METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Attachment IV

Health and Safety Aspects of the Eucalypt Biomass to Methanol Energy System

June 1982

MASTER

**Prepared by
Biomass Energy Systems, Inc.
Lakeland, Florida**

**For the
U.S. Department of Energy
Office of Alcohol Fuels
Under Grant No. DE-FG07-80RA50316**

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Attachment IV

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METHANOL PRODUCTION FROM
EUCALYPTUS WOOD CHIPS

Working Document 4

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Eucalypt Biomass to Methanol Energy System

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Henry H. Fishkind

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Biomass Energy Systems, Inc.
1337 Gary Road
Lakeland, Florida

For the
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HEALTH AND SAFETY ASPECTS OF THE
EUCALYPT BIOMASS TO
METHANOL ENERGY SYSTEM

BIOMASS ENERGY SYSTEMS INC.

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"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

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1.0 INTRODUCTION AND OVERVIEW

Floridians have the opportunity to install a eucalyptus wood energy system in the regional environment south of Orlando which offers a viable alternative to the ongoing and planned expanded use of coal. Of all the alternative energy technologies, the wood biomass approach incorporates renewability, recycling of carbon, and relatively benign environmental impacts when compared to the fossil fuels. It will be necessary in the next few years for many of Florida's industrial and utility energy consumers to choose between coal and wood. We believe the environmental, health, and safety balance weighs heavily in favor of wood. As more coal is burned in Florida over the next decade, the air and water quality data will become available to document or refute our interpretation. Because we perceive the wood energy system is in direct competition with coal, we have frequently made comparisons between the coal and wood impacts on the environment, health, and safety.

The purpose of this working document is to consider the health and safety aspects of the Eucalyptus biomass to methanol energy system. No energy resource system is truly "benign", although some, like wood, have apparent advantages in their health and safety aspects. It is acknowledged that all energy production technologies involve risks in health and safety, environmental pollution and degradation, and use of critical resources. There are long- and short-term considerations to these risks. Further, these risks translate into economic costs in building safer plants for energy technology and safer use of the energy source. Thus, relative risks are the appropriate basis for comparisons between energy technologies. We recognize that a synfuel product, like methanol, will replace its fossil fuel analogue. The environmental, health, and safety risks or costs of the displaced analogue have been eliminated and need to be credited to the balance sheet of the synfuel product. Ideally, gains can be achieved both from production and consumption of the methanol and from the displacement of fossil fuel.

There are many uncertainties in projecting health and safety impacts, even on the generic scale used herein, of both the eucalyptus energy forest and the methanol refinery. No one has installed a eucalyptus energy plantation of the type conceptualized by us; hence, there are no data available for analysis. Reasonably accurate extrapolations from our collective experience with silvicultural and agricultural ecosystems have formed the backbone of our analysis. Likewise, no modern wood-to-methanol plant is in operation. This points to the need for temporally staged environmental health and safety studies and expanded research as wood energy systems begin to come on-line. We regard this current assessment as no more than a beginning of an ongoing research and monitoring process.

Most of the current concerns over the direct combustion of wood as a public health hazard stem from the particulate organic matter and unburned hydrocarbons resulting from the incomplete combustion of wood in residential stoves and fireplaces (DeAngelis, et al., 1980; Butcher and Sorenson, 1979). These pollutants will not be an environmental or health hazard in our gasification process because combustion of the wood is virtually complete at the high pressures and temperatures under which we operate. There is an unfortunate tendency to transfer the well publicized environmental and health concerns over the widespread use of wood for residential heating to industrial wood energy systems which have quite different combustion technologies.

Biomass Energy Systems, Inc. (BESI) launched its wood-to-methanol project in 1980 on parallel tracks, assessing the feasibility of both a 100 MGY methanol refinery and a 100,000 acre eucalyptus energy plantation to provide an assured and constant feedstock for the methanol refinery. Changes in the world energy matrix rather suddenly have made wood fuel technology economically competitive with fossil fuels, especially coal and foreign petroleum distillates. Thus, what is new about today's wood biomass technology is the scale of wood fuel production necessary to meet exploding market demands.

Wood biomass energy is the most environmentally benign of all the large-scale energy systems and has an ecological soundness absent from the fossil fuel systems. Fundamentally, it is a solar technology where the leaf is the collector of solar energy which it converts and stores in the form of cellulose via photosynthesis. Wood and its byproducts are converted into energy and conventional fuel equivalents by combustion, gasification, pyrolysis, methanol synthesis, fermentation, or a combination of these processes.

Biomass is a renewable resource. In a renewable, biomass energy system there is no net release of carbon dioxide. That is, fuel is not taken from a carbon "sink". By the same token, nutrients and minerals to a major extent are recycled in the biomass energy system. Compared with nonsolar or nonrenewable energy systems based on fossil fuels, biomass production systems require less environmental control. Fortunately, wood offers more of the advantages of coal in terms of density and fuel value than most forms of biomass. Not only is the environment at less risk in the wood energy system, but so is the work force. Exposure to carcinogenic materials and toxic substances is far less when compared with coal and oil shale technologies.

Bioenergy programs must be designed to exploit the unique regional resource base. Because of the favorable climate and available lands, Florida, south of Orlando, is perhaps the most ideal region within the United States for creating a new, large-scale wood energy system. Forest planting is a land use highly compatible with the increasing human population which characterizes Florida's growth. The "organic" appeal of a renewable energy source from trees should result in public and political support, in contrast to the negative attitudes widespread in Florida toward strip-mining, industrialization, and other high-density developmental uses. Indeed, planting a million acres of eucalyptus energy forest on pastures, rangeland, and former flatwoods is a type of reforestation that would significantly enhance the regional environment, particularly in terms of water quantity and quality, air quality, and wildlife.

Establishment of additional woodlands is an environmentally desirable alternative to pasture and row crops, particularly on soils marginally suitable for agriculture. The installation of commercial wood fuel plantations is the only economically viable means of increasing forest acreage in the region. Although wood fuel plantations cannot compare with undisturbed native forests in biological values, they are ecologically benign compared to other, more intensive land uses in Central and South Florida. In fact, fuel production forests still provide many of the benefits attributable to natural forest ecosystems--soil and water conservation, air quality improvement, climatic control, wildlife habitat, and esthetic and visual enhancement. Furthermore, wood fuel systems offset the adverse environmental effects of alternative fossil fuel systems.

The regional abundance of available and suitable lands is crucial to the development of a large-scale, wood fuel system. There are well over a million acres of suitable land that might be converted to an energy plantation use. A commitment by landowners must occur before plantations can be established. Educating landowners to the exploding demand for wood fuel is necessary before they will incur the cost of installing the energy plantation. Most of the present land uses are of a low intensity/profitability and will be easily displaced by uses with higher economic returns. The dominant present use is for cattle grazing, primarily cow/calf operations, an industry under severe economic stress.

On an ecospheric scale, man's continued release into the atmosphere from storage of carbon dioxide not now part of the global cycle, through the burning of fossil fuels, threatens to bring about catastrophic worldwide climatic changes. The continued ravages of acid rain cannot be sustained. Burning of sulfur-containing fuels must be cut back. In a renewable biomass energy system, there is no net release of new carbon dioxide additive to the cycle. By the same token, nutrients and minerals are cycled from the energy farm to the gasification plant and then back to the energy farm or otherwise into the environment at large. Since wood contains a negligible quantity of

sulfur, acid rain resulting from the release of sulfur oxides into the atmosphere will not be a problem in biomass energy systems.

Biomass Energy Systems, Inc. developed an interest in the wood-to-methanol technology in the belief that an increasing percentage of the nation's vehicular fleet will operate on methanol instead of gasoline. Methanol is used neat to fuel automobile engines, and as a gasoline additive to improve octane. Methanol currently is used as an octane booster in unleaded gasoline, a use that will expand rapidly in this decade. Methanol in the neat, undiluted form can be used in an internal combustion engine with relatively minor modifications. Methanol in automotive engines is extremely clean burning and is rated the preferred fuel by EPA (Pers. Comm.) among the field of all synthetic alternate fuels.

Fluid fossil fuels will remain either in critically short supply, or will be exceedingly costly in the foreseeable future. The biomass energy system represents a way of using solar energy to produce fuels, solid, liquid, and gaseous, which will displace a significant segment of fossil fuel consumption over the long term. One ton of green eucalyptus biomass is equal in equivalent Btu's to one barrel of #6 fuel oil. Most importantly, the wood biomass equivalent is renewable. We do not believe that the economic success of the eucalyptus energy plantations is linked in any way to the construction of a methanol refinery. A sufficiently large acreage of energy forest, capable of providing a sustained, dependable, and predictable yield, will prove attractive to most users presently dependent on coal, oil, and natural gas.

In this report we will: (1) describe the basic Eucalyptus-to-methanol energy process and identify possible health and safety risks at all steps of the process, (2) describe the toxicology, and treatment for exposure to these substances, and propose mitigating measures, and (3) compare the health and safety impacts and risks of the wood gasification/methanol synthesis system

to those of the coal liquefaction and conversion system. Biomass is a renewable energy resource, and the biomass-to-methanol energy system is one of the most environmentally clean and occupationally safest of the alternative synfuel technologies at hand.

The scope of this report includes the health and safety risks of workers (1) in the laboratory and greenhouse, where eucalyptus seedlings are developed, (2) at the biomass plantation, where these seedlings are planted and mature trees harvested, (3) transporting these logs and chips to the refinery, (4) in the hammermill, where the logs and chips will be reduced to small particles, (5) in the methanol synthesis plant, where the wood particles will be converted to methanol, and (6) transporting and dispensing the methanol. Finally, the health and safety risks of consumers using methanol will be discussed.

2.0 A GENERALIZED SCENARIO OF THE EUCALYPTUS-TO-METHANOL ENERGY SYSTEM

Biomass Energy Systems, Inc.'s vision is that of a eucalyptus energy plantation, with 871 trees to the acre, each a cloned replicate of a proven superior parent tree, growing in the Florida sunshine and rainfall, producing a yield of hardwood fuel which far exceeds man's experience with most other natural or planted forests. Some eucalypt species have an astonishing ability to convert sunlight, water, and nutrients into stored energy. Individual Eucalyptus camaldulensis, the river redgum in Australia, planted on mined lands in Polk County have grown to 90 feet in height and 14 inches in diameter in less than seven years! One measured tree added 10% in volume during the winter months between December 1980 and March 1, 1981; a period of expected slow growth and cold temperatures. Our mensuration studies of this existing stand show a yield of 15 cubic meters per hectare per year, about one-sixth of the estimated potential production of intensively managed, cloned eucalypts planted on better sites under more favorable growing conditions. This ability of eucalypts to rapidly produce such a great volume of wood fuel with virtually no management costs between planting and harvest, makes them the outstanding candidate tree choice wherever the climate and environment permits.

Our data documenting the growth of a sample of select Eucalyptus camaldulensis trees in two plantations mined for phosphate, showed volumetric increases of 19% on sand tailings and 31% on overburden in the eighth year alone. Even to an experienced forester familiar with the voluminous eucalypt literature, this annual incremental growth increase is phenomenal! A one-acre hypothetical stand of 522 of these super trees, vegetatively cloned by tissue culture propagation, on a site similar to the overburden plot, would have increased in wood fuel volume this past year by 80 green tons! While we don't predict real world yields of this magnitude now, we do believe 20 green tons per acre per year is a very conservative estimate of yield from clonally propagated trees in the 7th or 8th year planted on newly reclaimed, phosphate-mined lands. The same hypothetical stand of 522 of these actual select trees would have yielded

335 green tons per acre with a harvest at eight years. Few, if any, land uses can outcompete a renewable wood energy crop with potential yields like those demonstrated by the river redgum, growing in Polk County, especially if marketed as a fuel for its Btu content! This potential wood biomass productivity is at the very heart of the Biomass Energy Systems, Inc. scenario.

Florida plantings of eucalyptus are drawn from a very limited gene pool for most of the species planted. Florida plantations derived from seedlings have been characterized as "aces and spaces", in which many or most of the spaces are occupied by inferior trees. Vegetative propagation of the best parent trees available is necessary to provide a nearly uniform stand of high-volume individual trees. Biomass Energy Systems, Inc. has perfected the laboratory techniques needed to mass produce plantlets cloned from superior parents by in vitro tissue culture propagation. We confidently predict minimum doubling of yield when clonal plantlets are used in place of seedlings. Seedlings of Florida grown Eucalyptus camaldulensis, the species we prefer and recommend, presently are not available in commercial quantities. Most mature individuals of E. camaldulensis in Florida fail to produce viable seeds. The use of clonal plantlets derived from superior parent trees is an essential element in the Biomass Energy Systems, Inc. scenario.

Genetically superior Eucalyptus plantlets will be cloned in the tissue culture laboratory and raised in greenhouses. These plantlets eventually will be installed on 100,000 acres of silvicultural biomass plantations in Central and South Florida at a rate of about 10,000 acres per year. After 6-8 years, the resulting mature trees will be harvested and transported to the hammermill. The mill and methanol plant might be an integral internal part of the plantation; or they might be as much as 50 miles distant. Coppice growth of the eucalypts will replace the harvested trees. Reworking the soil and planting new trees will occur once every 25-50 years. At the hammermill, the logs, air-dried in the forest, will be size-reduced to very small chips. The chips then will be converted into methanol by a Texaco gasification/methanol synthesis process yet to be tested in a pilot plant stage.

Conventional wood-fired boiler technology will power the hammermill and methanol synthesis plant. The wood feed, air-dried to a 15-20% moisture content, will be injected into the Texaco gasifier, which will be operated at approximately 2,600°F and 800-1,000 psi in a nearly pure oxygen environment. The residence time of an average wood particle will be approximately eight seconds.

This high temperature and pressure eliminates the production of olefins, phenols, tars, and heavy metals. The relatively small amount of ash remaining will be returned to the plantation soil after each cutting.

The gasification process produces almost pure carbon monoxide (CO), carbon dioxide (CO₂), hydrogen gas (H₂) and some ash. Some trace of hydrogen sulfide gas (H₂S) may be produced. The H₂S will be "scrubbed out" and the CO₂ separated from the H₂ and CO by a standard Benfield process. The CO₂ may be vented or routed to a greenhouse to enhance growth of commercial plants.

The H₂ and CO will be combined in the proper ratios in the shift reactor to form methanol gas in the presence of a catalyst. The methanol gas will be condensed to form liquid methanol. Paul (1978) and Reed (1981) describe these processes in greater detail.

The liquid methanol then can be used as an automotive fuel or additive, in fuel mixes for industrial and electrical utility boilers, and as a feedstock for further chemical synthesis.

A portion of the eucalyptus wood produced can be expected to flow into markets other than methanol, such as pulp and paper manufacturing, residential heating, direct boiler feeds, gasification into a gas boiler feed, and as a feedstock in chemical processes. A decade from now, phosphate mining companies can be expected to cogenerate much of their electrical energy requirement from eucalyptus grown on their own lands. Therefore, Biomass Energy Systems, Inc. must own or control by lease enough eucalyptus plantation acreage to assure a feedstock supply for the methanol plant.

3.0 HEALTH AND SAFETY IN THE LABORATORY AND GREENHOUSES

The eucalyptus biomass energy system begins in a tissue culture laboratory, greenhouses, and nursery. Exposure to chemical pesticides poses the greatest potential health and safety risk to laboratory and greenhouse staff. Pesticides vary in their toxicity. A correct mixture of worker protection and pesticide function can certainly be found. Education, supervision, and monitoring of the work force exposed to these chemicals is essential. Both pesticides and herbicides may be used in the production of cloned plantlets, but at this point it is premature to determine which chemicals will be used. All the proper application and storage precautions and regulations for any chemicals used in this operation will be followed, as stated on labels and in the supportive literature. Protective clothing and a breathing apparatus may be worn during the application of pesticides and herbicides. Safety showers will be available for washing away chemical contaminants. Workers will be trained to follow labeled instructions fastidiously.

Biomass Energy Systems, Inc. is developing conceptual plans for a large-scale adjunct greenhouse operation to produce food and ornamental crops in a carbon dioxide enriched environment, utilizing the waste stream of carbon dioxide from the refinery. A very large greenhouse complex is anticipated, based on the supply of carbon dioxide. The detailed planning of this facility is beyond the scope of this study.

Biomass Energy Systems, Inc. may contract with its sister company, Clonal Resources, Inc., for all the eucalyptus plantlets required to install the energy forest. In this case, Biomass Energy Systems, Inc. would not build and operate a tissue culture laboratory. The conceptual planning now underway does not allow for other than a broad-brushed treatment of these possible amendments to the primary scenario.

The use of pesticides, fertilizers, and other chemicals will be consistent with the state-of-the-art for the industry. All chemicals will be handled according to the manufacturer's specifications on the label and in the literature. All appropriate federal and state rules and regulations

will be followed to safeguard the environment and protect the work force. Education, supervision, and monitoring is necessary to minimize the occupational risks and exposure.

We do not expect the health and safety factors associated with the laboratory and greenhouse complex to differ from numerous, similar plant materials businesses now operating in Florida and the nation.

4.0 OCCUPATIONAL SAFETY ON THE BIOMASS PLANTATION

The most serious occupational hazards on the plantation occur during planting and harvesting. Forestry and agricultural workers have comparable injury rates (Watson and Etnier, 1981)

4.1 Risk of Injury to Plantation Workers. Based on 4-year averages from 1975 to 1978, forestry workers suffered 12.2 injuries per 100 full-time workers, with 5.0 lost-work-day cases and 80.3 total lost work days (BLS, 1979). The types of accidental injuries to the work force associated with biomass production and transport are difficult to eliminate and require ongoing programs to minimize.

The frequency and/or severity of injury among woods workers is evidenced by relatively high workmans compensation rates nationwide. For example, Florida's newest revised workmans compensation rate for loggers is \$20.85 per \$100.00. Other examples of rates are: roofers \$15.37 per \$100.00, machine shop employees \$3.34 per \$100.00, and retail store employees \$1.32 per \$100.00. High rates do not necessarily mean more injuries. Severity of the injury, the type of labor force employed, the job location, and employee turnover are but a few of the factors influencing workmans compensation rates.

4.2 Silvicultural Plantation Hazards. While the incidence of occupational injuries in the forest industry admittedly is high, the biomass plantation differs from conventional forest industries in several very important ways. First, the biomass plantation in Florida will be located on relatively level ground. Problems with "log roll", "equipment roll", and "fall from equipment" is often the case of mishaps in the western forest products industry. Safe tree harvest machinery for forest biomass crops is presently available. This type of machinery will cut down markedly on the injuries caused by the traditional falling of trees and handling of logs during forest harvesting. Traumatic injuries from chain saw accidents can be guarded against through education, supervision, the following of the

manufacturer's directions, and the use of now available protective clothing. We intend to be mechanized almost to the point of eliminating the use of chain saws. Chain saw kickbacks are the principle cause of logging injuries to the lower extremities which are a major (20-40%) component of all injuries (Safety Sciences, 1976).

4.3 Benefits of Mechanization. Mechanized logging equipment generally has increased production, decreased per-unit production costs, and lowered job related accidents and injuries. Strains, sprains, and other injuries have been reduced through the mechanization of cutting, loading, and transportation of the wood.

Manufacturers and sellers of mechanized logging equipment are guided and controlled by occupational safety and health standards. This includes roll bars, safety cabs, wire mesh enclosures, automatic shutoffs, and noise-level controls. Personalized safety equipment (hardhats, safety shoes, safety clothing, glasses, etc.) in conjunction with safety education, proper field supervision, and employee motivation will see even further reduction in both numbers and severity of traumatic injury associated with the harvesting of wood.

4.4 Site Preparation Risks. Complete site preparation through the elimination of trees, stumps, and competing vegetation eliminates some hazards normally associated with tree planting. Elimination or removal from the site to be prepared for planting, of all saleable materials, reduces the gross quantity of material to be handled during site preparation. An overall site preparation hazard reduction is realized by reducing the "time on site" required for job accomplishment. Whenever possible, the supervisor may keep a physical separation of heavy equipment by breaking down the site into component work units. Separation by space does not relieve individual equipment operators from exercising all reasonable and prudent safety precautions. When equipment is in motion, operators must be constantly alert for potential hazards to themselves and their equipment as well as infringement upon their right-of-way to the right, left, and in the direction of movement.

During site preparation, particular attention should be paid to limbs which may be stressed past the point of flexibility. A fractured limb is a high risk hazard to the equipment operator and others in the area. Cables used for dragging or pulling should be constantly checked for fair wear and tear or unusual use damage and repaired or replaced as necessary. Cable failure while operating under stress offers high potential for injury to all persons within the cable's operating length. Injury during site preparation is generally minimized by the safety components built into the heavy clearing equipment in the form of operator protection and warnings to others in the area.

4.5 Tree Planting Risks. During tree planting, normal over-the-road safety precautions should be followed in the transport of the nursery plants to the planting site. Planting probably will be done with a wheeled, tractor-drawn, three point hitch planter. Automated planters are not yet available due to the present variety of sizes for containerized stock. Total site preparation will eliminate many hazards associated with planting. The tractor operator and the planter must have some form of electronic communication. This is normally accomplished with a buzzer system actuated by the operator of the planting machine. This is an important safety precaution if the planter gets into trouble. The installation of a rearview mirror can give the tractor operator rear vision to confirm the good tracking of the planter and allow judgmental adjustments in tractor speed to maximize the efficiency of the planter. The person on the planter must continue to be alert and maintain an adequate distance between limbs and moving parts of the planting machine. While the use of containerized stock in styrofoam trays eliminates much of the weight associated with bundles of plants, persons loading and unloading plants are cautioned to use proper lifting procedures to protect against strain.

4.6 Wood Harvesting Risks. Wood harvesting offers the highest potential risk to injury in the eucalyptus-to-methanol project. Development of the feller-buncher, chain guards and automatic shut-offs for chain saws, the

delimbing gate, grapple-type skidders, and mechanized, but portable, slashers has removed many of the injury-causing hazards associated with wood harvesting. The feller-buncher mechanically severs and gently lays entire trees on the ground. Chain saws can be almost instantly shut down. The delimbing gate has nearly eliminated the axe. Grapple type skidders automatically grasp a bunch of trees and drag them to the loading deck or cutoff saw. Portable slashers cut and rack to size whole trees. It's rare in today's forest for a logger to be kicked by a mule; and, "widowmakers" are handled under the protection of an enclosed and reinforced protective cab on a feller-buncher. However, the safety features of new and developing forestry equipment still rely on the intelligence and common sense of the employee and an ongoing program designed to keep the safe worker informed and the injury-free worker on the job.

Studies of frequent and severe accidents in biomass production, point toward inadequate techniques and equipment design not under worker control. Watson and Etnier (1981) recommend:

- "(1) development of protective leg and knee guards to reduce incidence of saw cuts while allowing freedom of movement;
- (2) noise control;
- (3) practical design of equipment steps/ramps to reduce frequency and severity of falls;
- (4) equipment seat belts that allow unrestricted operator visibility;
- (5) cab designs for improved visibility and log puncture/roll-over protection; and
- (6) standardization of equipment control placement."

4.7 Biocide Exposure and Use. Because there are no known serious insect pests attacking the present eucalyptus standing crop in Florida, we anticipate little, or no use of pesticides. Herbicides will be used on an "as needed" basis. If defoliating insects do become a problem, we shall apply a pesticide, following all regulations and instructions for safe and

appropriate use. The remarks made for the greenhouse use of chemicals also apply for chemicals used on the plantation. No health problems resulting from the silvacultural usage of biocides is anticipated. Proper use should be followed and prescribed precautions taken. There are little data on the exposure of forestry workers to pesticides reported in the literature (Press, et al., 1977). There is a greater likelihood of a one-time use of herbicide at start-up than of insecticides at any time.

Herbicides and insecticides for use on the biomass plantation must be chosen for low toxicity to the occupationally exposed work force, and for biodegradability, meaning that the pesticide and its toxic metabolites will not persist in the environment. Insecticides must be chosen which will not bioaccumulate or biomagnify in the environment. Bioaccumulation is an increase in pesticide concentration as one moves from organism to organism through the food chain. Vegetative propagation of biomass trees favors rapid selection for properties such as pest resistance. For economic as well as safety concerns, the biomass forest managers will minimize the use of insecticides and herbicides.

4.8 Fertilizers. Fertilizer (rock phosphate) will be applied only at initial planting and after harvest. Commercially formulated agricultural fertilizers may be required on specific sites where soil chemistry dictates. Application procedures will be similar to those used in agriculture. There should be no occupational hazard other than from the machinery and equipment used.

4.9 Fire. The chances of fire on the eucalyptus plantation are probably less than for most other tree species. The undergrowth is rarely dry enough to burn (Cremer, et al., 1978), because the trees will be planted at a sufficiently high density to shade out much of the competing undergrowth. In addition, we will remove as much undergrowth as possible during site preparation prior to initial planting of eucalyptus. Thus, the only fuel for a forest fire will be the eucalypt leaves on the ground.

In the field, eucalypts seem to form a detrital mulch quickly. As a further precaution, fire lanes will be constructed on the plantation and reworked on an annual basis. It should be noted here that no maintenance fires will be used on the eucalyptus plantations. Therefore, a potential public hazard typically associated with pine forestry to navigation (i.e., no decrease in visibility on nearby roads) and health is eliminated.

4.10 Other Hazards. Foresters typically and regularly face heat and cold stress, insect stings, snake bites, wood dusts, pesticides, plant allergens, etc. in the course of their day to day work in the field. Such exposures may lead to respiratory distress and perhaps cancer on the long term.

Australian researchers (Specht, et al., 1975) have reported the occurrence of seasonal asthma outbreaks that are closely correlated with the seasonal flush in shoot growth of eucalypts in Australia. There has been no cause and effect relationship established. The authors hypothesize that the larvae and adult insects which attack the new growth may produce the asthma allergens in their fecal pellets. We are unaware of any report of asthmatic type allergic responses to eucalyptus growing in the U.S.

5.0 HEALTH AND SAFETY CONCERNS ASSOCIATED WITH TRANSPORTING LOGS AND CHIPS

Economics and land availability will determine the siting of the hammermill and methanol synthesis plant relative to the plantation. While we predict a mean transport distance of 30 miles from the plantation to the hammermill and refinery, the actual distance and routes are not known at this time. The transport distance determines the number and kind of trucks used for hauling logs, but we project a mean vehicle load of 25 tons. Logs will be hauled in standard, safety-approved highway vehicles and the professional drivers will be in standard cabs. Legal limits of gross weight and length of truck and load are clearly outlined by Florida statute. Permits are required for loads exceeding maximum lengths. We will comply with all highway laws and permit requirements. Undoubtedly, the greatest potential impact on public safety is associated with the daily trucking runs between the plantations and the refinery and their moving vehicle accident rate.

Both the loading and unloading points have a potential for workers being struck by log(s) rolling off a pile or a truck. Yard workers also are vulnerable to being struck by a piece of equipment. Truck rollover due to traveling at an excessive speed for road conditions is the most common highway accident cause (Watson and Itner, 1981).

The effect of moving the woody biomass from the forest to the primary utilization plant will be directly tied to the distance between the standing tree and a drum of finished product. As the distance between the point of growing to the point of distillation increases, so must either the weight of the loads transported or the number of over-the-road wood hauling units. Transportation costs are a major limiting factor controlling the distance feedstocks can be hauled economically to the refinery.

State and federal regulations limit the weight of individual loads. Individual loads also are limited by the stackability of the raw material and the vehicle height of obstacles along the route.

A typical whole-tree logging crew operation under field conditions should produce ten 25-ton (22.7 tonne) loads of wood per day. Using a 240 day annualized harvesting schedule, daily plant delivery will be about 6,000 tons (5,500 tonnes) and will require 30 operational logging crews, assuming an 80% efficiency rate. Thus, approximately 240 truckloads of wood per day will leave the plantation in a year. Using an average distance of 30 miles from plantation to plant, this would involve 24 trucks making ten 60-mile round trips per day, or 600 miles per day per truck for a year.

If and when truck traffic to and from the forest increases, present largely rural traffic patterns could be impacted by the increase in road usage unless the traffic moving capability keeps pace with vehicle increases by constructing additional traffic lanes or new routes of access to the final destination point of the traffic. Widening and/or repaving are options open to planners. The impact of the biomass facility probably will be minimal for at least three years after plant construction commences. It will be minimal for seven years after forest planting begins. These amounts of lead time, coupled with good and proper governmental planning and construction implementation far enough in advance of real need to assure timely completion, can make the transition to greatly increased traffic flows from the forest to in and around the methanol plant nearly painless. Preplanning and timely construction will provide access road systems which can avoid residential and urban areas. The accompanying absence of congestion will provide added factors of safety for all user vehicles.

The air emissions estimates for the heavy-duty diesel trucks that will be used to haul the logs and chips can be calculated with formulae published by USEPA (1977). In these formulae, the emission factor for a given air pollutant for a calendar year depends on the average speed and make of the truck. A site-specific and detailed environmental impact statement would include these calculations.

Plant location, yet to be determined, is the overriding factor. If Site No. 1, 90,000 acres in Southwest Polk County, were selected, the refinery could be centrally located and most of the feedstock transport would occur on the internal roads.

Another site has immediate access to a commercial waterway connecting to the Gulf of Mexico, and barge transport becomes a possibility.

Many sites have excellent rail line connections which might lead to development of a system using rail transport, tying in with the routes currently serving the phosphate industry.

Depending on final site selection, the transportation of the methanol product from the refinery can be expected to utilize a combination of highway, railway, and waterway routes. Planning needs to be much further advanced before we can more comprehensively address the transport issue. Methanol has been commercially transported by all of the above methods for several decades, albeit an explosive chemical requiring special handling and appropriate caution.

6.0 HAZARDS AT THE HAMMERMILL FACILITY AND FEEDSTOCK STORAGE AREA

6.1 Feedstock Storage and Air Drying. Eucalyptus feedstock from the plantation will arrive as logs and chips. During whole-tree harvesting, the crowns and branches will be chipped and loaded on chip vans with live-beds to aid in unloading. The chips will be stored in large piles at the plant site for several weeks to facilitate compaction and drying from the internal heat buildup. Front-end loaders will be used to move chips from the large piles to an auger feed system for movement to the steam boilers or hammer-mill. Most logs will be stockpiled in forest plantation yards for 2-3 months, during which time the moisture content is expected to fall to 20-25%. This will permit larger truck loads for the haul to the mill as well as greater combustion efficiency. Stockpiling at two locations poses both economic and safety considerations which may mitigate against using this technique all of the time. Additional drying of the whole logs will occur in the wood yard over a storage interval of 2-3 months.

Chips have been stockpiled for long periods of time by southern forest industries without decay or loss of wood substance. Indeed fuel value is increased by drying within the pile. However, there has been only limited experience with whole-tree chip storage. Fire is the primary hazard in chip storage. Internal pile temperatures should be monitored. Adequate fire suppression equipment and water supplies should be maintained in the yard area. We will be in compliance with all OSHA and Florida regulations pertaining to the handling and storage of wood and wood chips, as well as all local fire codes.

6.2 Ambient Conditions in the Wood Yard. Fugitive dust in the wood yard will not be serious enough to warrant control. The wood yard will be a noisy, dirty part of the site, with heavy traffic from logging trucks and chip vans. This is a highly sensitive area in the plant that will require close supervision and management to safeguard the environment and work force. Workers are at risk to being struck by logs and machines.

6.3 Hammermill Operation. At the hammermill plant, the logs will be chipped, dried and size-reduced along with those chips destined for the Texaco gasifier. The hammermill operation grinds the wood into small pieces (less than $\frac{1}{2}$ inch) to assure a more uniform feed into the gasifier. Because of the small size of the pulverized wood, combustion time in the gasifier is estimated to be eight seconds (Evergreen Energy, pers. comm.).

Fugitive dust is a probable impact from the hammermill operation which will be mitigated with baghouse technology. Dust levels could be explosive if not monitored and controlled, much as in grain storage elevators. We do not expect wood dust to be a major occupational health hazard, however. Except for manzanilla (Hippomane manchinella), no systemic effects have been reported for American woods. Generally, the adverse effects of exotic wood dusts are more severe than the dust from woods that grow in temperate climates (Gamble, 1979). No systemic effects have been reported for eucalypts, either. Plant design and worker protection will be in compliance with all OSHA regulations and specifications for wood hammermills and wood-fired boilers.

Noise is an unavoidable pollutant associated with the hammermill. Locating the hammermill away from residential areas, planting trees around the hammermill to muffle the noise, and designing the hammermill to minimize noise are all mitigating measures that will be taken. As mentioned in the supporting health and safety document, the workers will be protected as much as possible from noise, in compliance with OSHA standards.

Hammermills are a common element in the industrial environment and are not expected to interject any surprises or impacts that cannot be offset by current state-of-the-art design, operations, and management.

7.0 POTENTIALLY TOXIC SUBSTANCES AND HEALTH RISKS IN THE WOOD GASIFICATION/METHANOL SYNTHESIS PLANT

7.1 Introduction. In wood gasification/methanol synthesis, there will not be the potentially large quantities and varieties (Nowacki, 1980) of carcinogens, toxic heavy metals, and tars usually ascribed to coal liquefaction and conversion (Reed, 1981). The health effects of these two systems are compared in a later section.

In this section, we identify potential toxic substances, the sources of these substances, describe the toxicology, worker and environmental protection, and first aid and medical treatment for exposure to the problem chemicals. We wish to stress at the outset of this section that with proper plant design, construction, maintenance and monitoring, exposure to these substances will be drastically reduced or eliminated. We do not anticipate problems with these chemicals under normal operating conditions. The Appendix contains Section 10 of Document #7 (Davy McKee, 1981), which addresses the general safety regulations and procedures associated with a modern methanol plant.

In their comparison of the hazards of synfuels to the appropriate petroleum analogues, Ghassemi and others (1981) found that fuel-grade methanol was either similar to, or of lower hazard potential than gasoline. They also found that existing regulations for fuel methanol were adequate. We have had such a long experience with gasoline that we take the attendant hazards for granted.

7.2 Methanol. Methanol is a major industrial chemical in use at this time, and the methods for its safe handling and storage are well known. There are no "surprises" anticipated with respect to health and safety of the public or work force.

7.2.1 Sources of Leaks and Spills and Mitigating Measures. Methanol vapor can escape through tank, gasket and gasoline leakage, and lock hoppers, if any, for the gasifier feed. Such leaks can be avoided. Methanol will be stored in regular steel tanks, recommended by Paul (1978). Noticeable

corrosion has occurred with methanol in contact with lead-plated fuel tanks, magnesium, copper, lead and aluminum parts, as well as some synthetic gaskets. Water will be removed from storage tanks to avoid dilution, contamination and rust problems (Paul, 1978). The storage facility will be inspected at least twice yearly for leaks and faulty equipment. Proper floor design will contain spills within the plant. Under certain conditions, any leakage of methanol liquid could be recycled through the gasifier.

A tank farm consisting of enough tanks to satisfy storage requirements will be constructed. Perimeter and interior dikes will surround each tank to contain the spillage in case of rupture or leakage. A normally closed, storm-water drainage system will be provided for the tank farm. Only uncontaminated storm water will be discharged. Contaminated storm water and/or spilled methanol will be properly collected for recommended disposal. Storage areas will be designed so that spillage will not contaminate ground water and/or soil.

Because methanol is soluble in water, spills cannot be cleaned up by application of oil spill technology. By the same token, methanol is easily diluted with large quantities of water. Dilution will facilitate rapid dispersion to below toxic levels. The plant, storage facilities, and loading facilities will be equipped with water hoses for this purpose. Methanol can be removed from the aqueous phase by ozonation and activated carbon. Water treatment equipment at the plant will include activated carbon filters. Caution, the use of chlorinated water could produce chlorinated hydrocarbons and is not recommended.

The ecological effects of spilled methanol depends on the concentrations and species affected. It is toxic to most plants, animals, and aquatic organisms when concentrated (Paul, 1978). Dilute methanol appears to act as a plant growth stimulant and as a substrate for some microbes. Methanol spills in marine and freshwater are likely to have a minimal impact except where concentrations exceed 1.0 percent (Mueller Assoc., 1981). While concentrations of 0.5 percent produce narcosis in many aquatic insects, some crayfish

species tolerated 10 percent levels for up to 5 hours (DEliscu, 1977). Berger (1974) suggests the use of Pseudomonas fluorescens to consume spilled methanol. Conceivably, cultures of P. fluorescens could be kept at the plant in case of a methanol spill. However, dilution probably offers a quicker solution for rapidly reducing spills to nontoxic levels. Methanol is infinitely soluble in water and will dilute and disperse rapidly in the ecosystem (Johnson, 1980).

As mentioned, first-aid procedures and the evacuation of persons exposed to toxic concentrations of methanol, or to dermal contact with liquid methanol, will be well planned in advance. Employees will be educated as to hazards in the work place and their role in reducing risks.

7.2.2 Fire and Explosion: Emergency Procedures and Mitigating Measures. Methanol flammability limits are 7-36% by volume in air at standard temperature and pressure. Methanol burns with a clear flame that cannot be seen in sunlight. The flammability limits over the liquid surface can be decreased by dilution with inert species. Methanol will react vigorously with oxidizing agents. They must be kept apart. Because of its high vapor pressure, methanol must be carefully enclosed to prevent evaporation. Tightly-sealed containers may burst from built-up pressure if heated by the sun or other sources (Paul, 1978).

Methanol fires should be fought with a water spray rather than a jet in order to prevent spreading the flame. Alternatively, carbon dioxide, dry chemical, or foam fire extinguishers can be used effectively (Paul, 1978). Fire in the chip or wood piles can be extinguished by conventional means.

As with gasoline, methanol presents a moderate to potentially severe fire and explosion hazard. Article 30 of the National Fire Protection Association (NFPA) Code for Flammable Liquids provides guidelines and specification for the storage and handling of alcohols. Large storage areas will have to comply with the Clean Air Act and all pertinent Florida and local laws and regulations. OSHA standards have been promulgated to

protect the worker handling alcohols. Federal regulations governing transportation of hazardous materials by all modes are in place (Mueller Assoc., 1981).

Breakage in a gas line, or allowing an explosive gas bubble to form in the line, can result in an explosion. All lines should be inspected at least twice a year. In an emergency situation (such as a leak, spill, fire, or explosion), or even in a routine check or shutdown, a purge of nitrogen gas will be forced into the lines to avoid mixing with air, thus preventing creation of an explosive mixture and exposure of employees to methanol.

Oxygen going through the gasifier will be under pressure and is susceptible to explosion. Special corrosion-resistant storage tanks and lines will be used for the oxygen supply (Telesca, 1977). The oxygen should be stored in a separate building or area at atmospheric pressure, decreasing the chances of an explosion.

Tanks and inlets to tanks will be designed according to regulated specifications for the pumping and storage of flammable and explosive materials. At the product dispensing area of the plant, explosions will be prevented by a methanol vapor collection and condensing facility. Any leakage will be collected by the dikes in the dispensing area and the contaminated products sent through the gasifier again. Methanol entry will be into the bottom of tanks.

7.2.3 Health Effects, Toxicity, and Worker Protection. Methanol has different environmental and health effects from fossil fuel analogues, such as gasoline. The exposure routes are through inhalation, ingestion, and dermal or eye contact. Unquestionably the production of methanol results in a substantial risk to man.

Methanol has a lower vapor pressure than gasoline, therefore inhalation exposure is lower. Ingestion would be accidental or suicidal; and, methanol is already labeled a poison. Methanol is colorless and nearly odorless and

could be confused with water. The actual definition and limits of the risks of producing methanol from wood remain unknown because no commercial plants are in operation from which data can be drawn. Methanol is excreted slowly by humans in the urine and through the lungs. It is oxidized in the liver and brain to formaldehyde. The formaldehyde is oxidized to formate and then to carbon dioxide. Acute exposure to methanol causes depression of the central nervous system and severe acidosis. There is a lack of data on chronic exposure to methanol. Laboratory animals are less susceptible than people. The formaldehyde produced in the liver from ingested methanol is a mutagen and a suspected carcinogen. It is not known if methanol is transplacental or teratogenic (Johnson, et al., 1980). Gasoline, however, is also toxic. The benzene fraction (Table 7-2) is a known carcinogen and benzene is found in high octane gasoline (Paul, 1978). EPA has recently granted trial clearances for a limited time for the commercial use of methanol as a gasoline additive and octane extender. Methanol is extremely toxic, and drinking 1-2 ounces can cause death. The Threshold Limit Value for methanol inhalation is 200 ppm, a time weighted average (Mueller Assoc., 1981).

Methanol poisoning has immediate as well as long-term accumulative effects. On initial exposure to methanol, a mild transient narcotic and inebriating effect is experienced. Thereafter, a latent period from less than one hour to three days occurs. After this latent period, the toxic symptoms begin to appear, including: weakness, dizziness, headache, sensation of heat, nausea, abdominal pain followed by vomiting, dyspnea, acidosis, visual disturbances, convulsions, coma, and death. The presence and severity of the symptoms are dependent on the exposure, extent, and individual tolerance. Damage is caused to the central nervous system. The most obvious effect is on the optic nerve. The victim experiences a strong sensitivity to light, temporary or permanently impaired vision, or blindness in extreme cases. Also, the victim experiences muscle rigidity, tremulousness, and spasticity. Progressive degenerative damage occurs in the kidneys, liver, heart, and other organs. Many of the toxic effects described above are believed to be due to the metabolites of methanol formed in the liver and

TABLE 7-1

OCCUPATIONAL EXPOSURE

ESTIMATED TOLERANCE VALUES FOR METHANOL

<u>DURATION</u>	<u>ESTIMATED TOLERANCE VALUES FOR METHANOL (ppm)</u>
<u>Single but not repeated exposure</u>	
1 hour	1000 ppm
8 hours	500 ppm
24 hours	200 ppm
5x8 hour working days	200 ppm
168 hours	50 ppm
30 days	10 ppm
60 days	5 ppm
90 days	3 ppm
<u>Single or repeated exposures</u>	
1 hour out of every 24 hours	500 ppm
1x2 hr or 2x1 hr every 24 hours	200 ppm

SOURCE: Advisory Center on Toxicology (1959).

TABLE 7-2

METHANOL TOXICITY COMPARED WITH BENZENE AND GASOLINE

	<u>Eye Contact</u>	<u>Inhalation</u>	<u>Skin Penetration</u>	<u>Skin Irritation</u>	<u>Ingestion</u>
Methanol	2	2	2	1	1
Benzene	2	4	2	2	2
Gasoline	(2)	(3)	(3)	(1)	(2)

1 = MILD
 5 = EXTREME TOXICITY
 () = ESTIMATION, DEPENDING ON
 COMPOSITION

SOURCE: Paul (1978).

brain, particularly formaldehyde and formate acid. Ingestion of methanol brings the most rapid toxic response. Fifty to 100 milliliters (2 to 4 ounces) are fatal; and, 25 to 50 milliliters has been fatal when not treated immediately. Individual tolerance to methanol toxicity varies widely (Paul, 1978).

Table 7-1 summarizes occupational exposure and estimated tolerance values for methanol. Methanol toxicity compared with benzene and gasoline is summarized in Table 7-2. For each exposure route, methanol is equivalent to or less toxic than gasoline. According to Paul (1978), methanol is toxic to plants and aquatic life when concentrated.

7.2.3.1 Inhalation. Methanol has a very low vapor pressure of 100 mm at 21.2°C (Weast and Astle, 1979); thus, the fumes are a significant occupational hazard. High concentrations of methanol vapors can produce acute poisoning after brief exposures. Exposure to 1,000 parts per million in the air causes irritation to the eyes and mucus membranes. Exposure to 5,000 parts per million in the air causes stupor or sleepiness. One or two hours of exposure at a level of 50,000 parts per million will result in deep narcosis, or death. Tolerance levels are estimated by the Advisory Center on Toxicology on the basis of preventing the accumulation of methanol as metabolites in the body. These tolerances were set at 200 parts per million as the threshold tolerance limit for 8 hours in one 40 hour work week (Paul, 1978; Mueller Assoc., 1981).

The best protection against inhalation is leakproof equipment. We will explain later how to eliminate leaks of methanol vapor and minimize workers' direct exposure to methanol.

7.2.3.2 Ingestion. Information and education programs must emphasize the prevention of oral consumption of methanol. One to two ounces can be fatal if ingested. The almost odorless and colorless character of methanol renders it a candidate for accidental use, mistakenly drinking it as water or grain alcohol. Labeling with a colored dye could prevent

accidental ingestion. No siphoning of methanol fuel by mouth can be allowed. While commonly done, this is equally hazardous with gasoline. References to methanol as an alcohol should be tempered to minimize confusion with one of our favorite beverages, ethanol. Labeling of methanol at the fuel tank and source as a poison with the skull and crossbones appears to be effective in Asia (Reed, 1981). Workers will be educated to the toxicity of methanol as a part of their orientation.

7.2.3.3 Exposure Through the Skin. Methanol can be absorbed through the skin. Therefore, one could be exposed by spilling methanol on clothing. The skin is dried and oils are removed from the skin on exposure. Methanol is absorbed through the skin and will have toxic effects as mentioned above (Paul, 1978).

Methanol contact with the eyes can cause lesions. Direct contact through inhalation or ingestion can also cause lesions. Methanol exposure to the eyes causes blurring of vision, extreme sensitivity to light, and inflammation. Severe exposure can destroy the optic nerve, leading to blindness. Severe exposure can destroy the optic nerve, leading to blindness. Visual symptoms may clear up initially but return and cause blindness (Paul, 1978).

Safety clothing, gloves, and goggles will be provided and required at the facility for all workers in the methanol plant. According to NIOSH/OSHA (1978), only gloves made with "viton" have been shown to be protective against solvents and many carcinogens. These gloves are 10-14 times as expensive as other materials, and are not commonly used as protective gloves. However, we recommend use of these gloves even though the chances of a worker having direct contact with methanol are small.

7.2.4 First Aid and Medical Treatment for Methanol Exposure. First aid for eye contact with methanol is a water flush, promptly, for fifteen minutes with the eye kept open. An ophthalmologist should be contacted at once. In all cases, first aid should be given immediately and then a physician called as soon as possible. Exposure through inhalation will call

for the removal of the victim from the vapor area and, if breathing has stopped, artificial respiration. Spills on clothing require the immediate removal of clothing and washing of the skin to avoid further dermal absorption of the methanol. If methanol is ingested accidentally, the correct first aid is to induce vomiting and empty the stomach immediately. The Chemical Solvents Corporation provides the following treatment suggestions on packaging of methanol (Paul, 1978):

"Antedote if swallowed: give a tablespoon of salt and a glass of warm water and repeat until vomit fluid is clear. Give two tablespoons of baking soda and a glass of water. Have patient lie down and keep warm. Cover eyes to exclude light."

Medical treatment of methanol poisoning is through hemodialysis, along with the administration of ethanol and bicarbonate as necessary. Fixed bed charcoal canisters are also used in conjunction with hemodialysis. Peritoneal dialysis is less rapid and there are more complications involved in this treatment (Paul, 1978).

High benzene content gasoline has a greater toxicity than methanol on ingestion. Gasoline is much more toxic than methanol when inhaled, even though the threshold limit is higher, 500 parts per million versus 200 parts per million for methanol. The high polynuclear aromatic content of gasoline causes its vapors to be more carcinogenic than methanol (Paul, 1978).

7.3 Hydrogen Sulfide.

7.3.1 Sources and Mitigating Measures. Hydrogen sulfide will not be present in the plant atmosphere unless a leak has occurred. Even in the case of a leak, hydrogen sulfide is a minor constituent of the emissions in the case of a wood gasification plant (Reed, 1981). Hydrogen sulfide should be caught by the guard beds. Hydrogen sulfide can be a major hazard in a coal conversion facility (Nowacki, 1980). We do not anticipate a problem with this emission because of the low sulphur content of eucalypt feedstock and the absence of a concentration mechanism in the chemical process train.

7.3.2 Toxicology, Treatment and First Aid. Hydrogen sulfide is a strong irritant to respiratory organs ("rotten egg" smell). Its major effect is paralyzing the nerve centers that control respiratory movements. Exposure to concentrations above 1,000 milligrams per cubic meter is rapidly fatal. Exposure to concentrations of 400 to 700 milligrams per cubic meter is considered dangerous. On exposure to hydrogen sulfide, the olfactory nerve is immediately paralyzed and the potential victim can no longer smell the presence of hydrogen sulfide. Victims cannot see hydrogen sulfide since it is also colorless.

Chronic exposure to lower levels of hydrogen sulfide is not as dangerous as chronic exposure to carbon monoxide. In the blood stream, hydrogen sulfide is combined with oxygen from hemoglobin and is converted to inactive compounds such as sulfate and thiosulfate. Because of this rapid oxidation, hydrogen sulfide does not accumulate in the body. Low concentrations of hydrogen sulfide are relatively harmless. The odor perception level of hydrogen sulfide is between 1 to 40 micrograms per cubic meter, depending on the individual's olfactory sensitivity.

Non-fatal acute exposures to hydrogen sulfide may have permanent after effects such as chronic kidney and liver disease, and brain damage. Other symptoms of non-fatal acute exposure include metallic taste, fatigue, diarrhea, blurred vision, intense aching of eyes, and dizziness.

The laboratory indication of acute hydrogen sulfide poisoning is the presence of sulfhemoglobins in the blood. Workers will be required to have regular medical checkups. The symptoms include the characteristic rotten egg odor, and a grayish-green color of the skin, brain, and other internal organs, including the blood. Death from hydrogen sulfide exposure is attributed to hemorrhages and edema (water-logging) of the lungs.

Oxygen is administered as first aid in the case of hydrogen sulfide poisoning. Sodium nitrate is most effective as an antidote. Rapid recovery

after acute exposure is possible if the victim is removed to uncontaminated air. High concentrations of hydrogen sulfide cause almost instantaneous paralysis of the entire central nervous system. However, the heart continues several minutes after breathing has stopped and the victim still has a chance if removed to uncontaminated air. Hydrogen sulfide and carbon monoxide have synergistic effects; therefore, exposure to a combination of these gases is especially dangerous.

7.4 Carbon Monoxide.

7.4.1 Possible Sources and Mitigating Measures. Proper gasifier operation involves maintenance of sufficient temperature and pressure, coupled with proper gas routing through the gasifier, to insure maximum decomposition of the biomass feed. In addition, a proper reducing environment in the gasifier will maintain a producer gas stream in which the carbon monoxide-to-carbon dioxide ratio is relatively greater. Carbon monoxide will be used and reused as a reducing agent. Overall efficiency of the biomass-to-methanol system is enhanced by the greater gas stream (Reed, 1981). We stress here that leaking carbon monoxide and/or venting it to the environment will reduce the efficiency of the operation as well as pose environmental and health problems. Every effort to conserve, contain and recycle carbon monoxide will be made. As a result, we expect carbon monoxide to be of health concern only in the case of gas line leakage resulting in fugitive emissions. Tight seals on gas lines and regular inspection and monitoring should eliminate carbon monoxide as a fugitive emission during normal plant operation.

7.4.2 Toxicology, Treatment and First Aid. Carbon monoxide cannot be seen, smelled, or tasted. Exposure to high concentrations of carbon monoxide causes a cessation of breathing. Chronic exposures to low levels of carbon monoxide causes the long-term impairment of blood oxygenation and leads to systemic damage, mainly of the heart, brain, and blood vessels (Waldbott, 1978).

There are many warnings of the onset of disease due to chronic exposure to carbon monoxide. The work force must be educated, and then monitored for warning symptoms, including stiffness in the shoulders, backache, fatigue, and dizziness. With the progression of the disease, the exposed worker experiences shortness of breath on exertion, tightness and pain below the breastbone (angina pectoris), numbness in the arms and hands, and swelling of the face. Shortness of breath occurs mostly at night. The angina pectoris symptom of pain follows light work during the day. There is a chronic disease syndrome associated with carbon monoxide exposure. It was first studied in Japan in 1955. Subjects were exposed each morning to carbon monoxide levels of 2,000 to 3,000 parts per million. Of the 1,022 people observed, 35 percent had heart valve disease, a rate far above the national average. Even young people had arteriosclerotic heart disease (Waldbott, 1978).

Carbon monoxide has 300 times more affinity for hemoglobin than oxygen. Hemoglobin is the protein that transports oxygen in the blood. It is displaced by carbon monoxide and asphyxiation results. Eight hours of exposure to levels greater than 30 parts per million is considered hazardous (Waldbott, 1978). Levels greater than 30 parts per million causes carboxyhemoglobin levels of eight to ten percent in non-smokers. Persons under physical strain, and particularly arteriosclerotic people, are vulnerable at these levels of exposures. Persons with a chronic lung disease or anemia, in which the hemoglobin supply is limited, are particularly prone to poisoning by carbon monoxide. Carbon monoxide can harm pregnant women and result in the birth of abnormally small babies. In Los Angeles, an increase in death rates was observed on days of highest atmospheric carbon monoxide concentrations (Waldbott, 1978). Rabbits exposed for 8 to 10 weeks at levels of carbon monoxide of 200 to 350 parts per million, exhibited changes in blood vessels and enhanced cholesterol in vessel walls (Waldbott, 1978).

Following acute poisoning by carbon monoxide, there is a brief period of unconsciousness after which the victim has difficulty in speech, inability

to carry out simple activities such as tying a knot or buttoning clothes, visual failure, disorientation, and loss of memory. The skin is characteristically cherry red after carbon monoxide intoxication. Carbon monoxide poisoning victims develop erythema, a bright red skin eruption that tends to blister and usually clears up in two to three weeks. Prolonged inhalation of carbon monoxide produces white discoloration of the fingernails because of impeded blood supply. These symptoms of carbon monoxide exposure can be used to detect chronic or acute poisonings in the work force of the plant. Carboxyhemoglobin levels from blood tests can give direct evidence of exposure (Waldbott, 1978).

Oxygen is administered as first aid in cases of carbon monoxide poisoning.

7.5 Carbon Dioxide (CO₂).

7.5.1 Sources, Spills, and Mitigating Measures. An important aspect in the design of gasifiers is their ability to operate within the proper reducing environment in the reaction chamber. Recall that a reducing rather than an oxidizing environment not only produces more carbon monoxide in proportion to carbon dioxide, but the hazardous oxides of nitrogen and sulfur are not found. The production of carbon monoxide can be used in the production of synthesis gas. Any carbon dioxide produced in the gasifier must be removed from the raw gas stream before the syngas can be used for the synthesis of methanol. Of course, the burning of fossil fuels adds to the carbon cycle, while wood fuel combustion recycles carbon.

The Benfield process will be used to remove excess carbon dioxide and hydrogen sulfide gases. In this process, a solution of carbonate becomes potassium carbonate when CO₂ is absorbed. The potassium carbonate is regenerated by heating, and carbon dioxide is driven off (Reed, 1981). The CO₂ byproduct will be routed to greenhouses at the facility where it will be used as an enriched atmosphere for photosynthesis by plants, resulting in

major increases in productivity. The amount of CO₂ released is an index to the efficiency of the gasifier. Process design modifications that provided more hydrogen atoms could result in a greater output of syngas and less CO₂.

Carbon dioxide normally is not considered a polluting emission and there are no regulatory standards set thus far on the release of CO₂ to the atmosphere.

7.5.2 Toxicology of CO₂. Carbon dioxide is essential for photosynthesis, but high concentrations could have disastrous health and environmental impacts. Carbon dioxide released from burning fossil fuels increases the carbon dioxide concentration of the global atmosphere. The carbon dioxide concentration in the global atmosphere has been estimated as approximately 290 parts per million in the middle of the 19th century. Today that concentration has increased up to 335 parts per million. One-fourth of this increase occurred between 1967 and 1977 (Wilson, 1980). Evidence for this increase has come from carbon dioxide monitoring stations in Hawaii, Alaska, New York, Sweden, Australia, and the South Pole. The environmental impacts of high concentrations of CO₂ in the atmosphere (the "greenhouse effect") is discussed in the environmental impact document. Table 7-3 summarizes the toxic effects of CO₂. At concentrations of 2 percent in the inspired air, respiration is stimulated. Concentrations of 7 to 10 percent in the inspired air is fatal in a short period. We do not anticipate CO₂ levels higher than ambient in and around the work place.

While carbon dioxide emission control measures are theoretically possible, as in the acid gas cleanup described above for wood gasification/methanol synthesis, they may not be economically or technically possible on a larger scale. The control of the carbon dioxide emission problem must be solved at the source; that is, the burning of fossil fuels. If the burning of fossil fuels were cut back or controlled, the atmospheric increase of carbon dioxide could be stabilized.

TABLE 7-3

OCCUPATIONAL HEALTH--TOXICITY OF CO₂¹

<u>CONCENTRATION</u>	<u>HEALTH EFFECT</u>
2% in inspired air	Stimulates respiration
3% in inspired air	Ventilation of lungs is doubled
4.5-5% in inspired air	Breathing becomes extremely labored and nausea occurs
8.5% in inspired air	Blood pressure reading no longer obtainable, breathing becomes difficult, lungs become congested
7-10% in inspired air	Fatal within short period

¹SOURCE: Waldbott (1978).

While eucalyptus trees from the plantation (and all green plants) capture CO₂ from the atmosphere, burning of the methanol synthesized at the refinery recycles the carbon dioxide once again. However, there will be no net increase in the carbon dioxide content of the atmosphere resulting from the biomass energy gasification system. No geologic sink of carbon, such as a coal mine, has been tapped in producing methanol from wood. Carbon dioxide will cycle from the atmosphere to the biomass energy plantation, to the gasification plant, which will emit carbon oxides, thence to the methanol product. Finally, the consumer burns the methanol, releasing carbon dioxide to the atmosphere once again. Any conventionally powered equipment used in harvesting and transporting wood and methanol would tap a carbon sink for their fuel, thereby adding carbon oxides to the atmospheric cycle.

7.6 Medical Surveillance and Risk Assessment. Workers in synthetic fuel technologies will be exposed to potentially hazardous mixtures of compounds (Cheng, 1977; Thilly, 1977; Ames, 1977; Kilian, 1977). In the case of coal conversion and liquefaction facilities, there will be an infinite number of new compounds (Hites, 1977; Nowacki, 1980). These mixtures can not be tested compound by compound and their toxicology systematically determined. There are too many chemical species involved. Furthermore, the chemical species may have synergistic effects; therefore, the testing of the mixtures would be the only reasonable route of investigation (Nowacki, 1980). Monitoring of the individual workman is important in dealing with the risks of these unknown substances (Cheng, 1977; Doemeny, 1977; Kilian, 1977).

Once potentially hazardous byproduct streams have been identified, animal testing can point to threatening compounds. Prediction of human carcinogenesis is impossible using in vitro testing. However, there are some useful correlations here also. Mutations, germinal or somatic, seem to be involved in carcinogenesis. These types of effects can be pointed out through animal testing (Kilian, 1977). Ninety percent of the chemicals

found to be carcinogenic by animal or human data give positive results in in vitro testing from mutagenesis (Ames, 1977). The two factors involved in the formation of cancers which can be controlled are exposure to environmental mutagens and the ineffectiveness of immunosurveillance (Kilian, 1977).

To summarize, risk assessment for the work place can take on the following tasks: (1) once the potentially harmful substances are characterized, they can be compared by structural analogy to other proven harmful substances, (2) cell transformation systems can be tested in vitro, (3) bacterial test systems are available to detect mutagenic effects, and (4) animal toxicology can highlight threatening compounds and possible pathways of damage (Kilian, 1977).

Job rotation can be used in order to minimize the risk of exposure for individuals (Telesca, 1977).

Health monitoring systems are widely used in Europe. Chromosome studies of the work force there are common.

8.0 HEALTH AND SAFETY FACTORS ASSOCIATED WITH CONSUMER USAGE OF METHANOL

8.1 Methanol Blends. Methanol can be used as a gasoline blend (Johnson, et al., 1980). However, methanol apparently increases evaporative emissions through a physical-chemical interaction with gasoline (Kiteradge, pers. comm.). Another potential problem with methanol blends is phase separation in the presence of water. Methanol will dissolve in water, separating from the gasoline component. Corrosion of certain engine components made of materials susceptible to methanol corrosion also is a potential problem. On the positive side, methanol is more efficient than ethanol as an octane enhancer (Johnson, et al., 1980). Sun Oil Company presently is producing oxinol, a methanol and tertiary butyl alcohol additive. Some engine design changes may be needed for methanol blends. The data are contradictory and large scale experimental trials are currently underway.

Methanol used as an octane booster would eliminate lead emissions (Paul, 1978) that are the result of tetraethyl and tetramethyl lead additives in gasoline. The toxicity of lead in humans is discussed by Waldbott (1978) and Wilson (1980).

Petrochemicals release lead, mercury, fluoride, and cadmium into the environment. These are systemic atmospheric poisons that effect numerous human organ systems. These pollutants are emitted from petrochemical users, such as power plants and automobiles. They constitute the greatest public health threat in the human environment at the present time because they accumulate in the human system and contribute to or cause illnesses that develop slowly and insidiously (Waldbott, 1978).

8.2 Methanol as a Neat Fuel. Methanol can be used in an undiluted form as a motor fuel. On a Btu basis, gasoline has about twice as many Btu's per gallon as methanol. A gallon of gasoline contains approximately 117,000 Btu's, while methanol contains approximately 57,000 Btu's. However, methanol has properties which, as a fuel, yield higher performance values, than the Btu data indicate. Methanol has a higher octane value (Paul, 1978) and this permits higher compression ratios. Methanol

ignites and burns smoothly at a lean fuel-to-air ratio. This lean burn is characteristic of low emissions and high efficiency. The high flame propagation speed of methanol makes it ideal for stratified charge engines. Stratified charge engines give a leaner burn which contributes to efficiency and low emissions (Johnson, et al., 1980).

The Ford Motor Company is concentrating on methanol as the most likely candidate for an alternative fuel in the future. General Motors estimates that it can bring the methanol fuel vehicle on-line as fast as the methanol distribution system is developed (Johnson, et al., 1980).

Additional efficiency techniques are used in methanol engines. Exhaust gases are used to preheat the methanol; and, exhaust gases are used to disassociate the methanol to hydrogen and carbon monoxide before injection into the combustion chamber. The waste heat is therefore used to increase the sensible and latent heat of the methanol fuel (Johnson, et al., 1980). Again, changes in engine design may be necessary to insure the safety of the driver from these recycling exhaust gases and waste heat.

The overall reactivities of emissions from a methanol engine and a gasoline-methanol blend engine are less than that of a gasoline-powered engine (Paul, 1978). The environmental effects of the methanol engine compare quite favorably to the environmental effects of the gasoline-powered engine.

Future Fuels of America, Inc., headquartered in Sacramento, California has an effective ongoing program in converting new cars to operate on 100% methanol. The methanol cars are called "Liberators"; and, they are entering the commercial fleet market as well as the private sector. Future Fuels is planning a network of franchised methanol stations throughout California. The State of California authorizes up to \$1,000 per vehicle of income tax credit for converting a car to the use of at least 85% fuel grade alcohol. These are the strongly positive incentives and mechanisms necessary to convert a part of the automotive fleet from gasoline to neat methanol. Biomass Energy

Systems, Inc. anticipates within-Florida commercial fleet use of most, if not all, of the methanol produced from eucalyptus in its plant.

8.3 Engine Emissions. Engine emissions from methanol use will be quite different from gasoline. The carbon monoxide normally will be much lower. Carbon monoxide may be as much as 10 times lower, depending on the engine design and the operating conditions (Mitre, 1980). Nitrogen oxide formation will be reduced by engine design. Since the methanol burns at a lower temperature, the nitrogen oxide formation is reduced. This could lead to a decrease in the photochemical "smog" problem plaguing many cities. Nitrogen oxide production is exponentially dependent on temperature (Paul, 1978). The NO_x emissions can be reduced by engine design to fall well below the 1978 federal standard of less than 4 grams per mile with little sacrifice of engine efficiency. This eliminates the reducing stage of the three way catalyst in the emissions control device. Therefore, the emission control device is simpler. Polyaromatic hydrocarbons are much lower in the exhaust from methanol engines and the sulfur particulates are almost absent.

The emissions from methanol burning are unburned methanol, aldehydes, and particularly formaldehyde. However, an oxidative catalytic converter can oxidize eighty to ninety percent of the above emissions, plus the carbon monoxide. Engine design can reduce production of the pollutant through high compression ratios and lean mixtures compatible with high efficiency. Fuel atomization and vaporization also reduces production of pollutants in engines. Injection or mixing in of as much as twenty percent water can further reduce production of pollutants in the methanol engine (Johnson, 1980). Methanol can be mixed with water and burned at lean stoichiometric air-fuel ratios to further reduce nitrogen oxide emissions. Far more nitrogen oxide reduction is possible with methanol fuels than with gas. Carbon dioxide and hydrocarbon emissions also are reduced with the use of methanol instead of gasoline.

The overall reactivity of emissions from a methanol engine is less than with a gasoline powered engine. Methanol produces almost no sulfur oxide; therefore, the acid rain problem will be lessened with the use of methanol. Methanol is low in sulfur oxides because of strict desulfurization involved in methanol manufacture (Paul, 1978). Sulfur oxides are catalyst poisons and are removed from the syngas stream before the methanol synthesis (Reed 1981).

The extent to which atmospheric levels of formaldehyde could increase from large scale use of methanol is undertermined. If a significant problem with formaldehyde actually occurs, modifications in the exhaust system can control the aldehyde emissions. The basic toxicology of formaldehyde, a metabolite of methanol, is discussed in an earlier section.

The environmental effects of the methanol engine in comparison with the environmental effects of the gasoline-powered engine are discussed in the supporting environmental impact assessment document (Working Document 5).

8.4 Public Health Benefits of Methanol as an Octane Extender. Tetraethyl and tetramethyl lead are used as antiknock additives in gasoline. Their use in gasoline has created one of the more hazardous sources of environmental pollution. One gallon of gasoline contains up to 4 grams of lead. About 300,000 tons of lead were used in gasoline additives in 1968. This was twenty-five percent of the total lead used in the United States at that time. Lead use in gasoline has been declining, however, with the use of unleaded gas in newer models of automobiles. Coal contains about 54 parts per million lead. Increased coal use will increase atmospheric concentrations of lead (Waldbott, 1978).

About seventy-five percent of the particulate lead from automobile exhaust is less than 0.9 micrometers in diameter (Waldbott, 1978), a size that easily penetrates deep into the alveoli of the lungs (Wilson, 1980). The particulates are then extremely difficult to extract from the lungs, using the body's lung defense mechanisms (Waldbott, 1978; Wilson, 1980). Poisoning with tetraethyl and tetramethyl lead differs from poisoning with inorganic

lead because of the predominate effects of the organic form on the central nervous system (Waldbott, 1978). Occupationally exposed workers engaged in the production of leaded gasoline experience the following toxic symptoms after exposure for short periods: irritability, sleepiness, terrifying dreams, emotional instability, and gastrointestinal symptoms, including vomiting and diarrhea. Additional chronic exposure for the work force engaged in the production of leaded gasoline involves the victims becoming more and more irrational, with delusions and hallucinations. The onset of these effects is dramatically sudden. The victims have to be restrained or even put under sedation. This disease resembles acute alcoholic hallucinations, or catatonic schizophrenia. The chronic lead poisoning of urban populations with automobile exhaust fumes may either contribute or cause low grade lead encephalitis (Inflammation of the brain), with symptoms of depression, headache, and undue fatigue (Waldbott, 1978).

The symptoms from lead inhalation involve mainly the blood-forming mechanism, the gastrointestinal tract, and in the advanced stages of poisoning, the central nervous system. The kidneys and heart also can be affected by lead poisoning. The early stages of lead poisoning are evidenced by the victim being anemic with feelings of weakness and exhaustion. The victim has headaches and muscle pains, is clumsy and irritable, restless, easily distracted, and impulsive. Children with lead poisoning develop pain in the stomach and lower abdomen, constipation, nausea, and heartburn. Adults exposed to ambient concentrations of lead experience abdominal pain that can become so severe as to suggest bowel obstruction. Kidney diseases, particularly damage to the arteries of the kidneys, and the involvement of the proximal tubules occur in connection with lead poisoning. A crippling atrophy (shrinkage) of the kidney can occur. Jaundice and gout have been encountered in individuals with chronic kidney disease caused by lead poisoning. Advanced intoxication with lead poisoning causes brain damage. A strong affinity of lead for nerve tissue results in a large variety of neurologic symptoms, ranging from drowsiness to coma and epileptic convulsions. The disease can lead to early death or result in permanent injury. Even low-level, chronic exposure to lead causes permanent mental retardation in children (Waldbott, 1978).

A return to the massive consumption of leaded gasoline would threaten the public health and welfare. Methanol-blend alternatives, such as oxinol, warrant full field testing and consideration before the lead is put back into gasoline.

9.0 WOOD GASIFICATION/METHANOL SYNTHESIS VERSUS COAL GASIFICATION/LIQUEFAC-
TION AND CONVERSION: A COMPARISON OF HEALTH AND SAFETY EFFECTS

Characterizations of the potentially harmful substances generated as products and byproducts of the synthetic fuel technologies is an ongoing effort (Hites, 1977). While enormous effort would be required to characterize the toxic substances to be found in coal gasification and liquefaction, and similar shale oil technologies, the problem is far simpler in the case of wood gasification facilities. In the gasification of woody biomass at the methanol plant, emissions are fewer and less toxic.

The quality of the work environment of the energy forest compares favorably to the often hostile environments from which fossil fuels are extracted. The deep coal miner is subject to an occupational disease called pneumoconiosis. Pneumoconiosis is a debilitating and progressive disease resulting from chronic exposure to the environment in a deep coal mine. Virtually all deep coal miners show the effects of the disease. In the later stages, even if the miner leaves the coal mining industry, the debilitating effects of the disease grow worse. Surface and subsurface coal miners also are exposed to increased levels of radioactivity, heavy metals, and potentially carcinogenic and mutagenic compounds present on the coal dust. The coal miner also risks traumatic injury from accidents using the heavy machinery involved in coal mining.

Contrast this with the threat of traumatic injury from the machinery in wood biomass farming operations. The coal miner is subject to debilitating and insidious disease-causing agents, plus the traumatic injury threat; while the hazards facing the wood energy plantation worker usually are preventable accidents and injury. The use of pesticides on the eucalyptus energy forest will be nil, certainly far below the levels commonly used on food crops in the United States. At this point in time, there are no known serious pests attacking the present eucalyptus plantings in Florida. Thus, we do not expect the forest workers to be exposed to insecticides. The wood energy worker will spend his days in a clean environment, in sunshine, breathing clean air that is not laden with debilitating, disease-inducing dust and particulates. In the forest environment, where

sound is muffled by trees instead of reverberating through the shafts and walls of mines, the wood energy plantation work force definitely has a higher quality environment in which to labor than those producing alternative energy from coal.

Potential hazards for coal handling, coal feeding and preparation for gasification/liquefaction include exposure to coal dust, noise, gaseous toxicants (including ethane, ethylene, hydrogen, hydrogen sulfide, methane, nitrogen, argon and assorted hydrocarbons), and fires from possible spontaneous combustion in the coal storage areas (NIOSH, 1978). The attendant inhalation of the products of combustion also is a potential hazard in these processes. The dust and fines generated in the eucalyptus chipping and milling operations do not carry the burden of carcinogenic materials in the form of polycyclic aromatic hydrocarbons as do the equivalent operations in the coal conversion plants (Reed, 1981). Much of the chipping will occur at the harvest site.

Coal conversion mobilizes toxic trace metals and coal tars which have been shown to be highly carcinogenic (NIOSH, 1977, Reed, 1980). Exposure to coal tar products has been reported to produce phototoxic effects, such as skin erythema and burning and itching of the skin, photophobia, conjunctivitis, and skin and lung cancer in humans. NIOSH (1977) reviewed the toxicity studies for coal tar products. The wood gasification/methanol synthesis process will not produce the potentially large quantities of tars and trace metals associated with coal liquefaction and conversion.

Studies by Freudenthal, et al. (1975), UBTL (1975), and TRW (1976) concluded that in coal gasification schemes, the elimination of spills and leaks in early operations, when the coal is degraded, should minimize carcinogenic dangers. Independent NIOSH and DOE surveys at a coal liquefaction pilot plant have shown low airborne concentrations of benzene, toluene, xylene, and benzo(a)pyrene. Also, the NIOSH studies have shown low levels of airborne concentrations of aromatic amines and polynuclear aromatic

hydrocarbons (PNA's). Exposure levels were below current OSHA standards for the 7 aromatic amines tested. Exposure level standards do not currently exist for the 29 PNA's tested (Harris, et al., 1980). This NIOSH report (Harris, et al., 1980) identified pilot plant technology areas where improvement is necessary: materials of construction, piping and pressure vessels, rotating equipment, seals, valves, instrumentation, solid/liquid, and design technique.

The Sasol coal gasification/liquefaction plant at Sasolburg, South Africa, presently is the largest commercial process in operation; it has been operating for more than 20 years and employs approximately 5,600 workers. Although skin cancer was not observed among plant workers, the plant record keeping did not include chronic diseases such as cancer, and follow-up studies have not been undertaken (Harris, et al., 1980).

While organics, particulates, and polynuclear aromatic compounds can be leaked from all steps of the coal liquefaction technology, the only possible location for such emission in a properly run wood gasification system would be between the gasifier and the air scrubbing devices. The purge from the scrubbing liquid of the air scrubbers will be routed back to the gasifier for complete decomposition of the possibly carcinogenic organics, particulates, and polynuclear aromatic compounds. As already mentioned, all olefins and phenols are cracked and converted in the high temperature, high pressure gasifier. In the coal liquefaction plant these potentially harmful pollutants are present in the low parts per billion range (Evans, 1977). Wood gasifiers are designed so these pollutants fall below environmental concentration standards. However, knowledge of the toxicology of these varied classes of compounds unfortunately is inadequate (Wilson, 1980; Colwell and Sayler, 1978).

Polynuclear aromatic compounds and aromatic amines are potentially quite harmful, yet their effects and origins, especially in the coal liquefaction technology, are not well understood (Kilian, 1977; Wilson, 1980; Nowacki, 1980). The most probable route of occupational exposure in the

wood gasification plant is during welding operations on the lines from gasifier to air scrubbers, and during maintenance of the air scrubbing apparatus (Cheng, 1977). Proper precautions will be taken during these operations in order to protect the worker from exposure to possible carcinogenic and mutagenic materials. Workers will be protected against all routes of exposure. As mentioned, inhalation and dermal absorption are the two main exposure routes for potentially harmful substances in the gasifier system (Cheng, 1977).

Benzene soluble material has been found to be a great risk to welders in coal refining facilities. An appreciable amount of benzene soluble material was found on parts to be welded that appeared clean to the naked eye. These materials are potentially carcinogenic. In fact, carcinogenic material has been found on the skin of workers in solvent-refined coal plants. These workers, therefore, are required to change their clothing twice a day in specially segregated clean and dirty locker rooms, and a rigorous daily shower program is enforced. Special detergents used in the showers remove, hopefully, all the carcinogenic materials, along with all the natural skin oils. Cosmetic creams must be used to replace natural skin oils. Skin contamination must be monitored in the coal liquefaction and coal conversion plants (Cheng, 1977). Until further information is gathered from experience with pilot gasification plants, it is impossible to say anything more than the hazards will be far less severe (Reed, 1981). Skin contamination of workers can be monitored with solvent wipes and examinations of the material gathered from the skin surfaces (Cheng, 1977). Portable fluorometric monitors are also available to detect polycyclic aromatic hydrocarbon contaminations of work area surfaces (Schuresko, 1977).

In summary, there is good evidence that wood gasification/methanol synthesis processes pose potentially fewer and less serious health and safety problems than the coal gasification/liquefaction alternatives. Much of the waste in the wood-methanol processes is recycled. Proper design, maintenance and safety procedures can result in a safe and healthy work place.

10.0 CONCLUSIONS

Of all the biomass options now available, the expanded use of wood for energy has the greatest near-term potential. In regions of the U.S. with large standing crops of noncommercial forests, and in areas like Central and South Florida where the lands and climate favor highly productive energy plantations, the opportunity exists to produce methanol from wood feedstocks.

The wood-to-methanol technology is not a panacea. It does increase the energy options available to us. It is a viable automotive fuel alternative to gasoline. It is economical in the marketplace. It has been met with skepticism, reluctance, regulatory impediments, preoccupation with uncertainty, and infatuation with the "chicken-or-the-egg" syndrome.

There is nothing radically new and technologically complex about the gasification of wood and liquefaction of the syngas to methanol. Methanol has been around in large quantities for a long time and has caused health problems and even fatalities. Methanol is a toxic, flammable, explosive, hazardous substance. It is no different from the alternative fossil fuels in this respect. All sources of energy have environmental, health, and safety costs associated with their use. Is methanol less of a problem for modern man than gasoline or coal?

Relatively, man would seem to gain substantially from the use of wood for energy whenever that use displaces petrochemicals and coal. The known health and safety risks and hazards are less at every level in the wood energy system.

The Florida community well may ignore the eucalyptus-to-methanol alternative for decades to come. Because the concept is sound and technically achievable, perhaps in response to some future crisis, the community may overcome skepticism, indifference, and inertia and proceed with growing a renewable fuel alternative to gasoline. We hope so.

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APPENDIX

SAFETY REGULATIONS

AND

GUIDELINES

FOR THE

METHANOL PLANT

WORK FORCE

Davy McKee

BIOMASS ENERGY SYSTEMS INC.
DMC 2585

10 SAFETY

10.1.1 General

The following safety regulations are for guidance and cover operations of particular concern to the personnel responsible for the operation of the methanol plant. They are intended to supplement, not supersede any existing general safety regulations which cover all units of the factory and reference should be made to the latter for all points not mentioned below.

Mechanical craftsmen working on units will presumably be governed, in addition, by their own departmental regulations, but the plant operators should see that none of the regulations presented here are violated by mechanical craftsmen.

10.1.2 Maintenance of Equipment and Housekeeping

1. Fire extinguishers must be recharged or replaced immediately after use. All steam and water hose equipment must be put back in place after use. Access to such equipment must not be obstructed.
2. Gas masks must have fresh cartridges installed after use.
3. Operating equipment should be checked frequently for signs of leakage, overheating, or corrosion, so that unsafe conditions may be corrected before they result in serious consequences. Unusual conditions should be reported at once.
4. Guards around shafts, couplings, belts, etc., which have been removed for repairs to the equipment, must be replaced when repair work is completed.
5. Tools, pieces of pipe etc., should never be left lying on the platforms or railings of operating equipment where they can be knocked off and injure someone else.
6. Access to ladders and fire escapes must be kept clear. Waste material and refuse must be put in proper locations where they will not cause a fire or will not be stumbled over.
7. Liquid spillage must be cleaned up immediately.
8. In the event that electrical equipment does not function properly, notify the electrical department and keep clear of the equipment until the electrician arrives.
9. Gas cylinders should be stored so that they cannot fall over. Guard caps must be replaced over the valves of cylinders which are not connected up.

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10.1.3 Repair Work

1. Mechanical work around an operating unit must be kept to a minimum and the minimum number of men should be used.
2. No mechanical work on the equipment is to be done without a proper authorized work permit.
3. No burning, welding, open fires, or other hot work shall be allowed in the area unless authorized by a work permit.
4. No personnel shall enter a vessel for any purposes whatsoever until it has been adequately purged, blanked off as required, and tested to ensure freedom from noxious or inflammable gases.
5. Non-sparking tools must be used for making emergency repairs where hydrocarbon gases, hydrogen or methanol are present.
6. When flushing equipment with a fire hose, the fire hose must be equipped with a non-return valve.

10.1.4 Thermal Expansion in Exchangers

Because of serious accidents caused by thermal expansion of liquid trapped in exchangers thermal relief valves are installed. The following procedure is outlined in an effort to eliminate the need for blowing these valves.

1. When the cold side of an exchanger is to be by-passed while hot material is passed through the other side, the drain or vent should be tried before by-passing to see that it is not plugged.
2. When the exchanger is by-passed, the bleed or vent should be arranged so that the pressure can be dissipated at a suitable place.
3. Warning signs must be installed on all exchangers where it is possible to trap liquid in the cold side of an exchanger with hot fluid going through the other side.

10.1.5 Withdrawal of Samples

1. Samples to be withdrawn from the unit shall be done so only by authorized personnel.
2. Protective equipment, goggles and rubber gloves must be worn for sampling chemicals. A container must never be filled to the brim. Allow for expansion of the liquid if it solidifies.

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3. Avoid inhaling vapours released by withdrawn samples as they may contain toxic compounds such as H_2S , mercaptan, and carbon monoxide.
4. Samples of any gas should be taken only in approved sample bombs.
5. If metal cans are used for sampling, and the container is not otherwise earthed, an earth wire must be connected from the can to the sample valve to prevent ignition of the vapours by static electricity.
6. A sample should be slowly and cautiously withdrawn, particularly when the sample is set at a high temperature or pressure.
7. A large wrench must never be used to open a frozen sample connection on a small line; application of too much force may break off the sample connection.

10.1.6 Safe Handling of Volatile and Toxic Materials

This material is included in the manual with two purposes in mind, namely:

- a. Protection of personnel from injury or loss of life, and
- b. Preventing loss and damage to plant and equipment.

The rules given for process safety are those, in general, with which process people are vitally concerned. All process people must constantly keep in their minds that common sense, alertness, and good judgement must be exercised at all times. If there is any doubt in mind regarding the safety aspect of a particular operation, consult the supervisor for guidance and advice immediately.

10.1.6.1 Respiratory Protection

Gases, other than air, are harmful to human beings if inhaled in sufficient concentrations. Toxic gases may be classified as either asphyxiating or irritating. Asphyxiating gases may cause death by replacing air in the lungs or by reacting with oxygen carried in the blood, for example, hydrogen sulphide (H_2S), carbon monoxide and smoke. Irritating gases may cause injury or death not only by asphyxiation but also by burning, both internal and external: for example chlorine. To guard against inhaling harmful gases, you should:

- a. Secure a gas test certificate showing the gas condition of the vessel.
- b. Avoid standing on the side of an opening where escaping gas will be blown towards you.
- c. Provide ventilation.
- d. Wear the correct type of gas mask if required.

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10.1.6.2 Chemicals

a. Hydrogen

Under normal conditions, hydrogen exists as a colourless odorless, tasteless diatomic gas H_2 . It is the lightest known substance. Hydrogen is not toxic or poisonous in the sense that H_2S and carbon monoxide are toxic. However, gaseous hydrogen in large enough quantities can cause asphyxiation by replacing the oxygen normally in air that is needed to sustain life.

It is much lighter than air and rises to the top of any room or container in which it is present. Since gaseous hydrogen is colourless, tasteless and odorless, the risk of asphyxiation is seldom realized by the victim. The wide explosive limits of hydrogen make exposure to humans, except under closely controlled conditions, to air/hydrogen atmosphere extremely inadvisable.

Hydrogen gas leaks relatively easily. It will leak through smaller holes than most other gases. High hydrogen concentrations usually prevent coke deposits that can seal off a leak under some conditions, hydrogen can remove graphite deposits and carbide formations usually found in metal walls and thus form its own leak holes.

From a practical point of view, the harmful qualities of hydrogen stem from its extreme lightness, its wide explosive limits, and its rapid flame transmission. Hydrogen floats on top of any gas. Be sure vessels are thoroughly steamed and vented. Watch out for the tops of rooms where hydrogen might be present. There may be an explosive mixture up by the ceiling unless there is good roof venting. Treat all hydrogen streams containing more than 10 or 20 Volume % hydrogen as though the stream is pure hydrogen. If air is suspected to be present and there is more than 4 Volume % hydrogen treat the mixture as an explosive mixture and correct the situation immediately.

The 74 Volume % upper explosive limit means that any air-hydrogen mixture that has more than 5.2 Volume % oxygen is explosive.

b. Hydrogen Sulphide

Hydrogen sulphide is present both in the feedstock and in the fuel to the reformer. The H_2S is removed from the feedstock in the desulphurization section. Hydrogen sulphide is extremely toxic with concentrations above 20 ppm in air considered to be unsafe for breathing. In very low concentrations, the gas has an odor resembling rotten eggs. This warning of its presence must be heeded immediately. Because the gas has the property of paralyzing the sense of smell, the apparent absence of this characteristic odor is not proof that hydrogen sulphide is not present. In engineering areas where H_2S is present personnel must wear approved canister type gas masks. Where it is necessary to enter vessels containing H_2S , a fresh air mask or a self-contained oxygen breathing apparatus must be worn. The rules set down for inspecting, entering and working on vessels that contain H_2S must be strictly adhered to for the personal safety of employees.

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10.1.6.3 Nickel Carbonyl

Fatal cases of poisoning by nickel carbonyl are known and at least one of these in the USA was caused by entering a vessel in which nickel carbonyl had accumulated because of cooling of the plant containing nickel in the presence of carbon monoxide.

Clearly in order to avoid poisoning accidents, it is necessary to ensure that any austenitic stainless unit is cooled down in the presence of gases not containing carbon monoxide. If for any reason this instruction is not followed, then any vessel it is intended to enter should be thoroughly cleansed by steaming or other suitable means. The absence of nickel carbonyl must be established by chemical tests before entry is made.

Nickel carbonyl may be formed by the contact of carbon monoxide - containing gases with nickel by the reaction:

At normal steam reforming temperatures of 750°C or above the formation of nickel carbonyl is thermodynamically impossible. At temperatures below 350°C significant quantities of carbonyl may be formed.

Therefore should any austenitic stainless steel unit be cooled down in the presence of reformed gas or other carbon monoxide - containing gas, the formation of potential lethal quantities of nickel carbonyl may be expected.

It is possible that nickel carbonyl formed in cooling in the presence of carbon monoxide could condense in cold parts of the system, e.g. waste heat boilers, knock-out pots etc. with subsequent danger of poisoning if the vessel is opened. Due to the relatively high vapor pressure of nickel carbonyl, it will be practically impossible to prevent inhaling the vapor.

The initial symptoms which develop during exposure include headache, giddiness and nausea. These symptoms which would also be in part due to carbon monoxide, usually disappear within an hour of removal to fresh air.

The delayed symptoms usually appear after 24 hours and include headache, nausea, sleeplessness and pains in the chest. In severe cases respiratory distress increases and delirium occurs.

Nickel carbonyl would not be formed providing all parts of the unit are purged of carbon monoxide with nitrogen or steam before the reformer or other nickel containing parts of the plant are cooled to below 500°C.

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10.1.6.4 Methanol

Methanol as liquid or vapor is both inflammable and toxic.

Though methanol is toxic it does not present a serious hazard if sensible precautions are taken. The concentration in the general atmosphere of the plant should not exceed 3.5 ppm by volume. Care should be taken in entering confined spaces which may contain the vapor and the liquid should not be allowed to evaporate in buildings or working places. The liquid can be absorbed through the skin particularly by way of cuts or abrasions, and contact with it should be avoided. Protective equipment, usually gloves and goggles, should be worn when there is a risk of contamination, and any accidental splashes should be washed off with copious quantities of water.

First aid treatment for anyone suffering from inhalation of the vapor or ingestion of the liquid is to move them into fresh air and keep them warm and at rest. In serious cases, oxygen should be administered and artificial respiration applied, if necessary.

In case of congestion, an emetic or salt and water may be given.

If the liquid enters the eye, irrigation should be applied at once and should continue for at least 30 minutes. An irrigation bottle, containing an aqueous solution of 2.5% borax plus 2.5% boric acid, should be kept at hand in places where splashes may occur.

10.1.6.5 Preparing Process Equipment

As soon as possible after equipment has been pumped out, steamed, purged or flushed out sufficiently, all pipelines should be disconnected and blanked from the vessel in which work is to be carried out. All pipe connections should be blanked as close to the equipment as is feasible. It may be advantageous to prepare and blank several pieces of equipment as one unit rather than each individual vessel. This procedure applies only provided the same tests are made and the same precautions taken in all pieces of equipment.

It should be the responsibility of the process supervisor to determine how many pieces of equipment can be considered as one unit. Any deviation from the above described procedure should be brought to the attention of the supervisor.

Before allowing anyone to enter equipment, every effort must be made to free it of vapors and gas. Tests must be made by a gas tester in order to be certain that it is safe to enter.

When hot work is to be done, observe the following precautions:

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Inspect all manholes, catch basins, or other openings to sewers in the proximity of the hot work area and if necessary flush them out with water. See that the tops of such basins or manholes are covered with suitable materials, and see that at least three inches of earth are placed on top of the covering to prevent the escape of gases or the entry of sparks. Before a hollow object is heated, be sure that contained gas is free to escape. Authorized persons must issue hot work permits before work is started. Equipment preparation and provisions as outlined on the hot work permit shall be followed.

10.1.7 Opening Equipment

The opening of equipment such as pipelines, drums, and pumps presents a very special safety problem and unless the proper precautions are taken in preparing the equipment, mishaps may occur. A particular risk is present if the equipment to be opened is in corrosive or toxic chemical service.

To ensure safety in opening equipment, it is good practice to treat the equipment as if it were under considerable pressure or vacuum, even though all steps have been taken to relieve the pressure or vacuum.

In opening flanges or cover plates, first remove the bolts on the far side, away from and down wind of the person doing the work with a sufficient number of bolts allowed to remain tight on the near side until the connection can be wedged open.

Any unanticipated trapped pressure will then be released in a direction away from the person doing the work.

See that workers wear special protective equipment when opening lines, valves or vessels containing corrosive or toxic chemicals or hot or cold materials. If special protective equipment is required, this information should be indicated on the work permit.

10.1.8 Entering Tanks, Drums or Other Vessels

Necessary work permits must be issued before anyone enters a tank, drum or other vessel. Should there be any doubt about excessive quantities of gas at any time mechanical work is being performed, the operator should stop the work immediately. Additional gas tests should then be made to ensure that dangerous materials are not present. Every reasonable step should be taken to remove the maximum amounts of toxic vapors or gas.

Before allowing a person to enter a vessel, combustible gas tests must be taken at various points throughout the vessel to determine whether or not any combustibles are present. The general rule is that the vessel must be completely free of combustibles and toxic gases.

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Maximum ventilation must be provided in all cases. This provision shall include removing cover plates from vessels and may also include mechanical ventilation equipment.

In some cases when work is done within a vessel, it may be considered necessary to station someone outside the vessel so that he will be available to take action in an emergency. This precaution is taken to warn employees working in the vessel in case light hydrocarbons escape in the area, or some other recognized conditions occur which might jeopardize their safety.

Tanks or vessels which may contain sel-igniting scales or other deposits must be kept wet until such materials have been removed or changed in such a manner that they will no longer ignite.

10.1.9 Operating Cautions

The following rules should be carefully followed as neglect of these cautions may cause serious damage to equipment or personnel. These rules do not necessarily cover all points which might be included in such a list.

1. Always observe start-up and operating instructions for furnaces, pumps and compressors.
2. Never stand directly above or in front of fire box openings when lighting burners.
3. Never run a pump dry. Keep suction strainers clean. Maintain the correct liquid level in the vessels connected to pump suction lines.
4. Never run a centrifugal pump for more than a few seconds with the discharge fully closed.
5. Switch pumps regularly when spares are provided. This will help to ensure that the spare pump will be ready when needed.
6. Do not bring any unit on stream until it is confirmed that the oxygen content of the unit at atmospheric pressure is below 1% by volume.
7. Liquid spillage must be cleaned up immediately. Blanket any leaks with steam and immediately report leaks for repair.
8. Before starting operations, check all safety equipment to be sure that it will function correctly and be sure that all blanks are in the correct position.
9. Before lighting any burners always check that all fuel instruments are commissioned.

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10. Do not operate any catalysts at temperatures higher than the minimum necessary for the required reactions. Catalysts life will be seriously reduced if the temperature is not held to the minimum.
11. Operating equipment should be checked frequently for signs of leakage, overheating and corrosion so that unusual conditions may be corrected before they result in serious upsets. Unusual conditions should be reported at once.
12. Never remove any catalyst from a vessel without first checking and following the established procedures for rendering the catalyst safe.
13. No hot work shall be allowed unless authorized by a work permit. Catch basins, manholes, and other sewer connections must be properly sealed off to prevent leakage of gases which may ignite upon contact with an open flame.

10.2 FIRE FIGHTING SERVICES

10.2.1 General Statement

The fire protection and fire fighting equipment, installations and services that should be provided for the methanol process plant, utilities, storage and loading facilities comprise the following:

1. An independent fixed foam system for the protection of the storage tank area and rail loading area.
2. A buried firewater ringmain system with hydrants at appropriate spacing around the periphery of various process, utility storage and rail areas.
3. Site fire brigade equipment comprising fire fighting vehicles, trailers, hose, portable fittings, foam equipment, extinguishers, breathing equipment, protective clothing etc. These facilities are necessary for dealing with miscellaneous fires not specifically protected by the fixed systems, and as back-up to the fixed systems, in case they become damaged or otherwise fail to control the fire.
4. Independent fixed foam system for the protection of the lubricating oil/seal oil consoles and lubricating oil tanks for the process gas compressors.
5. Manual fire alarm system covering all process, utility, storage and rail areas.
6. Portable equipment to be held locally in all areas, for immediate use by operating personnel in case of small or moderate fires. This should include portable extinguishers, small wheeled units for manual use, hose and fittings, hose reels, portable foam equipment, spades, buckets, first aid kits, etc.

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10.2.2 Fire Fighting: Responsibilities of Personnel

On the occurrence of a fire the following actions must be taken by the appropriate personnel as indicated below:

10.2.2.1 By Local Plant Operators or Maintenance Personnel

1. The operator discovering a fire must initiate the nearest accessible manual fire alarm break-glass unit.
2. The operator (or operators) at the area of the incident should - if the fire is of small or moderate size - endeavour to extinguish it using portable extinguishers or small hose equipment.
3. In the case of larger fires which cannot be controlled by small portable appliances, the operator shall - after initiating the fire alarm - remain at a position from where he can conveniently direct the fire brigade to the incident.
4. Where appropriate, authorized operating personnel may operate the special fixed foam installations provided for fighting fires in storage tanks, the bunded areas around the storage tanks, the rail loading area and at the compressor lubricating/seal oil consoles. It is important that these systems - particularly those for the storage tanks - should only be applied when their use is fully justified by the circumstances. This is because, firstly, their use is considerably more expensive than portable equipment, and also because incorrect operation of the foam systems to the storage tanks will contaminate large quantities of the product or other stored liquid. As a safeguard against the incorrect use of these systems, the field push button units for their operation will be enclosed in cabinets which will be prominently labelled to say that they must only be operated by the authorized operating personnel or fire brigade personnel.

10.2.2.2 Action by Operating Supervisors

1. The fixed foam installations should be used when justified, but the supervisor should insure that these systems are only used up to the limit of the pumping and foam proportioning equipment.

If these limits are exceeded, the quantities of foam and the performance obtained at the various foam appliances will be adversely affected.

2. For fighting fires in the tank bunded areas, either portable extinguishers, manual hose equipment or the fixed foam monitors may be used, according to the size of the fire. With methanol spill fires, it is possible to extinguish by diluting the liquid with water or of course, by applying a suitable alcohol type foam.

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3. For some fires in processing units the most important action may be to isolate the section of plant or piping at which the fire has occurred, in order to cut off the supply of fuel to the fire. In some of these cases - particularly where the fires are on gas or hot vapor lines - it may be best to allow the fire to burn until the fuel source can be isolated, because, if the flame is extinguished and vapor continues to escape a large cloud of flammable vapor may escape and result in a very serious explosion hazard.

10.2.2.3 Action by Works Fire Brigade

The works Fire Brigade should be continuously manned for action day and night. On receipt of a fire alarm from the Methanol Plant, storage or rail loading areas, the brigade should immediately send a fire vehicle to the site.

10.2.3 Fire and Safety Regulations

The following safety regulations cover points of particular concern to the personnel responsible for the operation of the methanol plant. They are intended to supplement, not supersede any existing general safety regulations which cover all units of the factory and reference should be made to the latter for all points not mentioned below. Mechanical craftsmen working on units will presumably be governed, in addition by their own departmental regulations, but the plant operators should see that none of the regulations presented here are violated by mechanical craftsmen.

10.2.4 Firefighting and Protective Equipment

1. All personnel must know the location and use of all fire extinguishers, fire hoses and hydrants, fire blankets, gas masks and respirators, and other protective equipment such as hard hats, rubber gloves, etc.
2. Foam type extinguishers and water streams must not be used on fires around electrical equipment because the water solution will conduct electricity and may aggravate the difficulty or result in the electrocution of personnel.
3. Carbon dioxide or dry powder extinguishers may be used safely on electrical fires. Carbon tetrachloride extinguishers liberate poisonous fumes and should not be used.
4. Carbon dioxide, dry chemical or foam type extinguishers are suitable for most oil fires. For large oil fires, steam hose equipment or fog nozzles on the end of a water hose are suitable.
5. Gas masks must be worn whenever poisonous fumes are encountered, such as hydrogen sulphide.
6. Safety hats are to be worn around the plant by all personnel at all times.

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10.3 FIRE HAZARDS OF METHANOL

The flash points of methanol/water mixture are given below:

% Methanol by Volume	20	40	60	30	100
Flash point (°C)					
open cup	49	42	33	24	16
closed cup	41	33	24	16	9

The flammable limits of methanol/air mixtures are from 6.0% to 36.5% methanol by volume.

Some laboratory experiments have shown a maximum rate of burning of liquid methanol in turbulent air of 10 liters/hr/ft² of surface. In still air the rate was about 4 liters/hr/ft². Burning methanol differs from burning oil in that there is no evidence of 'boil over'. The liquid burns steadily at the surface while the bulk remains relatively cool. The fire can best be quenched by applying an alcohol-resistant foam which covers the burning surface and cuts off the supply of oxygen.

As a safeguard against fire, the storage tanks should be located in separate compounds and fitted with connections through which fire fighting foam can be pumped into the top of the tank from a point outside the compound. Flameproof motor and lighting fittings should be used in the vicinity and all equipment earthed. Tank wagons should be earthed during filling.

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7. Gloves and goggles or face shields are recommended for use when hot samples are being withdrawn.
8. Steam hoses and water hoses should be checked regularly.
9. If there is a fire or other emergency, sightseers or other persons not concerned in fighting the fire or handling the emergency should stay away from the area involved.

10.2.5 Fire Prevention

Practically all of the materials handled are highly inflammable and extreme precautions are needed to prevent fires and explosions. Each person must remember this while carrying out his work.

1. Smoking is ABSOLUTELY FORBIDDEN within the plant.
2. Matches which can be lighted by striking against any hard surface are prohibited.
3. Personnel must become thoroughly familiar with firefighting equipment in the location.
4. Firefighting equipment must be kept in designated accessible places which are well identified at all times.
5. Positively no one shall light a fire, or otherwise cause a possible source of ignition in the factory, except under the authorization of a work permit.
6. Do not use light distillate such as naphtha to clean machinery or for any other cleaning purpose. Use a heavier oil instead. Carbon tetrachloride is toxic and should not be used.
7. Firefighting equipment will only be used to fight fires. It is forbidden to tamper with this equipment. If equipment is used, notify the supervisor immediately.
8. Good housekeeping is an important part of fire prevention. Keep all areas free of waste paper and trash. Oily rags and oily clothes should not be left in lockers or tool boxes.