechanism involving the fresh surface of the iron chip. Iron II was chosen since iron is believed to be in this valence state on the surface of a fresh iron chip.[7] In these experiments, 400 ml beakers were prepared containing 250 ml of the fresh emulsion. To one of these beakers was added 1 % (w/w) of ZDDP. The other beaker was left uncontaminated. The pH's of the samples were checked and one milliliter of TEA was added to each beaker to offset the acidity of the $FeCl_2$. This was done to prevent the splitting of the emulsion simply due to a pH change. A sample of $FeCl_2$ was then added to both beakers to make them 300 ppm in Fe. The two beakers were stirred for one hour and then allowed to settle. They were observed for any changes between the sample with ZDDP and the one without. This experiment was also performed at 60°C to observe any temperature dependencies. These experiments were also carried out on a sample contaminated with 5% (w/w) ZDDP.

Wastewater Treatment

Samples of fluids were taken from the discharge of a wastewater treatment plant. This treatment facility is based on ultrafiltration where the primary membrane construction material is polysulfone with a MW cut off of 50,000.

The wastewater prior to the ultrafiltration system consists of basic emulsified oil, parts washing detergents, and floor cleaning detergents. The influent to the treatment system consists of ~ 3% oil by volume with a COD of ~ 35,000 milligrams per liter (mg/L). After ultrafiltration the average COD is 2,500 mg/L. The focus of these experiments is to investigate various technologies to lower the COD of this waste stream with a goal of achieving a reduction factor of 85% as measured by the following equation:

(2) $[(C_I - C_F) \quad C_I] \times 100 = R_F$

Where: C_I = COD initial, as received
C_F = COD final, after treatment tech.
R_F = Reduction factor, in percent

The technologies investigated were:

- Chemical precipitation with aluminum sulfate $Al_2(SO_4)_3$
- Chemical precipitation with ferrous sulfate ($FeSO_4$)
- Basic chemical oxidation with hydrogen peroxide (H_20_2)
- Basic chemical oxidation with potassium permanganate ($KMnO_4$)
- Basic chemical oxidation with sodium hypochlorite (NaOCl)
- Basic chemical oxidation with sodium dichromate ($NaCr_2O_7$)
- Basic chemical oxidation with ozone (O_3)
- Aerobic biological digestion with a select biological seed followed by ultrafiltration (MW cut off 50,000)
- Basic oxidation with ultraviolet light (UV)
- Advanced oxidation with ultraviolet and titanium dioxide in combination (UV + TiO_2)
- Advanced oxidation with ultraviolet and hydrogen peroxide (UV + H_20_2)

- Advanced oxidation with ultraviolet, hydrogen peroxide and ozone (UV + H_2O_2 + O_3)
- Advanced oxidation with high energy sonolysis (+E)
- Advanced chemical oxidation with sodium metaperiodate ($NaIO_4$)
- Membrane separation using single stage nanofiltration (MW cut off 300)
- Membrane separation using single stage reverse osmosis (MW cut off 150)
- Membrane separation using two stage reverse osmosis (MW cut off 150)

Each process was optimized extensively, with the primary objective being a high reduction percentage as calculated by equation 2. Cost to achieve this reduction was not considered.

RESULTS

Metalworking Fluid Failure

The initial grinding experiments with the ductile iron bar stock lasted 6.5 hours each and primarily centered on developing reproducible base line data on the uncontaminated emulsion. These experiments were important in understanding the best case behavior of the cutting fluid. The results of these initial tests can be seen in Table 1. Initial data show some variability with an average change after grinding with iron of -8.2% plus or minus 6.6%. The amount of iron chips in the sump changed from sample to sample, but no dependence on fluid stability was observed. In general, the pH dropped during the grinding experiments as shown in Figure 1. There did appear to be a relationship between the drop in pH during an experiment and the amount of iron chips present in the sump. When the amount of chips were the highest the pH drop was the smallest. The extraction recoveries on the freshly prepared "before grinding" emulsion samples were consistently around 85%. Table 2 displays the data from the $FeCl_2$ chemical experiments. All of the experiments were carried out at an iron concentration of 300 ppm.

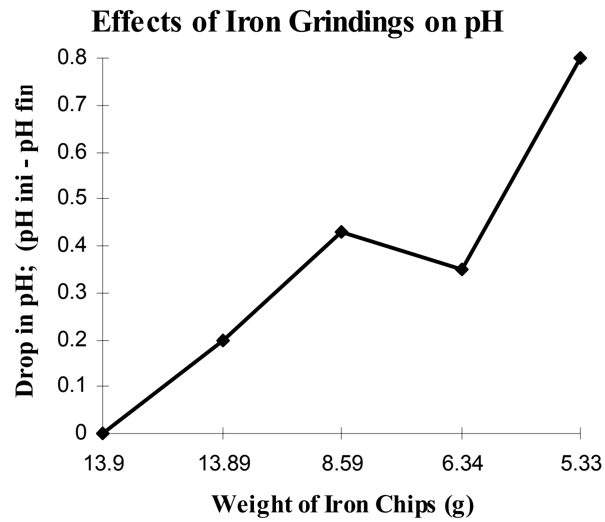

Figure 1.

Table 1. Results of baseline grinding experiments with uncontaminated G-2 coolant.

Exp. #	Emulsion %	pH initial	pH final	% Recovery	Relative Change (%)	Wt. of Fe grindings(g)
1.2	4.410	8.39	8.17	85.92	-3.09	13.89
1.3 Ext Eff.	NA	NA	NA	88.09	NA	NA
1.4	4.124	9.28	8.93	81.95	-17.36	6.34
1.5	4.093	9.36	8.57	82.78	-3.653	5.33
1.6 DI Blank	NA	NA	NA	0.00	NA	NA
1.7	4.164	8.91	8.91	86.22	-3.772	13.9
1.8	4.071	9.17	8.72	87.11	-13.33	8.59

Table 2. Results of Experiments using FeCl as iron source.

Rm T	[Fe] ppm	TEA	initial pH	final pH	initial color	final color	Cream?	Free Oil	Split?
1% Z	300	.90g	9.46	9.34	gray	green-gray	Y	little	N
No Z	300	.79g	8.57	8.43	gray	red clay	Y	little	N
~60C									
1% Z	300	.77g	8.47	7.80	gray	green-gray	Y	little	N
No Z **Rm T**	300	.89g	8.54	7.70	gray	red clay	Y	little	N
5% Z	300	1 ml	8.3*	7.57	gray	green-gray	Y	little	N
No Z	300	1 ml	9.58	8.61	gray	red clay	Y	little	N
~60C									
5% Z	300	1 ml	7.34	6.51	gray	green-gray	Y	little	N
No Z	300	1 ml	8.66	7.19	gray	red clay	Y	little	N

* Estimated Data

The table shows data for two series of experiments, comparing the effects of 1% and 5% ZDDP. Triethanolamine (TEA) was added to try and buffer the acidic effects of the $FeCl_2$ and keep the final pH above ~8.5. We found no case of catastrophic coolant failure with the complete separation of the phases. At both the ZDDP concentrations, no real differences, with the exception of color, were observed between the sample containing the ZDDP and the one without. This green color change is also noticed in the HC residues of ZDDP containing samples after the extraction procedure.

Figure 2 follows the longer term effects on fluid stability which result from contact with ZDDP in the absence of iron. This figure depicts the percent change from the original HC content of two emulsion samples. One was contaminated with 1 % (w/w) ZDDP and the other was an uncontaminated control. The experiment lasted 56 days. We can, therefore, say that 1 % ZDDP without the presence of iron does not seem to have any detrimental effect on the stability of the emulsion as measured by this method. It is interesting to also note the shape of the ZDDP containing sample curve in this case.

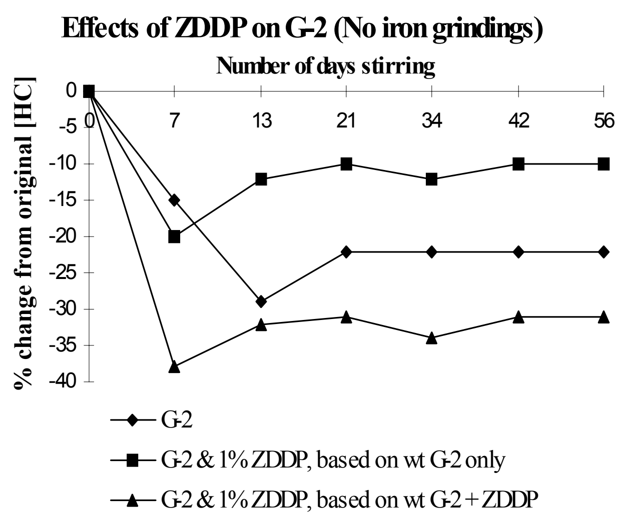

Figure 2.

Wastewater Treatment

The most promising results of this approach, that is technologies that yield a reduction of COD greater than 85%, are summarized in Table 3.

Table 3.

Technology Approach	% COD reduction
Advanced chemical oxidation with sodium metaperiodate ($NaIO_4$)	100
Membrane separation using two stage reverse osmosis (MW cut off 150 → 150)	95
Membrane separation using single stage reverse osmosis (MW cut off 150)	90
Membrane separation using single stage nanofiltration (MW cut off 300)	85

CONCLUSIONS

The above modified EPA method for hydrocarbon extractions works well for the purpose of assessing the health of water soluble emulsions. The data was reproducible and demonstrated relatively high extraction efficiencies of ~ 85% on a consistent basis. The commercially available ZDDP additive we used was also extracted with comparable efficiencies.

Also of interest is the apparent dependence of the drop in pH of the system and the quantity of iron chips present. The reason for this is also not known at this time, but is under further investigation.

Based on just the preliminary results in Tables 1 and 2 and Graph 1, pure ZDDP, by itself, without the presence of iron, does not appear to have a derogatory effect on cooling fluids. However, the authors admit that these test results are too limited to be conclusive. Our next tests will show the reaction of ZDDP in the presence of iron formed in the grinding process. Additionally, since many Eaton facilities have reported fluid failures in apparent connection with high volumes of tramp oil containing ZDDP, it may be possible that additional chemical reactions are occurring that affect emulsion stability. Of course, additional research must be completed for this investigation to be conclusive. Grinding experiments containing varying concentrations of pure ZDDP are now in progress and will soon be carried out over periods of days instead of hours on a grinding machine which better simulates a plant machining environment.

Our research did indicate technological approaches for advanced wastewater treatment that met our project objectives. Eaton will continue to research these selective technologies to insure these processes can be engineered safely and economically for in plant use.

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DISCUSSANT's COMMENTS and OPEN DISCUSSION

Dr. HENRY LICK, Ford: If we could have the Discussants come up now, also with the other Session Arrangers because as soon as we're done with the Discussants portion and some short question and answer period, we're going to go into the closing session. Dennis O'Brien with NIOSH will start off as the first Discussant.

Dr. DENNIS O'BRIEN, NIOSH: I'll be real brief. I only have comments on one paper and that's Bob Kramer's excellent paper on the cost of control.

Frank Mirer mentioned earlier this morning that he felt that the most it would take would be to get all the enclosures in place and all of the air cleaners working appropriately to meet the 0.5 milligram per cubic meter goal. I'm concerned about the ability to maintain that level after all this new equipment etc., is installed. Bob [Kramer] described several different control scenarios with single collectors, and collectors that are servicing several machines. I think in any plant, space is really at a premium and these small unit collectors are typically located on top of machines, hanging from the trusses, or possibly even on the roof. I'm concerned if machines are really installed in this fashion, that maintenance will be a very big problem, and that possibly the cost of maintenance may be underestimated here.

Another cost that really hasn't been considered is the cost of monitoring. I referred this morning to the American Conference of Governmental Industrial Hygienists, Industrial Ventilation Manual and their recirculation guidelines that are contained therein. That includes things like bypass to the outside in the event of collector failure and a system of monitoring the performance of the unit, and this can be either secondary filtration and monitoring the pressure drop across that, or some type of real time monitoring device. Those costs weren't figured in and of course those kinds of costs would be much greater for a unit collector than a centralized type system.

Dave Hands' poster indicated that new is better than retrofit. Will lower limits hasten the purchase of new equipment, and how is that cost figured into the equation? Thank you.

Mr. JOHN STEIGERWALD,Cincinnati Milacron: I can't help but comment on the point that Heinz [Nagel] and Bill [Johnston] made about the major reason for coolant use, considering the fact that I represent an organization that manufactures them, so I have to create a dichotomy here and that is, if all the coolant was used for flushing reasons, then move all the nozzles for flushing purposes.

Second is the tooling technology that was discussed, as well as the coolant fed tooling and really the theoretical values of chip formation technology do indicate that it has a primary function of lubrication, and I think that should be stated. And yet I do understand that volumes of fluids are necessary for chip removal purposes and that the specific intent potentially is not for that purpose in and of itself.

The charts that were done on the cost of investment with regard to a 0.5 level, I thought that was quite interesting. I reflect back to my earlier comments to the absent in mind again. There's a whole industrial environment out there that basically isn't represented in those costs in regards to a 0.5 level, not that that's good or bad. These are the small to medium size shops.

We need to recognize that there's well over a million machine tools that are out there in an active mode that are really not part of what was shown in those charts, and if that was true, the same installation costs there might be applicable. I think that's merely a recognition of the investment necessary for the net result of benefit that is to be achieved. Cost/benefit analysis does present a question to be dealt with.

And the final comment I'll make is on the work that John Burke from Eaton Corporation has done. I think that's an interesting area. There's an enormous number of questions, even from an ILMA type company, with regard to ZDDP and its net effect, and we look forward to the future work in that area because right now, there are a lot of opinions that are being tossed about within that area.

In the wastewater treatment area I find the work that's going on with secondary and tertiary type processes for ultimate water reuse most interesting. Again, I think one of the focuses from an ILMA organization perspective and the independent companies that it represents is the amount of waste minimization we can actually achieve. Let's not forget the root cause, and conditions, let's also support the process by finding the sources of the waste and potentially reduce the load going to a waste facility.

Again from an ILMA perspective, we appreciate AAMA's putting together this Symposium and allowing our active involvement. Thank you.

Dr. WILLIAM WATT, Chrysler: Now that I'm not as rushed, let me just thank you for giving me the opportunity to be a Discussant. I've never done that before and it's a unique position. I note that as a Discussant, if the Symposium goes well, the Discussant claims he's part of it and gets credit for it going well. If it doesn't go well, he's able to disassociate himself and say it's not his fault. And I say that, Frank, as it seems to me that's kind of like working for the International UAW, isn't it? (I told Frank earlier I was going to take a shot at him, in jest, so he was expecting that.)

Some brief comments on the last three papers. With regard to the presentation on the cost of controls, I thought that was a very nice way for us to estimate costs. Actually those costs are a little under what we at Chrysler thought they were. We had estimated a bit above that, but still there are substantial costs for control, nonetheless.

Regarding Mr. Nagel's presentation, I emphasize a point that he made about the enclosure being built up with the machine. This is not something that's very readily retrofitted. And that's unfortunate because obviously, we have a lot of existing machinery out there. Let me point out that I believe this would be the best control, this dry-floor guarding type of control. However, it does look like something you would need to phase in, so don't rush back to your plants next week and say "we're going to have this good German-style guarding." Yes, we would like to all have it eventually, but it's not something that's going to be done very quickly. It would have to be phased in.

Finally, John Burke's presentation reminds us that it's not just an art. There is a science to coolant control, and we start collecting facts and start measuring concentrations, and not make guesses at what happened, but actually measure and evaluate it. And I note his discussion and determination of ZDDP being a cause of problems, and of course then that means we can go back to the hydraulic oils and look for ZDDP free hydraulic oil. That's the kind of thing we can do with some factual information. We can go back to ILMA and the coolant manufacturers and start asking them to get rid of this material or, give us that material.

And finally a point regarding that issue. We have covered a lot of aspects concerning coolants, but John [Burke] just touched on some of the environmental considerations and I just want to remind you that while we have health related issues driving the management of coolants, there are other concerns, such as the environmental ones. There's a lot more going on and perhaps somebody needs to have another Symposium some day to follow-up. No, not necessarily you - I don't want you to have a heart attack Dave [Felinski]. Thank you.

Dr. HENRY LICK, Ford: For about the next 40 minutes or so we will entertain questions.

Just one point I would like to make first. Bill Watt mentioned in his comments that he thought the costs were somewhat low. I wanted to point out that Bob Kramer's slides and figures referred only to Ford plants. I think John Steigerwald made a good point in that you would have a lot of smaller and medium size shops you would be including, plus you've got 70 million square feet of machining area in General Motors, so there is a lot of multiplication to go in there. It [the cost] is going to be quite high.

Mr. Daniel Rousseau: Dan Rousseau with Aercology. Just a couple of points to make.

If you go with one large collector, there are some problems that you should be aware of. And just one thing I would like to mention is say you have 50 machines hooked up to this one large collector and Scenario 1: You get a fire. You just lost 50 machines.

Secondly, a unit like that is going to require one large blower and what happens, blowers do not last forever. The blower goes out and you're going to be down two to three weeks, possibly longer, waiting for a new blower to come.

And no one is going to be willing to work with no pollution control at all.

Dr. DENNIS O'BRIEN: Well, when you have got a machining operation, nobody has a power plant just for that operation. Nobody has a power plant just for the individual machine tool. You supply compressed air as a utility in a manufacturing operation. You don't have an individual compressor for each machine tool. You don't have an individual restroom for each employee that mans each machine, so why have an individual unit collector for each machine?

Some of the other issues you mentioned about, like a blower, well you can have a large collector but have several blowers.

Mr. Rousseau: Yes. I'm not going with three or four machines. It's probably ideal going with like 50 or 60, you could have some major problems and have some down time if something were to happen.

Mr. ROBERT KRAMER: I would say in the business we usually use five to eight machines on that type of thing, but only larger collectors. Over 12,000 CFM usually come into transfer lines only.

Mr. Rousseau: Okay. One other last question. All the test data has been run and a lot of it has been done with different filters, one of the filters being a HEPA filter. The one thing that I hadn't seen and one of the big pollutants, or one of the big things we have been talking about, is evaporation and having vapors that are going through.

Nothing that I have seen is showing that anybody is testing activated carbon or other adsorbent materials after your HEPA filter for absorbing these vapors.

Mr. KRAMER: We have been looking at it and we are in the very preliminary stages right now of doing this, speaking about the people from North Carolina, (Dr. Leith, *et al*) and they're doing it in several ways; not only with looking at the filters themselves, but they are also looking at the whole mechanism of vaporization. But it is definitely a problem and that's one of the reasons why in some ways I said that I don't know if we could even make point five because almost everything that goes into a vapor will come out of a vapor too. Where it comes out is a problem.

Dr. William LUCKE: Bill Lucke, Cincinnati Milacron. I have a suggestion I'd like to throw out for comments, especially from Dennis [O'Brien] and Larry [Fine] since he's up there now.

Every machine shop in the country does have a mist collector in place that if you go up on the cat walks and get to the structural iron and things and touch it, your hand sticks to it and you come away with something on it. That is the fluid mist that the operators are exposed to. It's got all the degradation products, contaminants, the mixtures of fluids and everything in it, PNAs, if they are there.

This could be collected and used to test for biological activity, chemical composition and what have you. You can do an Ames test on it, you can do a sister/chromatid. That you have got a chance there to maybe get some testing in place. If you find activity, fractionate that material and see which fraction has the activity in it.

What do you think?

Dr DENNIS O'BRIEN: We visited several plants. Bill Heitbrink [NIOSH] has got an ongoing study out in Iowa. He's not doing any mutagenicity testing, but he has collected material from the collectors and is analyzing it to see what it was. It does sound like a good idea.

Mr. William Kilgore: Bill Kilgore, General Motors. I just wanted to make a quick point of clarification on the 0.5 milligram per cubic meter level. In '93 we had a negotiated agreement between the UAW and General Motors that we were going to reduce total particulate to machining fluids to two milligrams per cubic meter by January of '94. By January of '95, to one, and in January of '96, in a couple of months from now, to point five, but there was an asterisk on that point five, and it was pending further studies. Our Occupational Health Advisory Board, some of the members of whom are here attending this Symposium, are going to make a recommendation to our National Joint Committee in December on whether to remove or keep that asterisk in place, so I just wanted to make that point of clarification.

Dr. HENRY LICK: Since I see that Frank [Mirer] is next in line, let's avoid that discussion. Let's avoid contractual issues.

Dr. Franklin Mirer: Frank Mirer, UAW. No, I wasn't going to talk about that at all. I was going to talk about cost estimation and how we can move onward with this process. I thought the presentation, which I didn't hear, but read the extended abstract relative to costs of controls, has possibly got us to the outer limit of what it would cost grinding away and banging away at the existing technologies. It's my view that what we have there is basically what it would cost if we went into the plants and there was nothing there at all now and we were going to try and control naked machines, something in that regard.

Now the issues that lead us to that and I would like to continue the discussion actually, so I would be pleased if Bob [Kramer] would stay up at the podium, frankly. I think here is what the deal is if we're going to approach this in a cooperative and effective way and I'm just going to repeat myself again.

First, [we need to determine] what are the exposures now to the actual operators with some kind of statistically robust sampling strategy so we know what the exposures are.

Secondly, have we got all the equipment working and I guess that's actually the second step. The first step is get everything that's there working the way it's supposed to be working. And that includes getting the enclosures back on, get the collectors working the way they're supposed to, make sure we're delivering the proper amount of exhaust as it was designed, address the issue of blow-back from the collector, address the issue of negative pressure, which is very serious in many facilities and try and get the supply air up to there and then proceed to get, as I said, a statistically robust view of who is over-exposed and who is not over-exposed.

At that point we know or have a better idea of what it is that has to be put in, in terms of incremental controls.

I guess the second issue is: Have we addressed all the other coolant operations which we know are contributors to exposure. Which is to say, it's obvious walking through the facilities that a lot of the exposure is coming from a coolant running when maybe it doesn't have to be running. A lot of the exposure is coming from carryover from one part of the plant to another and background. Some of the exposure may be coming back up from the flume. We have a lot of other issues to address before we slap another thousand CFM and another enclosure on to each and every machine station. So again, I much appreciate the effort and I much appreciate these costs per individual station. In my view that's a starting point for seeing where we would have to go, but it would not be appropriate to aggregate that over every machine in the whole country and say that's what the cost of control would be.

Mr. ROBERT KRAMER: From what I understand, you had an early copy of the extended abstract and it didn't show the last slide that I did do that showed the different machines that exist now and what percentage of collectors we actually have in our plants now, and what the state of the equipment is now. There is another sheet that I will be giving you as soon as this is done.

But you are definitely right in the fact that there are a lot of other things that have to be looked at, coolant systems, hydraulic systems, different systems throughout the plant that definitely have to be looked at. A lot of lubrication, even of conveyance systems. Some of them still use spray coolants, or spray lubricants for their monorail conveyors. These things all have to be looked at. There's no two ways about that.

Mr. Dennis Braun: Dennis Braun from Interlube Corporation. We are members of ILMA, but I'm commenting basically from the standpoint of Interlube. I'm sure quite a few other members of ILMA would have the same kind of background and it's just basically a comment I want to give.

Some of the technology that was talked about by the professor from Wayne State [Dr. Gulari] this morning, a very good presentation, but I wanted you to know that the polymers and the things that she talked about, this technology has been around for a long time. Our company has utilized the polymer technology for over 25 years that she talked about in terms of lubricating oils.

We did experiment and work with the poly-ox resins over 15 years ago. The problems with that material is that it degrades very rapidly under high shear and we have to take all of these things into consideration. I heard a couple of commentors, as well as a couple other comments at lunch and so forth that led me to believe that there might be some people thinking that its new technology, and I want to be sure that you're aware that it wasn't.

Mr. Allen Krodel: Al Krodel from Amoco Petroleum Products and I have a question for John Burke. Just a point of clarification, really. The hydraulic fluid that you used in your tests, that was a ZDDP containing anti-wear hydraulic fluid?

Mr. JOHN BURKE: Yes.

Mr. Krodel: Just a commercial product?

Mr. BURKE: Yes.

Mr. Krodel: Do you know what level the ZDDP was in that?

Mr. BURKE: Point four percent.

Mr. Ike Tripp: Ike Tripp, Etna Products. This is a question for John Burke. John, compliments on your paper, particularly on the wastewater treatment. As you know, the EPA is currently getting ready to implement some new effluent guidelines and one of the concerns there, I think falling on to the issues of cost relating to enclosures, is what are the approximate costs per liter and the like for the new nano-filtration system that you have installed. Can you discuss that in general terms?

Mr. JOHN BURKE: Based on the membrane testing we did, we should get about a year life on the membranes and that would be a cost of about $10,000 to replace all the membranes in the system. That's a very conservative number. If we don't go two years on those membranes, I'll be surprised, because based on the three months we have been operating, we have seen no loss of flux rate.

The cost to treat, generally just for reference, we use an assumed cost of about a half a cent a gallon for the ultrafilter and for the nanofilter we're using somewhere about 1.2 cents per gallon treated for the nanofilter.

The cost to run the evaporator, remembering that the reject off the nanofilter is roughly seven percent of the total flow, so you have to go through some subsequent math there, we use eight cents a gallon for the cost to evaporate, using natural gas, at about $8 per MCF. So if you want to continue that process and say that out of 100 gallons, 93 goes to drain and seven gallons goes to the evaporator and then you have got to evaporate seven, I think you can just do the math, which is fairly quick. Does that answer them all? Okay.

Dr. WILLIAM WATT: I have a question for Heinz (Nagel). You mentioned in the enclosures that they were open top. How do you relate them to mist control and ventilation? Do you have something that lowers onto it, or how does that work?

Mr. HEINZ NAGEL: I did not quite get the question.

Dr. WATT: You mentioned the enclosure is open at the top. How do you control mist?

Mr. NAGEL: It’s not the enclosure. It's only open in the dry area. It's fully enclosed in the machining area where we have coolant exposed to the cutting tools and to the workpiece. The units carry shields which are sealed against the enclosure on the top and on the sides, but the unit itself is open on the top for ease of maintenance and accessibility. If you have to remove a head and things like that, you can pull it up without removing a guard.

Mr. David Tepper: David Tepper and I'll remain unaffiliated for this comment. I hope I get this out right. It's a comment on monitoring and legislation, I guess, in general. The monitoring thing. Why do we continue to handcuff ourselves? Here's an industry trying to make improvements to worker health and safety by adding air cleaning equipment that is absolutely not mandated by regulation.

Nobody has to add mist collectors, nobody has to add containment enclosures, at least at this point in time there's a few places that are probably over the limits and here we're adding the collectors to make these types of improvements in most cases, on a voluntary basis. We're not degrading the air quality in the plant with emissions from the collectors themselves. I guess that's always kind of bothered me in terms of that type of monitoring requirement on air cleaning equipment that's recirculated in a plant that is only making the process better, recognizing there could be, I guess, some fungal growth or bacterial growth and things like that that could go in there.

I guess it's kind of analogous to a clean water act requiring me to monitor coolant flow. It doesn't make a whole lot of sense. Maybe you can provide comment. I just wanted to get that off my chest.

Dr. DENNIS O'BRIEN: Let me give you a comment first. If you were going to ventilate that operation through the ambient air, would you have to put a filter in line? Would you have to put an air cleaner in place? I suspect EPA would require you to do so.

Now, essentially what you have got with your body, the closest your bloodstream comes in contact with the outside environment is through this maze called your lungs. If you have done any fishing, you have seen gills. We essentially have our gills internally and we are exposed to this environment.

You are essentially supplying breathing air to people. I would say that you want to make sure that that equipment is functioning properly at all times. You control the quality of your process. You monitor the pH of your fluids. All I am saying is that you need some sort of surveillance system built into the operation of your plant that's going to warn you of equipment failures and avoid needless exposure to the people in those facilities.

Without the monitoring system, there's really nothing to bring it to the attention of maintenance. This isn't going to be a high priority maintenance item. Like Bill Lucke said, you don't have to climb that ladder and get up into the rafters of the plant or climb on top of the machine to look at it. So, you need something to cry out for attention.

Mr. Tepper: I don't disagree with that. I'm just not sure that we need to legislate it. That's all.

Dr. O'BRIEN: I don't think there has ever been any mention of legislating that.

Dr. HENRY LICK: That's only a requirement in the State of Michigan, and the DNR has been disbanded anyhow. I'm sorry, I couldn't pass that up. It just takes too long to get a permit.

Mr. Walter Diachuk: Walt Diachuk, Helical Dynamics again. I have a short one for Bob Kramer. In his model for air flow design, is the energy of the cut or the horsepower, or the spindle horsepower figured into the equation, or is just the enclosure and the escape routes?

Mr. ROBERT KRAMER: Basically, no, I did not do it. I know you have a way of doing that, that you haven't entirely passed on to me yet. No, we did not go into that. It is not a true science by any means. It is one of those things that we have been doing and it works most of the time.

Mr. Patrick O'Neal: My name is Pat O'Neal. I'm a UAW worker at the Cleveland Engine Plant No. 2. We have heard comments about "walking the talk." Well, the Cleveland Engine Plant No. 2 has walked the talk. We have one of the most up-to-date oil mist collection systems anybody would want to see.

We seem to have more visitors to Cleveland Engine Plant No. 2 than Disneyworld; no, seriously. We have team areas that have white tablecloths just like this [pointing to the white tablecloth in front of him] here out in the plant and they stay there for weeks and weeks because we have 26 oil mist collector systems within the plant and anybody who has ever walked in the plant will definitely say oil mist systems are working. I have worked for 30 years in the trade and I've climbed many beams, and today after two years, I could climb those beams and work very safe. There is very little oil mist up there.

We have, believe it or not, a white ceiling and we have been in operation now over two years at full blast, and we still have a white ceiling. We have three-stage oil filters and they are working good. As far as maintenance goes, we have people who go around and monitor. We have gauges that they read and they change the filters and clean the filters as necessary. So far we haven't changed (that I know of) any HEPA filters and we have the ability to go inside or outside, but if you ever build any enclosures, it's not a commercial for GROB, but they are by far the best I have ever seen. They are really good. Excellent, as a matter of fact. Oil mist systems do work because I work with them every day and what a difference from just ten years ago. Thank you.

Dr. HENRY LICK: He forgot to tell you he was a member of the team that helped put that together too. It is a fact that the employees have been involved with that issue and Gifford Brown who is the Plant Manager of that site, doesn't like it when I say that people should go visit Cleveland Engine to see what the future looks like, but that plant is below 85 decibels. You don't need hearing conservation in that plant. The control levels are less than point five. We're quite pleased.

We also have the receipts in the drawer, Frank [Mirer].