Yuba

LOTHROP & WEST

Joan S-B

Copy of a magazine (?) article printed possibly, about 1975

YUBA STEAM VEHICLES

The Yuba tractor was built as an experimental, prototype vehicle between about 1946 and 1951 by a small group at Yuba Manufacturing Company, San Francisco and Benicia, California, as a possible successor to the "Ball Tread" crawler tractors manufactured by Yuba in the early teens. The new tractor work started from scratch with ideas and sketches, clay and wood models and machine drawings, one unit of the vehicle at a time, to carry out the special concept of an on-road and off-road, earthmover style tractor on pneumatic tires with four-wheel drive and propelled by steam. Reliance was placed upon the earlier Doble work, but there were many changes from most past practices.

The vehicle was earthmover size. It had a single, box beam, central frame member with two independently sprung (knee action) rear wheels and two independently sprung front wheels steerable about vertical pins above each front tire. On a turn, the inside front wheel could steer to a cross-wise position, the tractor pivoting about the ground point of the inside rear wheel.

The steam generator was a horizontal drum about 32 inches in diameter and about 60 inches long extending longitudinally above the frame beam at the front. Air was taken in

3000 wds.

through a belt driven, radial vane blower on the rear end of the generator and was blown forward through an insulated air jacket surrounding the generator and to a burner at the front of a central combustion tube extending along the central axis of the generator.

Diesel oil was forced into the combustion tube by mechanical pump through antidribble valves and atomizing nozzles (and sometimes a small pilot nozzle) controlled by a device that raised the oil pressure on one nozzle to a maximum, then dropped the pressure and cut in a second nozzle. After another pressure rise on both nozzles, the pressure dropped as a third nozzle was cut in and then rose again on all nozzles to increase the fire over a ratio of 8 to 1. The nozzles were cut out and the pressure dropped in corresponding steps to reduce the fire. Ignition was by a 12-volt system firing a spark plug. A glow plug was also used with heavier oils.

From the rear of the central combustion tube, combustion gas doubled back almost around itself in a surrounding sleeve and flowed toward the front of the generator. From the front the gas again doubled back almost around itself in another surrounding sleeve to the generator rear and exhausted to atmosphere. Feed water from a cross-wise tank at the top of the machine behind the driver's bench seat went to a three plunger force pump then to three small steel tubes wound parallel to each other in a co-axial, helical coil in the outermost combustion gas passage or sleeve. This outer coil could be slid into and out of the generator jacket on a built-in rail. The outer coil had three bolted, exterior connections to three similarly wound but larger tubes in an intermediate, helical coil located in the intermediate combustion gas passage and also slidable in and out on a rail. The intermediate coil tubes merged into a single exterior connector joined to a single large tube helically wound and surrounding the central combustion tube and also movable in and out on a rail. This was an approximately counter-flow arrangement.

The large coil connected to a scale trap and a poppet throttle controlled by a pedal through a vacuum servo. The steam temperature-pressure control was by a steel tube and quartz rod thermostat joined to one end of a little balance beam or "whiffle-tree", the other end of which was moved by a steam pressure Bourdon tube. The center of the whiffle-tree could be adjusted to vary the effective length of its two arms to select a ratio between steam temperature and pressure. The whiffle-tree turned the burner off and on and turned the water pump off and on. This maintained an arbitrary ratio of steam pressure and temperature over most of the working range as a sort of artificial saturation curve. For example, a chosen ratio might be 300°F and 500 psi, 600°F and 1,000 psi, and 900°F and 1,500 psi, the latter two being the usual operating values. Occasionally, 1,000°F and 2,000 psi were used.

Steam from the foot throttle went through ball joints to four engines mounted one on each wheel at the inboard side of the tire, the front engines steering with the wheels. Each engine drove through its own planetary transmission settable at each engine by hand between low range for off-road (about 10 mph max) and high range for on-road (about 40 mph max) and a neutral for engine test. Each transmission drove through a planetary gear reduction in the outside hub of its wheel. From the engines the exhaust steam went to fin and tube condensers about a foot thick and four feet square on each side of the frame and each cooled by a two-bladed propeller fan about three feet in diameter. Condensate drained to a sump tank and was lifted by a small pump to the top water tank.

Because of the need for a large amount of quick, auxiliary power (about 40 horsepower), a four-cylinder, electrically started, "Jeep" gasoline engine was mounted centrally on the frame. By shaft and belt the "Jeep" engine drove the combustion air blower, the fuel oil pump, the lubricating oil pump, an electrical generator, the water pump, the condenser fans, an air compressor for air brakes, the hydraulic steering pump, various auxiliaries and also furnished vacuum for some servos. The "Jeep" engine had a speed governor controlled by the foot pedal operating the steam throttle and so corresponded in speed roughly to tractor speed and load. This maintained, with the off and on fire and water controls, the desired steam pressure and temperature.

Each wheel engine afforded 50 horsepower and had a design speed of 2,000 rpm. In use, each engine operated with a two throw, counterbalanced crankshaft turning about a vertical axis in two ball bearings. Four single acting cylinders, two on each side of the crankshaft in the same plane, carried trunk pistons joined through wrist pins and by connecting rods to plain bearings on the crankshaft. Pressure lubrication from the central lubrication pump driven by the "Jeep" engine was supplied to all the bearings before they were loaded. Cylinder wall lubrication was by splash. No oil was injected into the steam, which was kept oil-free. The engine operated with a dry sump. Return oil and blow-by water went to a central oil separator, the water was evaporated and the remaining oil recirculated.

Each cylinder (2 3/8" x 2 3/8") had a spring closed poppet inlet valve at the side and a spring closed poppet exhaust valve in the head (F head). Each valve was connected by its own push rod, bell crank and rocker lever mechanism to a valve actuator group including a group of six disk cams fixed one above another on the upper end of the crankshaft. The cams, in descending order from the crankshaft top level, were number 1, a reverse exhaust cam open at bottom dead center and closed at top dead center; number 2, a forward exhaust cam open at bottom dead center and closed at top dead center; number 3, a reverse inlet cam open at bottom dead center and closed at 60% cutoff; number 4, a forward inlet cam open at top dead center and closed at 10% cutoff; number 5, a forward inlet cam open at top dead center and closed at 30% cutoff; and, at the bottom level, number 6, a forward inlet cam open at top dead center and closed at 60% cut-off. The engine had about 1% clearance volume. No compression was used. There were no pressure relief valves for water. The engine could run slowly on water at domestic pressure.

Rotatable in the crankcase around the axis of the crankshaft and occupying four levels opposite to and radially spaced from the top four cams was an upper ring. This upper ring supported for radial movement four roller tappets spaced at 90° to each other and lying in the same horizontal plane or level as the number 1, or top, reverse exhaust cam. Another four similar tappets in the upper ring lay in the next lower level of the number 2 or forward exhaust cam. The tappets of the second four were also at 90° to each other but were not directly under the tappets of the top set, rather being angularly displaced about 15° from such position. The next lower set of four tappets was in the plane of the number 3 or reverse inlet cam, each tappet being axially beneath the reverse exhaust cam or number 1 tappets. Finally, lowermost in the upper ring was another set of tappets in the fourth level of the forward inlet 10% cam and disposed axially beneath the exhaust forward tappets in the number 2 level.

Just below the upper ring was a two-level lower ring separately rotatable about the axis of the crankshaft and circling around the number 5 and 6 cams. This lower ring carried four equally spaced radial tappets in the plane of the number 5 or forward inlet 30% cam and a final set of four radial tappets in the plane of the number 6 or forward inlet 60% cam. These last were spaced about 15° from the tappets for the 30% or number 5 cam.

The upper ring had a radial arm lying between two pistons in a top shift cylinder disposed horizontally on the crankcase. Compressed air to one end only of the top shift cylinder moved both pistons and the arm toward the other end of the cylinder and rotated to and held the upper ring in one extreme position. Compressed air on the other end only of the top shift cylinder (the first end being open to atmosphere) rotated the top ring to its alternate, extreme position and held it there. The lower ring also had a radial arm lying between two small pistons concentric in two large pistons themselves movable in a lower, horizontal shift cylinder on the crankcase. These small pistons could be moved individually by compressed air on only one cylinder end to shift the lower radial arm to either end position and to hold it there. Furthermore, the lower arm could be centralized by putting compressed air simultaneously onto both ends of the lower shift cylinder, whereupon the two large pistons around the small pistons moved against the arm and against opposite sides of a central stop projecting radially into the cylinder but out of the path of the small pistons. The large (and small) pistons thus centralized the lower arm between them and held the lower ring in intermediate position.

For each valve there was a pressure lubricated rocker lever pivoted at one end on a pin having its axis parallel to the crankshaft and connected through a crank lever to the appropriate valve push rod. The free end of each exhaust valve rocker had a head wide enough to extend axially into the path of tappets in the top two levels. In one extreme rotated position, the top ring positioned the four tappets in the top level against the heads of the respective exhaust rocker levers and against the reverse exhaust cam in the top or number 1 level. Simultaneously, in that extreme position the upper ring positioned the four tappets in the number 3 level against the reverse inlet or number 3 cam and against the very broad heads of the inlet rocker levers, the inlet heads extending axially over the lower four levels. In moving toward the other extreme position, the top ring first moved all of those eight reverse and inlet tappets out of contact with their respective rocker levers and into an ineffective location. Upon further rotation the upper ring then positioned four other tappets in the number 2 level against the broad head of the exhaust rocker levers and against the number 2 level forward exhaust cam. Simultaneously, appropriate other tappets were shifted to engage between the inlet rocker lever heads and the forward inlet 10% number 4 cam.

By thus turning the top ring back and forth through about 30° between its two extreme positions (in each of which the top ring was firmly stopped and held by air pressure against the selected end of the top shift cylinder) the valve events changed between forward (10% cutoff) and reverse (60% cutoff).

During this time the bottom ring was held centered by air pressure on both ends of the bottom shift cylinder to keep all tappets in the lower ring out of contact with both the 30% forward cutoff cam, number 5 level, and the 60% forward cutoff cam, number 6 level.

Were either of those longer forward cutoffs desired, the top shift cylinder was still held in its forward 10% position and air pressure was left on only one end of the bottom shift cylinder. This turned the bottom ring about 15° from its central, neutral position and put another four tappets against the head of the inlet rocker levers and against the inlet 30% or number 5 cam. Thus, both the inlet 10% cam, number 4, and the inlet 30% cam, number 5, simultaneously actuated the inlet rocker lever to open the inlet valves. At 10% stroke the inlet 10% cam, number 4, lost contact with its tappets, but the inlet 30% cam, number 5, continued to hold its tappets against the inlet rocker levers and the inlet 30% cam until 30% of the stroke passed. If 60% cutoff were desired, the bottom ring was rotated to its opposite extreme position by air pressure in the other end only of the bottom shift cylinder. This moved the four tappets in the lowest level of the lower ring against the inlet rocker lever head and against the inlet 60% cam, number 6, while moving the inlet 30% tappets away from the end of the inlet rocker levers and away from the number 5 cam.

The parts of this mechanism, while numerous, were simple. The valve events were easily changed whether the engine was running or stopped. The tappets cammed against leading and trailing inclined faces on the rocker lever heads to wedge the proper valves open and compress their springs in any crankshaft position and for any selected valve events. Instant shifts between forward and reverse and to any cutoff from any other position were made without axial loads and without severe wear.

For operation of the tractor from cold, the four range boxes were put into either off-road or on-road condition. The ignition switch for the "Jeep" engine was turned. The "Jeep" engine started and ran at a fast idle. The fire automatically ignited. Steam-up was automatically accomplished in set ratio all the way up to set temperature and pressure and was quick because of the large power available. The engine valve control lever was put into forward or reverse starting position (60% cutoff) and the emergency brake released (closing a shunt pipe from engine inlet to exhaust) as the throttle pedal was depressed. The vehicle was power steered and maneuvered indefinitely, cutoff being changed at any time and forward and reverse being shifted at random under load and for braking. The automatic control took care of pressure and temperature and the propeller fans did their best to give complete condensation. For shut down, the throttle was closed, the vehicle braked to a stop, the emergency brake was set, and the ignition switch turned off. The operator had no other controls.

In an earlier engine, the configuration was similar, except that at the top of the crankshaft there was a single, axially shiftable drum made up of six cams, as described, but having intervening spacer or ramp disks with conical or inclined faces. By a power-actuated fork mechanism the cam drum could be axially moved along the crankshaft to insert the selected cams beneath the desired rocker levers. This went through its motions reasonably well and transmitted the cam motions through torque tubes to the push rods. But there was excessive wear on the conical or ramp disks and the torque tubes were spongy. This design was therefore discontinued. It was followed by another valve arrangement in which outer cam rings were swung almost radially across the crankshaft by inner cams concentric with the crankshaft. There was no axial shifting movement. This failed when the actuating mechanism bent some parts when the inner and outer cams jammed due to unfavorable load angles. The third system, described above, was then satisfactorily adopted.

Tractor specifications were:

Performance:

Drawbar Horsepower................200
Max. Speed.......................40 M.P.H.
Max. Tractive Effort (Ballasted)..32,000 lbs.

Dimensions:

Wheel Base........................124 1/2"
Tread............................76"
Ground Clearance..................24"
Length...........................20'-10"
Width............................ 7'-11 1/2"
Height........................... 7'-2"
Weight...........................24,000 lbs.
Turning Radius...................12'-2"

Tire Equipment:

Front and Rear...................16.00 x 24 -- 20 ply

Brakes:

Four Wheel........................20 x 8 Air Powered
Parking -- Rear Wheels...........Mechanical

Capacities:

Fuel Oil..........................115 gals.
Gasoline.......................... 15 gals.
Water............................. 40 gals.
Lubricating Oil................... 12 gals.

In addition, a very light, portable, complete plant of about 10 horsepower was built for boat propulsion. This system was about as described except for scale. A battery driven electric motor took the place of the "Jeep" engine. The condensers were under water, as was the steam engine. That had three cylinders in line with an overhead cam shaft. There was a similar valve shifting mechanism with one forward cutoff and one reverse cutoff.

Also, there was an elaborate concept study putting an entire plant quite similar to but larger than that of the tractor into an Army M48 tank.

A surviving engine from the destroyed tractor has recently (1975) been used for laboratory testing at Steam Power Systems, San Diego, at even higher temperatures and with good results.