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A NEW WAY TO BURN

A glowing, churning sand-bed, fuelled by anything from high-sulfur coal to old tires, puts out plenty of steam.

By Walt Patterson

One afternoon more than a decade ago, a British engineer named Douglas Elliott tapped a bit of coal, ground to crumbs in a kitchen blender, into a tin can mounted on the wall. Below the can was an ordinary small open fireplace – ordinary, that is, at a casual glance.

For instead of burning coals, a red-hot bed of sand gently undulated like simmering lava. As the coal trickled out of the can onto the glowing bed below, each crumb exploded into flame with a pop and a blue-white flare. It burned only about two pounds of coal an hour, but the little fireplace glowed fiercely, delivering much more warmth than its size suggested.

The fireplace, at Aston University in Birmingham, England, was no mere conversation piece. It was a simple, striking demonstration of a concept called fluidized bed combustion. Some say that FBC will transform the use of humanity's oldest technology – fire.

Like any combustion system, the end product of FBC is heat, which can generate hot water or steam or run turbines to produce electricity. Unlike other systems, however, FBC boilers can burn low-grade fuels, everything from high-sulfur coal to rice hulls. Suitably designed, an FBC system can use soaking wet coal mixed with rock.

It can burn peat, heavy oil, and oil shale; wood and wood waste, including sawdust; urban and industrial trash; even, at one plant in Wales. Sewage sludge that is half water. Yet emission of sulfur and nitrogen oxides is kept so low that neither tall stacks to disperse the flue gases nor fussy wet scrubbers to trap them in liquid are needed. If nothing else, FBC means that coal, our most abundant but naggingly pollution-prone energy source, could be exploited in almost any form, helping to stave off future energy crunches.

The basic principle of FBC is simple: Blow air up through a box full of fine sand. When the air just lifts the sand grains, they churn and tumble like a boiling fluid. They have become a "fluidized" bed. Stirred with a spoon, it feels like thin oatmeal. A block of wood will float on it. Then the churning particles are heated red-hot, to about 900 degrees Fahrenheit. This can be done by injecting propane or natural gas into the air-stream and igniting it in the bed. Once the bed is hot, the start-up gas can be shut off and fuel fed in. The heat released by the burning fuel will keep the bubbling bed of sand incandescent at about 1,500 degrees Fahrenheit. The hot sand stores heat so well that even cold, wet fuel such as wet coal will not appreciably chill the bed. Heat is transferred through direct contact with the hot sand particles, so water tubes or air tubes immersed in the bed will collect heat perhaps five times faster than in an ordinary boiler. That means an FBC unit can be smaller than an ordinary boiler that puts out the same amount of steam, and cost less.

FBC controls worrisome pollutants - oxides of nitrogen and sulfur - simply and elegantly. An FBC boiler transfers heat so efficiently that it can operate several hundred degrees cooler than a conventional furnace or boiler. At this lower temperature little of the nitrogen in the air inside the FBC unit combines with oxygen to produce nitrogen oxide. If the fuel contains sulfur, crushed limestone or dolomite is fed in along with the fuel. Within the bed, the sulfur in the fuel reacts with the calcium in the red-hot stone to form solid calcium sulfate that is trapped in the bed and removed with the ash. An FBC unit can capture at least 90 percent of the sulfur in the fuel.

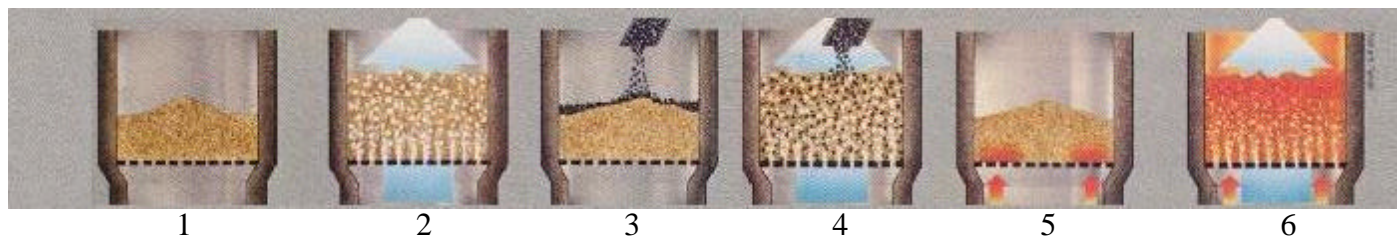
For more than two decades, the official and commercial reaction to FBC amounted to studied indifference. Until the mid-1970s, the transatlantic community of FBC engineers was so tiny that most of them knew each other by their first names. Their tenacity finally has paid off. An FBC conference in Philadelphia last October drew some 700 people from 17 countries, and major companies now promote FBC technology.

Only 10 years ago FBC engineers were living hand-to-mouth. Douglas Elliott, probably the founding father of FBC, did much of his pioneering work in the 1960s at the laboratories of Britain's Central Electricity Generating Board - but the government body was flatly uninterested in pursuing his ideas. He resigned in 1968 to accept a professorship at Aston University.

Still a believer, in 1972 Elliott founded Fluidfire Developments with Michael Virr, a young British engineer. In a cramped workshop on a Birmingham back street, they worked to design and market FBC boilers and furnaces. When Elliott died of cancer in June 1976, FBC was still barely out of the lab. Virr hung on, scrambling for capital and orders. By 1982, Fluidfire - now Stone Fluidfire - had a full-scale factory, and a sister company, Johnston Boiler, had become the most active U.S. manufacturer of FBC equipment. One major customer is Campbell Soup, which uses FBC-generated steam to precook its products. Two small units have been installed at an Indiana public school to provide heat.

Another pioneering FBC firm, Foster Wheeler, has built a large boiler right under the noses of the federal government's air pollution regulators, at Georgetown University in Washington, D.C. It heats campus buildings by burning cheap coal with a high sulfur content - two to three percent compared to less than one percent in low-sulfur coal. After starting up in 1979, it turned out that the equipment used to clean up the combustion gases permitted the boiler to run at no more than 80 percent of capacity. Pushed beyond its limits, the filter system would break down. Restricting the boiler was a nuisance because it was 20 to 40 percent cheaper to operate than the oil- or gas-fired boilers the university had been using. But even before a larger filter system was installed last summer, the stack gas easily met local air quality standards. And with the new system in place, the university can run the boiler full blast.

With such signal virtues, why has FBC taken so long to catch on? The short answer is that until OPEC forced the issue, scarcely anyone wanted to burn low-grade or troublesome fuel. Oil and natural gas were cheap, convenient, and plentiful, could be burned in simple, compact units, and left no residue. Why bother with coal, much less with trash?



A fluidized bed starts with sand on a grating. When air is blown up through the sand, above, so that the particles are lifted but not sent flying away, the sand bed "boils" much like a liquid.(1 and 2) Coal poured

onto a stationary bed of sand forms a layer on top. But added to a fluidized bed, the lumps of coal are dispersed throughout by the turbulence of the churning sand.(3 and 4) Heat applied to a bed of sand at rest travels slowly, so that the bed temperature varies from one spot to another. The mixing action in a fluidized bed, above, quickly spreads out the heat.(5 and 6)

In a fluidized-bed boiler, air is blown up through a sand bed until the particles rise and tumble about. Oil or gas is ignited in the bed and turned off when the sand is about 900 degrees Fahrenheit and red hot. The burning fuel - coal here - lifts the temperature to about 1,500 degrees. Limestone is fed in, to trap most of the sulfur as calcium sulfate, removed with the ash. The useful product, steam, is generated from water pumped through tubes in and above the hot bed.

Elliott and Virr were not the only pariahs. Raymond Hoy at the British Coal Utilization Research Laboratory had two large experimental FBC boilers running before 1970. But by 1972 cuts in government and industry funding had reduced his engineering staff from 80 to six. Hoy persevered by taking on assignments from the U.S. government. When in 1967 Jim McLaren and his colleagues on the FBC team of Britain's National Coal Board discovered the sulfur control effect, scarcely anyone else cared. The team, deprived of funds, dispersed. The first sizable FBC unit in the United States was built in Alexandria, Virginia, just outside Washington, D.C., by John Bishop, a mildly eccentric but brilliant engineer. His sudden death in 1972 came when FBC could ill afford to lose an advocate.

OPEC's price hike later that year rekindled interest in coal, heartening FBC supporters. But the recession that followed meant that FBC's two major potential markets - heavy industry and electric utilities-were in no mood to invest in new equipment. Then the first prototype FBC power station in the United States, at Rivesville, West Virginia, proved troublesome, reinforcing utility company doubts. And it could generate only 30 megawatts of electricity, enough for a city of about 20,000 but dwarfed by a typical non-FBC generating unit of 700 megawatts. But the Tennessee Valley Authority, undeterred, went ahead in September 1979 with an experimental FBC boiler large enough for a 20-megawatt power station and fired it up last May,.

"Back in the mid-1970s, TVA felt the need for new equipment that could use fuel that had been restricted from use because of environmental standards," says Roy Lumpkin, TVA's former manager of the pilot plant. "We were up against the high transportation costs of low-sulfur coal, but we had cheap high-sulfur coal right on our doorstep, And the waste products from scrubbers were disconcerting; the waste from FBC - dry, granular stone and ash - appears to lend itself to natural blending with the environment." TVA aims to have a 160-megawatt prototype FBC power plant operating by 1989.

Other electrical utilities began to take notice of FBC. "Utilities are interested in burning high-sulfur coal, in fuel flexibility, and in building coal-fired power stations in locations where you could not ordinarily burn coal," explains Shelton Ehrlich, manager of FBC programs at the Electric Power Research Institute in Palo Alto, California. and a former colleague of John Bishop. Northern States Power, a Minnesota utility, converted an old coal-fired boiler to an FBC unit that now burns wood waste from local suppliers. The burner started up in November 1981 and now runs 16 hours a day generating 15 megawatts of power from fuels that include municipal solid waste, chopped-up rail-road ties, old tires, and agricultural waste. The institute is now gearing up for a tenfold jump, a demonstration power plant capable of generating 100 to 200 megawatts of *electricity*.

Most FBC boilers work at atmospheric pressure. But in 1967 Douglas Elliott and Raymond Hoy thought of putting an FBC unit inside an airtight shell and pumping in air under pressure. The greater volume of air would increase the amount of oxygen, greatly enhancing the heat output from an FBC unit of a given physical size. At his lab in Leatherhead, Hoy built, in the 1960s, what was for a decade the world's largest pressurized FBC unit.

About eight years ago, the American Electric Power Company and the Swedish turbine manufacturers Stal-Laval took a new look at the idea. Flue gas from a pressurized FBC unit, reasoned engineer Henrik Harboe of Stal-Laval, is not only hot but also at high enough pressure to be fed directly into a gas turbine to produce electricity. A coal-fired gas turbine, cheap to build and cheap to run, is all engineer's dream. The exhaust gases from the turbine can raise steam to generate more electricity, or supply heat directly. American Electric, Stal-Laval, and the German boiler-maker Deutsche Babcock have built a large test rig at Malmo, Sweden, to get enough information to design a prototype pressurized FBC power plant.

Engineers in the United States, Finland, and Germany are purchasing "circulating-bed" designs. Here the air rushes through the bed at high speed, carrying the bed-particles up and out of the combustion chamber into an adjacent hopper that returns them to the bed again. As with a pressurized design, the high rate of oxygen supply makes possible very high rates of heat release. The design also keeps fuel confined to the air-stream more effectively than in an atmospheric boiler, so clogging of the filtering system is lessened. The design already is being used to heat water pumped down oil wells to stimulate production.

FBC engineers disagree, sometimes pungently, about the comparative virtues of different designs. And they concede that bugs remain to be worked out. It is difficult, for instance, to remove dust and particles from the flue gas in a pressurized FBC system - junk that pits turbine blades, clogs the turbine, and corrodes metal parts because of alkali in the coal. But that's what test rigs, pilot plants, and prototypes are for, they argue.

At last October's conference in Philadelphia, the Russians revealed that they have mounted a major FBC campaign. Several industrial units are now operating, fueled by materials from anthracite to oil shale. At the previous conference, in 1980, the Chinese had revealed, without amplification, that the People's Republic had 2,000 FBC units in operation. This time the Chinese offered details. The FBC units are supplying electricity and heat to villages all over China. Four hundred of them burn lignite, a coal so soft it resembles peat, the other 1,600 burn what the Chinese call "stone-like coal," a gravelly material that is up to 70 percent ash.

The most advanced use of FBC is in Scandinavia. One unit operating at a Finnish paper mill burns peat and wood waste that is more than half water, generating 200,000 pounds of steam per hour to convert wood chips to pulp. Other units now running or due to start up this year will burn peat, wood waste, and even municipal refuse.

At the other end of the scale, perhaps the most unexpected impending development of FBC will be home heating. Stone Fluidfire's factory near Birmingham has built three prototype units, smaller than a family freezer and fully automated, to burn solid fuel and provide space and water heating. "We want to put 50 or 60 of them in houses in the U.S." as a demonstration, says Michael Virr of Johnston Boiler. The oil glut, he notes, has depressed prices, removing much of the incentive to develop coal-burning home furnaces and pushing back the market several years.

But FBC is in no danger of slipping back into near-oblivion. The crumbs of coal sifted into Douglas Elliott's tiny fireplace have become mountains poured into huge boilers. Prometheus would be proud.

Walt Patterson writes from London about energy and the environment.