WATER CONTAMINATION OF STEAM TURBINE LUBE OILS—HOW TO AVOID IT

by

William L. Coleman

Manager, Steam Turbine Department (Retired)

Dresser-Rand Repair Shop

Houston, Texas

William L. Coleman is a native of Arkansas. He graduated from Louisiana Tech University with a Bachelor of Science degree in Mechanical Engineering (1944). He has been associated with the product line of the Terry Steam Turbine Company (now part of the Steam Turbine Division of Dresser-Rand) for over forty years. He has had extensive experience in application engineering, sales, service and repair shop supervision. Recently retired from the Services Division of Dresser-Rand where he held the position of Manager-Steam Turbine Department in the Houston Repair Shop. He helped organize the Houston Terry Repair Facility in 1968, which was the first and has been through the years, the principal Terry Repair Facility outside of the factory. He has had a major role in developing repair methods and techniques used in the repair shop.

Mr. Coleman is currently involved in consulting activities.

ABSTRACT

Ever since steam turbines have been built, contamination of the lube oil by watert has been a persistent problem.

Water contamination will result in rusting of ferrous components, accelerate sludging leading to sticking of mechanisms. In advanced cases, if water is pumped by the oil pump, immediate bearing failures result. Aeration of oil as it leaves the bearing is the reason why most forced feed (lube) turbines experience a constant inflow of air into the bearing housings. If this air has a dew point above the coolest place in the oil system, water contamination results.

Raising oil reservoir temperatures and better flingers frequently help and sometimes eliminates the problem, but a dry gas purge, either dry nitrogen or dehydrated air, has been proven to be very effective. For best results and safety, the dry gas purge should be introduced into the bearing housing seal.

INTRODUCTION

Water contamination of lube oil, occurring rather commonly in small or modest quantities, does not result in apparent or immediate problems. But, in time the effects will range from appreciable to severe.

Water contamination results in:

- Rusting of ferrous components in the lube systems. This causes wear of bearings and shaft journals, and sticking of oil lubricated mechanisms, such as mechanical trip mechanisms, oil trip cylinders and pilot valve (governor) mechanisms.

In some instances, admittedly unusual, rusting of ferrous components has dislodged hard particles which have then embedded in the bearings and actually machined away the shaft journals.

There have been many instances where water has been present for a long time resulting in extreme rusting of oil drain lines and oil reservoir covers. Once this condition exists, it is virtually impossible to get the system clean. Because of this, some users have specified stainless steel drain lines and oil reservoirs.

Small and medium (100 to 1500 hp) turbines usually have ball thrust bearings. This writer firmly believes that incidences of short bearing life are attributable to water contamination.

- In an extreme case, one might receive the report that "oil is overflowing from the reservoir." This has happened and is often the result of sufficient water accumulating in the oil system to displace so much oil that oil overflows from the reservoir. If continued unchecked, the water level can rise until the oil pump picks up the water and bearing failures with their unpleasant consequences will quickly follow.
- Most present-day lube oils contain additives which are necessary to make the oil perform without excessive oxidation, foaming, sludging, and general deterioration. Water contamination of the lube oil will often remove or wash out these additives.
- In addition, water will promote formation of emulsions, which in turn can plug oil filters and leave deposits in the bearings.

Evidently then, water contamination of lube oil will eventually cause serious problems and this deficiency should not be ignored.

In most cases, the moisture source is gland leakage, although water also can enter by means of a cooler leak. Testing the water sample for dissolved solids will distinguish between the two sources of contamination. Steam condensate gland leakage is quite low in dissolved solids, whereas cooling water is moderate to high in dissolved solids.

As the lubricating oil leaves the bearings, the oil becomes aerated. Some bearing designs promote greater aeration than others, but all bearings aerate the oil. This aerated oil then flows out of the bearing housing or bearing box into the drain line and on into the oil reservoir. Some air separates from the oil in the bearing box, some separates in the drain line, and the rest separates from the oil in the reservoir. The air released in the reservoir then collects above the oil and exists through the reservoir vent (Figure 1).

Thus the oil flow is removing air from the bearing housings or boxes, and releasing the air in the reservoir. Air flows into the bearing boxes to replenish the air taken away by the oil. The bearing boxes are usually tight and generally the air enters along the shaft. Quite near the place where the air enters the bearing box is the gland case, which in many instances is leaking at least some steam. As will be examined later, in many instances this steam leakage is normal and expected. If this steam leakage is sufficient to raise the dew point of the air being drawn into the bearing box above the temperature of the underside of the oil reservoir cover, then air released in the oil reservoir causes dew to form on the underside of the oil reservoir cover. When these dew drops fall into the oil, water contamination exists.

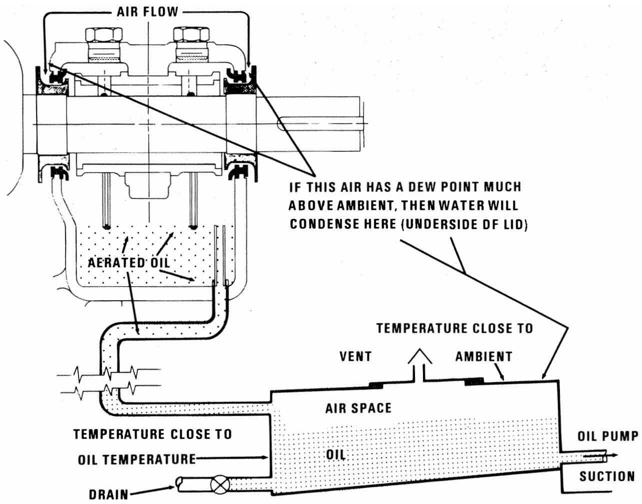

Figure 1. How Gland Leakage Enters the Oil System.

Review the turbine end glands. There are two basic types—carbon rings and labyrinths. With both types there is flow. Both types can be likened to throttle bushings. The user desires relatively low flow in either case, but in no instance will "NO FLOW" be achieved.

CARBON RINGS

Carbon rings are relatively inexpensive and the normal design aim is to achieve essentially line-to-line fit with the shaft at operating conditions. Because the expansion coefficient of carbon is about half that of steel, there is a differential expansion problem to contend with that becomes increasingly difficult as temperatures and speeds become higher. This fact, coupled with the phenomenon that new carbon rings generate greater frictional heat for several hours until they are run in, requires carbon rings to have greater clearances in some circumstances. Hence, the leakage flow will be greater than that obtained under optimum conditions. The general practice with carbon ring glands relative to removing the steam that does leak through the gland is to bleed the leakage off the shaft through a leakoff, and to depend on one (or two) carbon rings to prevent excessive amounts of steam to get past the last ring. Anything that will elevate the pressure in the gland at the leakoff location such as, restrictive leakoff piping, will increase the leakage past the gland and raise the dewpoint where the air is drawn into the bearing housing (Figure 2). Vacuum removal at the leakoff, obtainable with eductors or gland condensers, is not generally considered necessary with carbon rings. Nevertheless, these methods would be practical except for the added installation and operating expense.

LABYRINTH GLANDS

Labyrinth-type glands are normally used in larger turbines and certainly favored in high speed and hot machines. Leakage is typically two to three times those of carbon rings, since labyrinth clearances generally range from 0.012 in to 0.025 in. Vacuum removal of the gland steam leakage is usually necessary with labyrinth glands. A properly designed, installed, and operated gland condenser system will not experience any gland leakage beyond the gland and should not experience water contamination of the lube oil (Figure 3).

Over the years, many "time-honored" measures have had varying degrees of success.

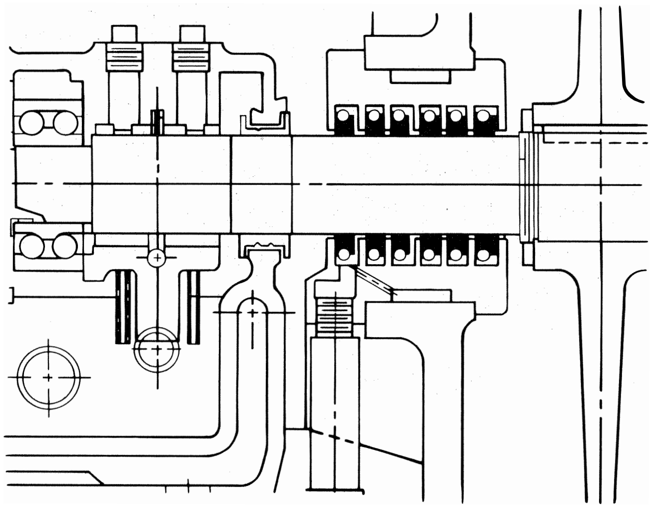

Figure 2. Carbon Ring Glands.

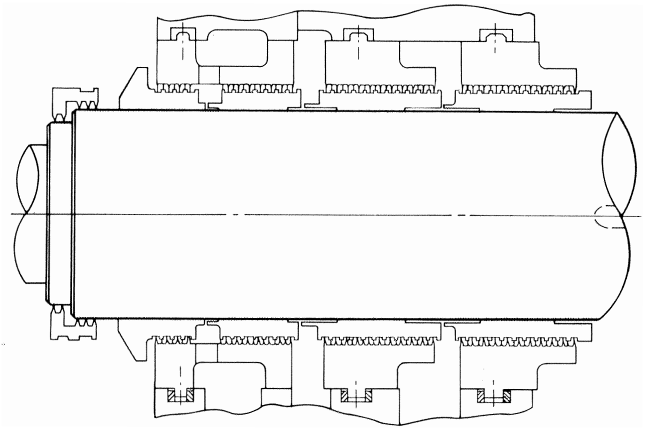

Figure 3. Labyrinth Glands.

- The temperature of the underside of the oil reservoir cover will be greater than ambient temperature, but less than oil reservoir temperature. Recommended oil temperatures in the reservoir range from 130°F to 165°F. In most instances of water contamination, raising oil reservoir temperatures will reduce the problem and sometimes eliminate it. Lowering the oil temperatures will aggravate the problem. Cold weather exposure generally makes the problem worse.
- Better shaft flingers between gland and bearing housing seals are effective since increased ventilation at this point will reduce the dewpoint of the air drawn into the bearing box.
- Some bearing housing seals are on the market that sometimes work by resisting inflow of air at this point. The air inflow hopefully takes place at an alternate entry point, perhaps one with a lower dewpoint.
- Any change that will reduce gland leakage will improve the situation. Condensing turbines have a seal steam loop. The pressure in the exhaust end gland need only be slightly positive to prevent air ingestion at the exhaust end. Sometimes excessive sealing steam pressure increases gland leakage, resulting in water contamination.

Remember Gland Leakage Does Not Have To Be Visible. If the gland leakage is sufficient to raise the dewpoint above the temperature of the underside of the oil reservoir, then water contamination will result.

- In the writer's opinion, the best way of coping with this problem is to install a dry gas purge at the bearing housing seals. The dry gas may be air (such as dehydrated instrument air), or dry nitrogen. A small flow of dry gas is introduced into the bearing housing labyrinth seal. In this way, the appetite of the aerated oil for air is satisfied with dry gas.

The dry gas purge will actually dry the oil. Dry nitrogen normally will have a greater effect. Dry gas flow quantities are on the order of 5 ft ^{3}/hr to 60 ft ^{3}/hr, per seal.

It is much preferred to introduce the dry gas into the bearing housing seal rather than directly into the bearing housing. If the gas is introduced directly into the housing, it is quite possible to over blow, which will blow oil out of the housing onto the hot gland case, and a fire may result. When purging into the seal (even with excessive purge flow) no operational problem will result except for perhaps wasting some purge gas.

Another advantage of the dry gas purge is that even with steam seals in poor condition, especially carbon rings, the dry gas purge continues to protect the oil system from water contamination.

The installation of a dry gas purge into a bearing housing seal usually requires some planning, but is not particularly difficult. If the turbine does not have a labyrinth seal at the housing end, while the turbine is in the shop, the housing end may be bored to receive an aluminum seal. Generally, there is not a suitable boss for drilling over the seal and, usually either 1) cut a vertical hole with an end mill of such size to take a 1/8 in or 1/4 in nipple, which is brazed in place, or 2) braze a boss on the end of the housing, and then drill and tap for a 1/8 in or 1/4 in pipe nipple. In either case, the connection into the seal is by a 1/16 in hole. (Figure 4, 5, and 6). The 1/16 in diameter admittance hole was adopted years ago, when the air was metered by having 1.0 psig air pressure against a 1/16 in orifice. A better way is to use a small inexpensive (under $50.00) rotameter for lower flow adjust-

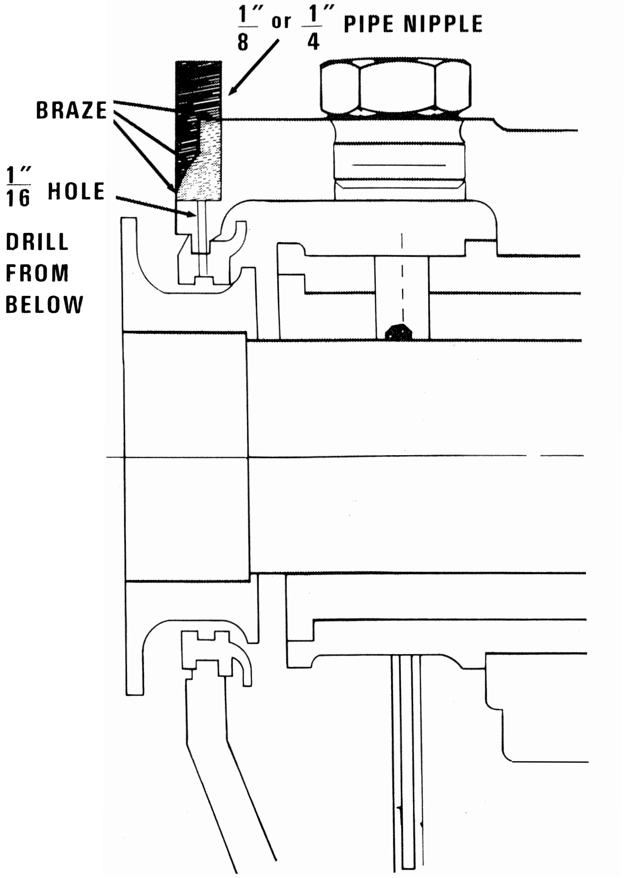

Figure 4. Dry Gas Purge With Pipe Nipple.

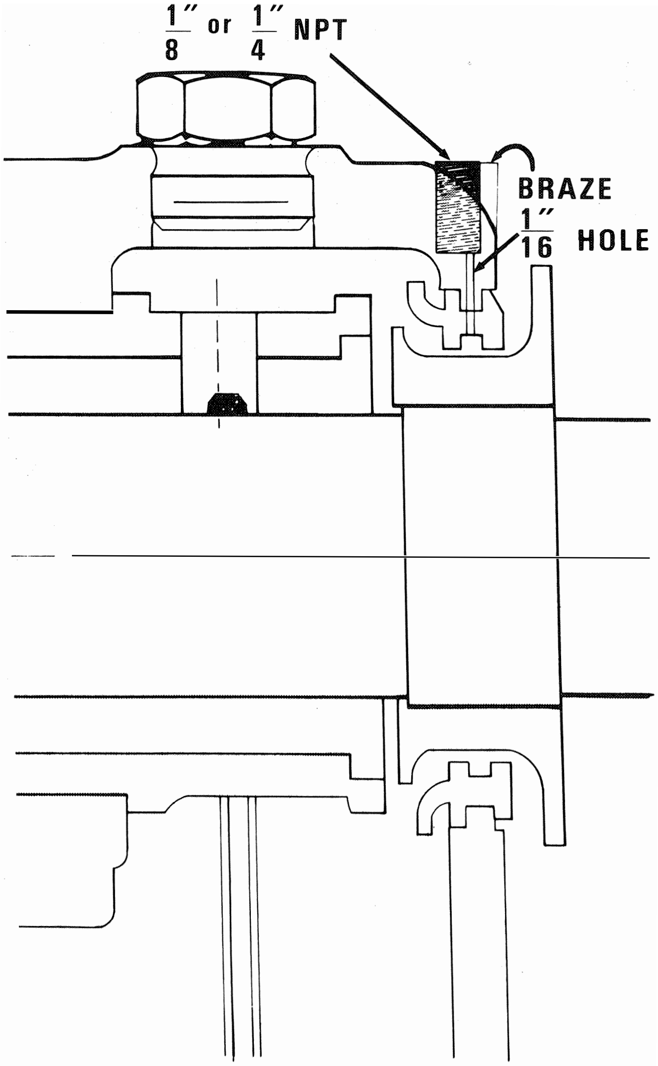

Figure 5. Dry Gas Purge with Brazed Connection.

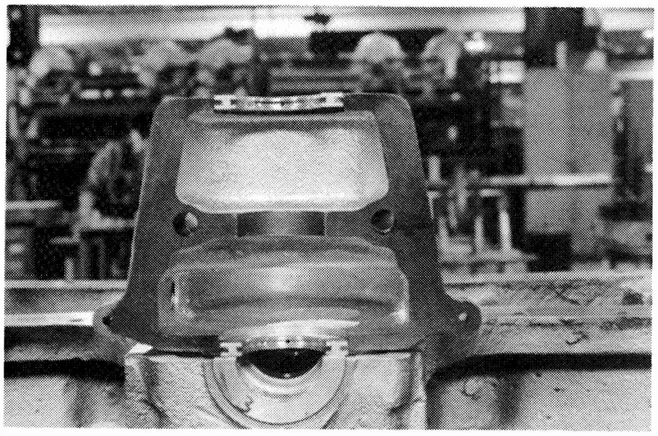

Figure 6. Small Turbine Showing Purge Gas Entrance into Bearing Housing Seal.

ments (Figure 7, 8, and 9). It is essential that purge flow enter an annular space around the shaft. This annular space may be on the shaft, but usually one can be found on the stationary seal. In some turbines, the purge entry hole will have to be angled to connect to the annular space. The annular space is necessary to distribute the purge flow completely around the shaft in order to buffet any moist air from entering the housing.

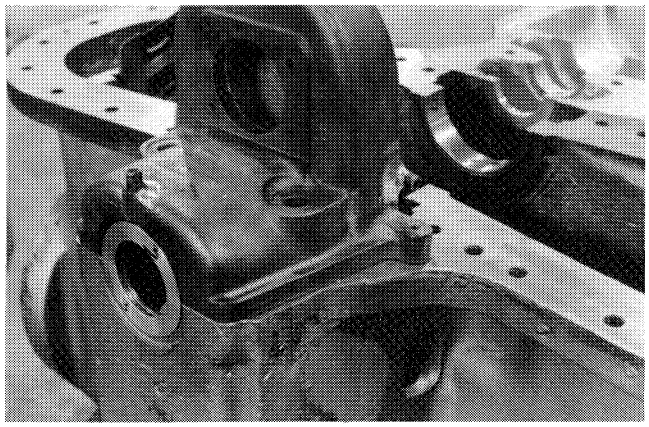

Figure 7. Small Turbine Showing Purge Gas Connections.

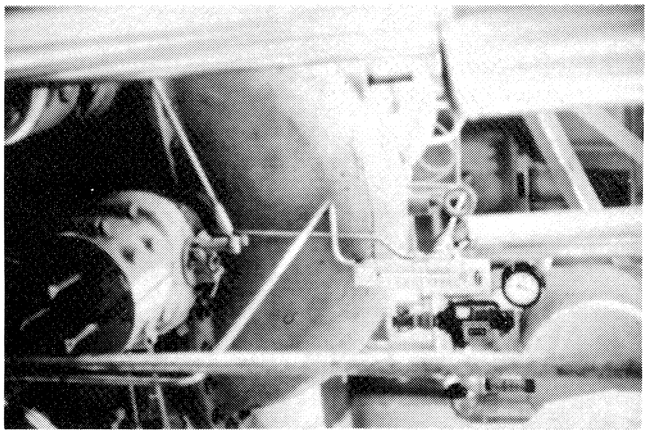

Figure 8. Same Turbine Showing Installation.

WATER REMOVAL

It is certainly preferable to keep the water out of the oil system rather than to let it accumulate and periodically remove it. However, on machines not yet adapted for dry gas purge and experiencing the problem, the two methods for coping with the problem are as follows:

Centrifuge

A centrifuge purifies a small slipstream of oil, but is only marginally satisfactory.

Vaccum Oil Purifier

Vacuum oil purifiers are much preferred. They, too handle a slipstream, but are capable of reducing water concentration to much lower levels (down to 10 ppm). Vacuum oil purifiers are available in a variety of designs, especially for combined oil systems supplying oil also to process compressors, some of which have process gas contamination. [1, 2, 3].

Some general notes may be helpful:

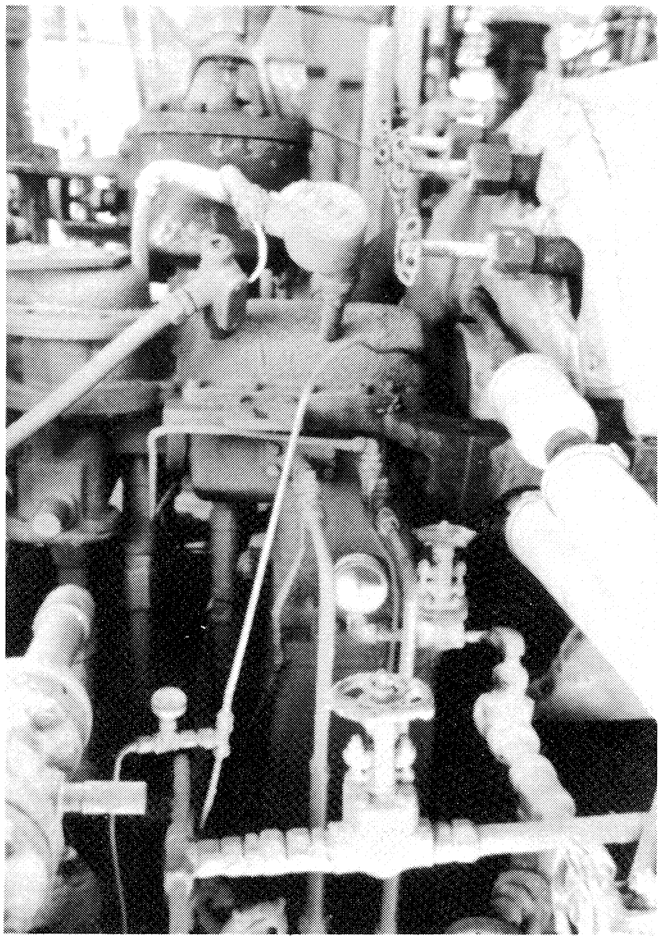

Figure 9. Large Turbine Installation Showing Purge Gas Installation.

- Free water generally exists above a saturation level of around 120 to 150 ppm.
- Oil becomes cloudy in the range of 200 to 500 ppm.
- A centrifuge is effective in removing free water down to about 30 ppm above the saturation level.
- On the Texas Gulf Coast, experience is that if oil is dried below 100 ppm, and subsequently exposed to the atmosphere, the oil will absorb water up the saturation level of 150 ppm. Additional water will exist in the free state.

CONCLUSIONS

All of the users contacted by the writer have reported that in their experience if the oil is maintained in a visually clear condition, they have what they consider to be satisfactory operation. However, several literature references report that if antifriction bearings are present, water contamination, in virtually any quantity, will ultimately have adverse effects on the antifriction bearings in proportion to the water concentration.

Dry gas purge has been proven to be an effective, low installation cost, low maintenance cost means of keeping water out of steam turbine lube oil. Nitrogen is preferable to air, since it is usually drier and contains no oxygen. Very satisfactory results have been obtained with dehydrated air.

The writer's first experience in applying air purges to steam turbines was in a refinery in Beaumont, Texas, some 35 years ago. The results have been excellent. Many other successful installations have been made through the years. Although the writer has heard a few scattered reports of dry gas purge installations that failed to achieve the desired goal, all the installations that had his involvement have been successful at keeping water out of the oil [4].

REFERENCES

1. Bloch, H. P., "Criteria For Water Removal from Mechanical Drive Steam Turbine Lube Oils," ASLE Paper No. 80-A-1E-1, Presented at the 35th Annual Meeting Anaheim, California (1980).
2. Bloch, H. P., and Amin, A., "Optimized Vacuum Purification Methods for Lubricating Oil," Presented at Fifth International Tribology Conference, Technische Universitaet Esslingen, West Germany (1988).
3. Bloch, H. P., *Improving Machinery Reliability,* Houston, Texas: Gulf Publishing Company (1982).
4. Coleman, W. L., "Steam Turbines—Water in the Lube Oil" Presented at the Rotating Machinery Repair User's Council Meeting, Long Beach, California (1987).

ACKNOWLEDGMENTS

The writer wishes to acknowledge contributions in preparing this paper by Glenn Taylor, Dow Chemical Company, Freeport, Texas; W. E. Nelson, Amoco Oil Company, Texas City, Texas; Charles Zirkelbach, Union Carbide Corporation, Polyolefins Division, Seadrift, Texas; David Clayton, Southwest Spectro-Chem Labs, South Houston, Texas; Jerry Wilkerson, E. I. Du Pont De Nemours & Company, Incorporated, Beaumont, Texas; Michael Dull, Exxon Chemical Company, Baton Rouge, Louisiana