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TIRE DERIVED FUEL:

ENVIRONMENTAL CHARACTERISTICS AND PERFORMANCE

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PERSPECTIVE

We are slowly awakening to critical limitations of our global resources and environment. We are recognizing the importance of conserving natural resources through optimum utilization, including minimizing and reusing resources contained in materials previously considered to be "wastes". We are also recognizing that our air and aquatic environments have limited abilities to absorb abuse. In an ideal world, we would endlessly recover and reuse all resources - and we would do so without detrimental impact upon our environment.

Although most of us agree with this ideal objective, we have significant differences of opinion about practical compromises required in today's real world. Some are fixed on achieving the ideal "perpetual recycling" objective and are unwilling to support interim compromises for fear of jeopardizing achievement of the ultimate objective. Others recognize the value of resources conserved through interim steps and believe that these steps contribute to the evolution of even greater conservation gains.

This debate has impacted virtually all "waste" materials, including scrap tires. Tires represent a significant resource. Ideally, a tire's polymerized rubber mixture would be perpetually reused. However, today's applications for this material consume less than 10% of the waste tires generated annually in North America. These markets are growing, but even the most optimistic projections show markets for less than 30% in 5 years.

Should the remainder of this resource be squandered through landfilling? Should it become a public liability and health hazard through stockpiling in hopes that market limitations will miraculously disappear sometime in the future? Or should it be utilized as an energy resource on an interim basis until higher value uses are developed? Since no one consciously wants to waste a potentially valuable resource, the answer should depend upon its compatibility with our environment. Avoiding unnecessary consumption of natural resources through alternative use of waste tires is a worthwhile objective if it can be done without a counter-balancing negative impact on our environment. As a result, it is appropriate to examine chemical characteristics and historical environmental experience of tires as an energy resource.

CHEMICAL CHARACTERISTICS OF SCRAP TIRES

The chemical characteristics of any energy resource impact its environmental acceptability. Tires are a hydrocarbon-based material derived from oil and gas. Some inorganic materials are added to enhance reactions or performance properties. Tires have a heat content of 14,000 to 15,500 Btu/pound, depending on the type of tire and degree of wire removal. By comparison, coal that may be displaced by use of tires typically contains 10,000 to 13,000 Btu/pound.

The composition of tires and coal vary depending on type and source. However, Exhibit 1 provides representative proximate and ultimate (elemental) analyses of tires (with and without bead wire) and a bituminous eastern coal.

A comparison of the proximate analyses indicates that tires offer efficiency advantages versus coal. For instance, tires generally have a lower moisture content than coal. Since the energy required to heat and vaporize inherent water is generally non-recoverable in the energy conversion process, lower moisture content can translate into higher energy utilization efficiency. The lower ash content of TDF without wire offers a similar advantage. A tire's higher volatile-to-fixed carbon ratio enhances its ability to combust rapidly and completely. Based on proximate analysis, tires compare favorably to coal as an energy source.

Based on ultimate analysis, tires offer some additional advantages. Their lower sulfur content (especially in terms of pounds/million Btu) offers the potential advantage of decreasing SOx emissions compared to many eastern coals. Their lower carbon-to-hydrogen ratio can theoretically reduce carbon dioxide generation since hydrogen converts to water in the combustion process. Lower inherent nitrogen content could marginally decrease NOx emissions. The chlorine content of tires is higher in this specific example, but it is comparable to many coals.

Elemental ash analysis provided in Exhibit 2 indicates that tires generally contain metal concentrations comparable to, or lower than, coal with one notable exception. Zinc oxide is added to tires as part of the rubber vulcanization process at levels approaching 1.0 - 1.5% by weight. Therefore, zinc levels in tires are much higher than coal. As a result, applications using tires as an energy resource must be able to control zinc emissions to avoid a negative environmental impact.

From a chemical standpoint, tires offer both environmental advantages and disadvantages versus coal. Therefore, tires must be used in applications that utilize their advantages and properly control their disadvantages for them to provide a valuable and environmentally-friendly energy resource.

HISTORICAL ENVIRONMENTAL PERFORMANCE

Background

Scrap tires have been utilized as a supplemental energy source in Japan, Europe and the United States since the 1970s. The experience base has increased significantly during the last 10 years as tires have been recognized as an acceptable fuel for some combustion processes. Applications using scrap tires have broadened to include cement kilns, industrial boilers, traditionally-conservative utilities and dedicated electrical generation facilities. The following discussion provides examples of demonstrated environmental performance for major applications.

Pulp and Paper Industry

The pulp and paper industry combusts bark and waste wood in stoker-fired boilers to provide steam and power required for processing operations. Wood is combusted on moving grates that also transport residual ash from the boiler. Coal, oil or gas can be fired into the boiler above the grate to enhance combustion and maintain operating temperatures, especially when wood moisture content is high.

This application utilizes tire derived fuel (TDF) obtained by processing scrap tires into uniform, flowable chips generally about 2 inches by 2 inches in size. Bead wire is often removed magnetically to avoid fouling of grates and ash handling systems. TDF can be introduced separately or as an integral part of the wood mixture with relatively simple, inexpensive metering systems. TDF's high volatile component enhances combustion of wood on the grate and improves fuel efficiency.

The environmental impact associated with use of TDF in this application is dependent upon characteristics of the displaced fossil fuel and system environmental control equipment. The two predominant factors controlling environmental acceptability are SOx and particulate (zinc oxide) emissions. SOx emissions may decrease if TDF displaces coal with a higher sulfur content. Alternatively, SOx can be controlled by scrubbers present in some systems, especially if the scrubbers operate at a neutral or basic pH. Particulate emissions can be controlled by electrostatic precipitators (ESPs) or baghouses. In general, the most environmentally acceptable applications occur when coal is displaced in systems with baghouses or ESPs.

Based on review of available information, more than 26 U.S. paper mills are currently using significant quantities of TDF in compliance with applicable regulations, with others undergoing testing. The Champion facility in Bucksport, Maine has been one of the largest users of TDF since 1990. Their boiler is capable of consuming up to 3.5 tons of TDF per hour (14.5% by heat input) to produce almost 500,000 pounds of steam per hour.

Exhibit 3 provides environmental data associated with performance testing conducted at this site in 1989. A baseline test was conducted using their normal mixture of gas, bark, coal and sludge. TDF was then substituted for coal at levels representing 6.3%, 10.3%, and 14.5% of heat input. At the maximum TDF level, NOx, SOx and total hydrocarbon emissions remained virtually unchanged, while particulate matter increased 6%. Among the metals, beryllium and chromium decreased, lead remained below detection limits and cadmium increased. Zinc increased significantly percentage-wise, but total quantities remained acceptable. Overall particulate emissions remained well within acceptable limits.

Performance data has also confirmed environmental acceptability of TDF in similar paper mills and industrial boilers in at 20 states. Several of these states (including Oregon, Washington and Florida) are recognized for their environmental sensitivity and rigorous regulatory enforcement. However, these applications must be carefully screened to define facilities capable of using TDF within environmentally acceptable limits. Only a small percentage of industrial boilers have the required combination of system design and fuel usage conducive to appropriate TDF usage.

Public Utility Boilers

Canada and the United States have executed agreements designed to reduce the impact of acid rain through mandatory reductions in SOx emissions. Major coal-fired utilities using midwestern and eastern coals are under intense pressure to achieve mandatory reductions at minimal cost to their customers. They are faced with purchasing expensive low-sulfur coal or making substantial capital investments in additional air pollution control equipment. As a direct result, conservative utilities have begun to recognize the potential value of TDF as an alternative fuel with a lower sulfur content than local coal. Use of TDF offers an opportunity to concurrently reduce both SOx emissions and fuel costs, while providing a partial solution to historical scrap tire disposal and stockpiling problems.

Over one million whole tires were utilized annually at Ohio Edison's wet bottom boiler in Toronto, Ohio. The company conducted comprehensive environmental tests at incremental tire utilization rates up to 20% of heat input, as summarized in Exhibit 4. In this case, SOx emissions increased slightly compared to the coal being used at the time, but NOx and particulate decreased significantly. Analysis of bottom ash transport water showed no increase in dissolved or total metals. The facility operated in full compliance with applicable regulations.

TDF usage in utility cyclone boilers is also expanding rapidly. Pulverized coal is introduced tangentially into a large cylindrical chamber and combusted, with ash falling into a wet collection system at the bottom. TDF must generally meet stringent size restrictions (1 inch by 1 inch or less) to enhance complete combustion. This size also enhances TDF movement through coal handling systems.

Otter Tail Power Company has been using up to 60,000 tons of TDF per year at its plant in Big Stone, South Dakota. TDF has reportedly proven to enhance combustion control and efficiency when added to their primary low-Btu lignite fuel. The facility operates in compliance with all applicable regulations, but detailed data is not available.

Wisconsin Power and Light has conducted extensive tests using TDF as a supplemental fuel in its cyclone boiler at Beloit. The system has an ESP for particulate control. Comparative criteria pollutant data is provided in Exhibit 4. Particulate, SOx, hydrochloric acid and hydrofluoric acid concentrations decreased with use of 7% TDF. However, NOx, CO and hydrocarbons increased, but remained within applicable permit limits. WP&L constructed its own TDF processing facility based on economics and supply considerations, but encountered initial difficulty in achieving production expectations.

In addition to these examples, TVA and Illinois Power have conducted extensive trials and have commenced usage of TDF in cyclone boilers. In total, current data indicates that over 40 electric generating facilities are using TDF as an energy resource. Tires have even been used as a primary fuel in dedicated, specially designed power boilers in California and Connecticut using 5 million and 10 million tires per year, respectively. After some initial difficulties associated with scale up of this technology, these facilities have reportedly operated in compliance with strict new-source performance criteria.

Cement Kilns

Scrap tires have been used as a supplemental fuel in cement kilns in Europe and Japan since the 1970s and currently represent a rapidly growing application in North America. Only Calvaras Cement in California consumed waste tires 9 - 10 years ago, but more than 35 kilns currently use whole tires or TDF as a supplemental energy source. Many others are conducting performance tests targeted at future use.

Some factors impacting current interest in scrap tires as a supplemental energy source in kilns deserve mention:

Logistics - Kilns are often located near market population centers with large waste tire quantities and difficult tire disposal problems, providing efficient logistics.

Energy Intensity - Kilns are energy intensive, allowing consumption of 500,000 - 1,500,000 million tires/year/kiln. TDF energy cost savings versus fossil fuels can provide a competitive economic advantage.

Rigorous Combustion Conditions - A unique combination of high temperatures, long residence times and turbulent air flow promote complete combustion of organic compounds contained in tires.

Inherent SOx Control - Limestone used in cement manufacture is commonly used in APC systems to absorb SOx, providing inherent SOx control.

Ash Utilization - Ash resulting from tire combustion becomes an integral component of the cement product, displacing purchased natural resources and eliminating ash disposal requirements.

Broad Applicability - Demonstrated technology allows use of tires in older long kilns, as well as newer preheater and precalciner units.

Although these factors encourage use of tires as a supplemental fuel in kilns, demonstrated performance is a critical consideration in establishing environmental acceptability of this application. Extensive environmental data has been generated for a variety of kiln configurations and fuel displacements. Time limitations preclude discussion of all available data, but several examples are included.

Exhibit 5 provides comparative data resulting from comprehensive tests conducted by Florida Crushed Stone. TDF representing 14% energy displacement was introduced into the riser section of their preheater kiln. Particulate and SOx emissions declined with TDF use. Volatile organics increased but semi-volatile organics decreased by an even greater margin, resulting in a net reduction in organic emissions. Changes in metal concentrations were nominal. Comprehensive testing of dioxins and furans showed a net reduction of over 50% with TDF use. Florida Crushed Stone is currently using approximately 800,000 scrap tires per year as an alternative energy source in full compliance with all applicable regulations.

Performance results for Ashgrove Cement's kiln in Durkee, Oregon are provided in Exhibit 6. Emissions of particulate, SOx, chlorides and all heavy metals declined or remained constant. Total hydrocarbons increased about 10%, but polynuclear aromatics declined about 10%. This plant's performance is accepted in one of the most environmentally-sensitive states in the U.S.

Even within Canada, use of tires as a supplemental fuel in cement kilns has been accepted by most provinces as an environmentally acceptable and appropriate use of this resource based on testing performance. Tillbury Cement completed TDF trials at their facility in Delta, British Columbia during September-October, 1990. Tillbury's kiln is equipped with a 4-stage suspension preheater, planetary coolers, and an electrostatic precipitator. All fuel is normally introduced at the firing end of the kiln, but TDF was added between the preheater and kiln sections to provide about 7% of the kiln's energy requirement. Two tests were conducted for each of the baseline and TDF usage trials. Testing results are provided in Exhibit 7. Particulate and HCl emissions decreased significantly. SOx and NOx emissions increased but remained within acceptable levels. There were no material increases in metals.

SUMMARY

Scrap tires can be an environmentally-compatible alternative energy resource when used in appropriate applications. Energy utilization is an important component of successful scrap tire management programs within the U.S., allowing this resource to be used rather than wasted. The net result has been substantial conservation of non-renewable fossil fuels. When the demonstrated performance of tires as an energy resource is objectively evaluated, many jurisdictions have concluded that our environment is better served by recognizing the value of this resource rather than wasting it while waiting for ideal solutions.

EXHIBIT 1

COMPARATIVE CHEMICAL CHARACTERISTICS

PROXIMATE ANALYSIS (% AS RECEIVED)

CHARACTERISTIC	COAL	TIRES W/WIRE	TDF W/O WIRE
MOISTURE	7.76	0.75	1.02
ASH	11.05	23.19	8.74
VOLATILE	34.05	54.23	67.31
FIXED CARBON	47.14	21.85	22.93
TOTAL	100.00	100.00	100.00

ULTIMATE ANALYSIS (% AS RECEIVED)

CHARACTERISTIC	COAL	TIRES W/WIRE	TDF W/O WIRE
CARBON	67.69	67.00	72.25
HYDROGEN	4.59	5.81	6.74
NITROGEN	1.13	0.25	0.36
SULFUR	2.30	1.33	1.23
ASH	11.05	23.19	8.74
CHLORINE	0.01	0.03	0.09
MOISTURE	7.76	0.75	1.02
OXYGEN (DIFF)	5.47	1.64	9.67
TOTAL	100.00	100.00	100.00

Source: Babcock and Wilcox

EXHIBIT 2

ELEMENTAL ASH ANALYSIS (%, OXIDE FORM)

ELEMENT (OXIDE)	COAL	TIRES W/WIRE	TDF W/O WIRE
ALUMINUM	20.70	1.93	13.11
CALCIUM	3.30	0.56	3.80
IRON	18.89	0.35	2.37
MAGNESIUM	0.79	0.10	0.68
PHOSPHORUS	0.62	0.10	0.68
POTASSIUM	2.06	0.14	0.95
TITANIUM	0.82	0.14	0.95
SILICON	47.98	5.16	35.05
SODIUM	0.48	0.13	0.88
SULFUR	4.33	0.99	6.72
ZINC	0.02	5.14	34.81
METAL		85.26	
TOTAL	100.00	100.00	100.00

NOTE: ALL OTHER ELEMENTS LESS THAN 0.10%

SOURCE: BABCOCK AND WILCOX

EXHIBIT 3

COMPARATIVE EMISSIONS FROM
CHAMPION INTERNATIONAL MILL AT BUCKSPORT, MAINE

(EXPRESSED AS LB/MM BTU)

CRITERIA	BASELINE	14.5% TDF (BY HEAT)	PERCENT CHANGE
NOx	0.274	0.273	< 1
SOx	0.508	0.510	< 1
PARTICULATE	0.053	0.056	+ 6
TOTAL HYDRO.	1.17 E-3	1.18 E-3	< 1
BERYLLIUM	1.06 E-6	0.73 E-6	- 31
CADMIUM	0.60 E-6	0.78 E-6	+ 30
CHROMIUM	12.1 E-6	6.36 E-6	- 47
LEAD	< 10 E-6	< 10 E-6	- -
ZINC	0.26 E-3	2.56 E-3	+ 885

EXHIBIT 4

COMPARATIVE EMISSIONS FROM A WET BOTTOM POWER BOILER

OHIO EDISON'S TORONTO, OHIO FACILITY

(EXPRESSED AS LBS/MM BTU)

CRITERIA	BASELINE	10% TIRES	20% TIRES
SOx	5.30	5.71	5.34
NOx	0.601	0.436	0.387
PARTIC.	0.0631	0.0564	0.0453
LEAD	0.0963 E-3	0.0963 E-3	0.0912 E-3

COMPARATIVE EMISSIONS FROM A CYCLONE BOILER

WISCONSIN POWER AND LIGHT

CRITERIA	BASELINE	7% TDF	CHANGE (%)
PARTICULATE (LB/MMBTU)	0.52	0.14	- 73
SOx (LB/MMBTU)	1.14	0.87	- 34
NOx (LB/MMBTU)	0.79	0.91	+ 16
CO (LB/HR)	1.52	7.26	+377
HYDROCARBONS (LB/HR)	5.16	10.27	+ 99
HCL (LB/HR)	25.77	19.89	- 23
HF (LB/HR)	1.86	1.34	- 28

EXHIBIT 5

ENVIRONMENTAL PERFORMANCE DATA TDF INTRODUCTION INTO RISER SECTION OF PREHEATER KILN AT FLORIDA CRUSHED STONE

CRITERIA	UNITS	BASELINE	14% TDF
Particulate	grains/dscf	0.0104	0.0103
	pounds/hour	56.80	52.21
SO2 Emissions	ppm @ 10% O2	96.4	118.5
	pounds/hour	595.15	551.30
Volatile Organics	pounds/hour		
Acetone		0.02	0.02
Benzene		0.08	0.15
Toluene		0.01	0.20
Chloromethane		<0.01	0.03
Others		<0.03	0.04
Total		0.15	0.44
Semi-volatile Organics (C16-C18)	pounds/hour	5.01	0.90
Metals	pounds/hour		
Aluminum		6.86	8.13
Arsenic		<0.004	<0.004
Barium		0.02	0.02
Cadmium		<0.005	<0.005
Chromium		0.02	0.01
Cobalt		0.005	<0.002
Copper		0.03	0.03
Iron		1.39	1.30
Lead		0.13	0.04
Magnesium		0.50	0.55
Mercury		0.04	0.01
Molybdenum		0.02	0.02
Nickel		<0.02	<0.02
Selenium		<0.004	<0.004
Silver		<0.009	<0.009
Titanium		0.22	0.26
Vanadium		<0.02	<0.02
Zinc		3.12	1.68

EXHIBIT 5 - CONTINUED

ENVIRONMENTAL PERFORMANCE DATA
TDF INTRODUCTION INTO RISER SECTION
OF PREHEATER KILN AT FLORIDA CRUSHED STONE

CRITERIA	EQUIV. TOXICITY FACTOR	AVG EMISSION RATE (10 E-6 LB/HR)		EQUIV 2378-TETRA DIOXIN EMISSIONS (10 E-6 LB/HR)	
		COAL	14%TDF	COAL	14%TDF
DIOXINS					
2378-tetra	1.00000	0.004	ND	0.004	ND
12378-penta	0.50000	0.035	ND	0.017	ND
123478-hexa	0.04000	0.048	ND	0.002	ND
123789-hexa	0.04000	0.084	ND	0.003	ND
123678-hexa	0.04000	0.125	ND	0.005	ND
1234678-hepta	0.00100	1.210*	0.062*	0.001	<0.001
octa	0	5.221	1.100*	0	0
other tetra	0.01000	0.308	0.061	0.003	0.001
other penta	0.00500	0.473	0.079	0.002	<0.001
other hexa	0.00040	0.766	0.114	<0.001	<0.001
other hepta	0.00001	1.693	0.114	<0.001	<0.001
subtotal		9.667	1.530	0.037	0.001
FURANS					
2378-tetra	0.10000	0.096	0.061	0.010	0.006
12378-penta	0.10000	0.024	ND	0.002	ND
23478-penta	0.10000	0.036	ND	0.004	ND
23478-hexa	0.01000	0.048	ND	<0.001	ND
123678-hexa	0.01000	0.024	ND	<0.001	ND
234678-hexa	0.01000	0.120	ND	0.001	ND
123789-hexa	0.01000	ND	ND	ND	ND
234678-hepta	0.00100	0.066	ND	<0.001	ND
234789-hepta	0.00100	ND	ND	ND	ND
octa	0	0.048	ND	0	ND
other tetra	0.00100	0.204	0.149	<0.001	<0.001
other penta	0.00100	0.139	0.088	<0.001	<0.001
other hexa	0.00010	0.006	0.009	<0.001	<0.001
other hepta	0.00001	0.072	ND	<0.001	ND
subtotal		0.883	0.307	0.017	0.006
TOTAL (10E-6 lb/hr)		10.550	1.837	0.054	0.007

EXHIBIT 6

ENVIRONMENTAL PERFORMANCE DATA TDF INTRODUCTION INTO RISER SECTION OF PREHEATER KILN AT ASHGROVE CEMENT

CRITERIA	UNITS	BASELINE	9-10% TDF	PERMIT LIMIT
Particulate	lbs/hr	5.27	4.83	18.0
Sulfur dioxide	lbs/hr	<1.5	<1.2	6.3
Chlorides	lbs/hr	0.268	0.197	NA
Total hydrocarbons	lbs/hr	3.0	3.3	NA
Polynuclear aromatic hydrocarbons (PNA) Naphthalene, Dibenzofuran, Phenanthrene	lbs/hr	0.0058	0.0053	NA
Heavy metals	micrograms			
Arsenic		0.2	0.2	NA
Cadmium		3.0	2.0	NA
Chromium		30	ND	NA
Nickel		30	ND	NA
Zinc		35	35	NA
Copper		37	13	NA
Lead		ND	ND	NA
Iron		400	200	NA
Barium		ND	ND	NA
Vanadium		ND	ND	NA

EXHIBIT 7

ENVIRONMENTAL PERFORMANCE DATA TDF USAGE AT TILLBURY CEMENT

INORGANIC EMISSIONS

CRITERIA (MG/DSCF)	BASELINE			7% TDF USE		
	TEST 1	TEST 2	AVERAGE	TEST 1	TEST 2	AVERAGE
Particulate	64.2	67.9	66.1	32.4	31.6	32.0
HCl	2	3	2.5	<1	<1	<1
SOx as SO2	3	3	3	3	4	3.5
NOx as NO2	877	930	904	1062	1123	1092
O2 (vol % dry)	13.3	13.0	13.2	12.5	13.0	12.8
CO2 (vol % dry)	14.3	14.8	14.6	14.5	14.7	14.6
Metals						
Class I						
Lead	0.013	0.011	0.012	0.0016	0.0024	0.0020
Antimony	0.00045	0.00034	0.00040	0.00045	0.00028	0.00037
Copper	0.0089	0.0070	0.0080	<0.001	<0.001	<0.001
Manganese	0.0019	0.016	0.009	0.012	0.0083	0.010
Vanadium	0.0009	0.0010	0.0010	0.00035	0.00032	0.00034
Zinc	0.046	0.068	0.057	0.039	0.049	0.044
Class II						
Arsenic	0.0011	0.0013	0.0012	0.00051	0.0022	0.0011
Chromium	0.0067	0.0077	0.0072	0.0330	0.0099	0.0216
Cobalt	0.00094	0.00091	0.00093	0.00036	0.00025	0.00031
Nickel	0.013	0.011	0.012	0.0135	0.0065	0.0100
Selenium	0.0015	0.00035	0.0009	<0.0001	<0.0001	<0.0001
Tellurium	0.00023	0.00019	0.00021	0.00021	0.00030	0.00026
Class III						
Thallium	<0.0059	<0.0063	<0.0061	<0.0031	<0.0031	<0.0031
Cadmium	0.0015	0.0015	0.0015	0.00075	0.00058	0.00067
Mercury	0.010	0.007	0.009	<0.0019	<0.0019	<0.0019

NOTE: < denotes lower than sensitivity of the analytical procedure for the specific conditions