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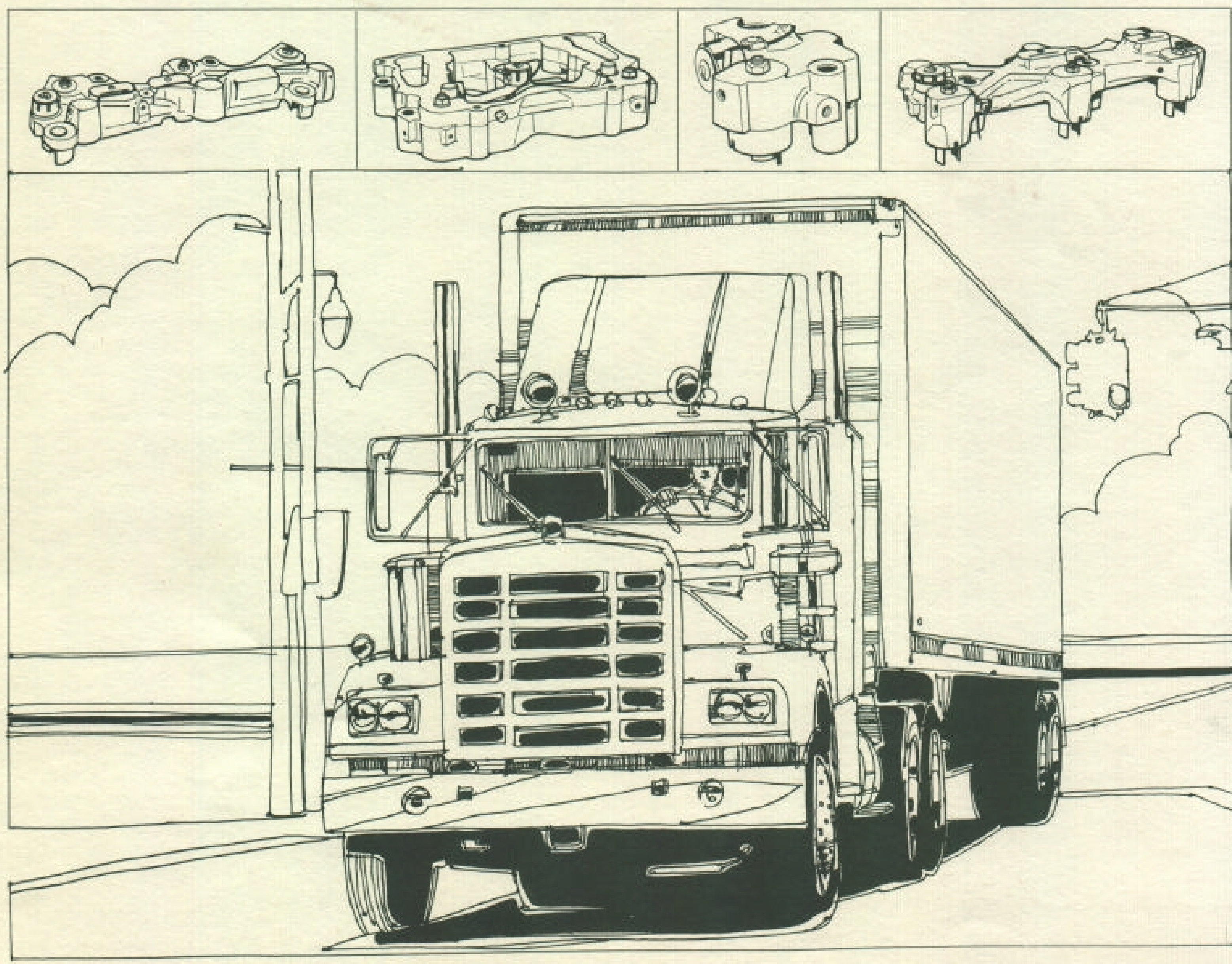
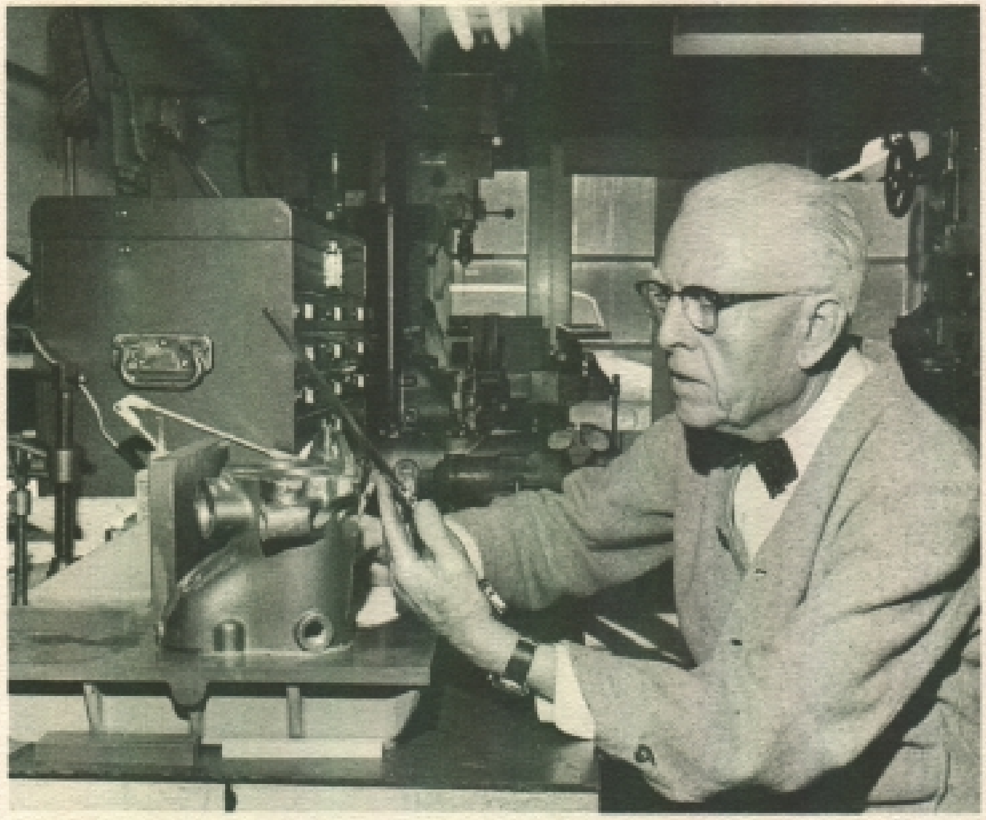
Jacobs® Engine Brake Retarder
Bloomfield, Connecticut
October 17, 1985





Clessie L. Cummins at work in his Sausalito shop.

A History of The Jacobs® Engine Brake

By C. Lyle Cummins, Jr.

Long steep downhill grades not only provide anxious moments for truck drivers, but they also add extra hours behind the wheel. The advent of the Jake Brake® compression engine retarder brought an opportunity to end this fear almost entirely and at the same time to safely raise average speeds.

To a motorist or a bystander, the Jacobs Engine Brake, commonly known as the "Jake Brake," is sometimes associated with a characteristic "popping" exhaust noise heard when a truck is decelerating or descending a hill. To the truck driver, it is a device that turns his engine into a retarder, giving him about the same braking effort at the wheels as his engine puts out when it is producing power.

How does this work? Quite simply, the Jake Brake retarder turns a diesel engine into an air compressor. Rather than store the energy of the pressurized air in the cylinder, created by the piston coming up on the compression stroke, the Jake Brake retarder mechanism hydraulically opens the exhaust valve near the end of the upward piston stroke. The stored energy in the cylinder is released to the atmosphere so that when the piston descends on what would normally be the power stroke, no pressure remains in the cylinder to act on the piston.

Thus, the energy transferred from the driving wheels into the compressed and highly heated air (through gravity or forward momentum of the vehicle) goes mostly out the exhaust pipe, with a portion entering the cooling water from heat transfer through the cylinder walls. This has two results: on long downgrades the engine cooling system remains at near normal operating temperatures, and in the case of turbocharged engines there is sufficient exhaust energy to allow the turbine of the turbocharger to power the companion compressor and maintain a high enough degree of boost to increase the retarding effort.

A diesel, being a free-breathing engine by virtue of having no valving or venturi restrictions (carburetor) offers inherently less braking effort than a gasoline (spark ignition) engine even though the diesel engine has about twice the compression ratio of the spark ignition engine (which obviously means that it requires more effort to force up the piston on the compression stroke), that work is given almost entirely back (less friction and heat transfer losses) when the air is allowed to expand on the next outward stroke. Conversely, the spark ignition engine becomes a vacuum pump when being motored with the throttle closed. This is a basic reason why the spark ignition engine is so much less efficient than the diesel or compression ignition engine when operating at idle or light loading. Of course this assumes that the fuel is essentially shut off and no combustion can occur–which is true with the diesel engine but not so with the spark ignition engine.

Although the Jacobs Engine Brake has been on the market since 1961, the need for it was terrifyingly demonstrated to its inventor, Clessie L. Cummins, some thirty years earlier. In those times, Clessie was trying to prove the worth of the automotive diesel engine as well as to learn firsthand the kind of engine the trucking industry most needed. In August of 1931, one of these combination test and publicity stunts found him, Ford Moyer, and Dave Evans driving a Cummins Diesel-powered Indiana truck from New York to Los Angeles in an attempt to set a new truck speed record across the continent.

One of the first things proven was that the diesel engine does indeed offer less braking than a gasoline engine of equivalent size, placing a greater burden on the vehicle's braking system. With the higher speeds being driven on this test run, plus the load on board that included the Cummins Diesel 1931 Indianapolis race car and extra equipment, the intrepid trio soon found it necessary to place more reliance on prayer than on brake linings.

All went reasonably well until the descent of Cajon Pass, on old U.S. 66 leading into San Bernardino, California. A long, winding and steep gravel road, criss-crossed by a busy mainline railroad, almost led to the demise of the truck, its driver Clessie L. Cummins (who was to become the "father of the U.S. automotive diesel"), and a frantic crew who were tossed around their bunks in the cargo box behind the cab. In Clessie's words:

"About dusk on the fifth day, we reached the top of Cajon Pass west of Barstow, California. Before retiring to the sleeping compartment, Dave had warned me against this thirty-five-mile stretch of mountainous downgrade. 'Wake up Ford and me when you get to ***Kayhone*** *Pass,' I had understood him to say, 'I don't want to be in this box when you start down that twister with the kind of brakes we've got.' I had heard but not seen, my Spanish being nonexistent, the word Cajon failed to register when the sign appeared. Soon, however, I realized my error. The brakes wouldn't hold. Now running in third gear, I tried desperately to get into a lower speed. Nothing doing. I saw I would just have to ride it out.*

Well down the long grade by now, I suddenly saw something moving across the road ahead. There was a long dark shadow and then a red glow flared in the sky. I realized with new alarm that a freight train was cutting across our path. The truck roared on. Dave and Ford screamed bloody murder in the compartment behind me. And I clung to that steerring wheel like a madman. Had Mack Sennett been on hand with a movie camera, he would have gotten enough footage for one of his famous Keystone Kops features.

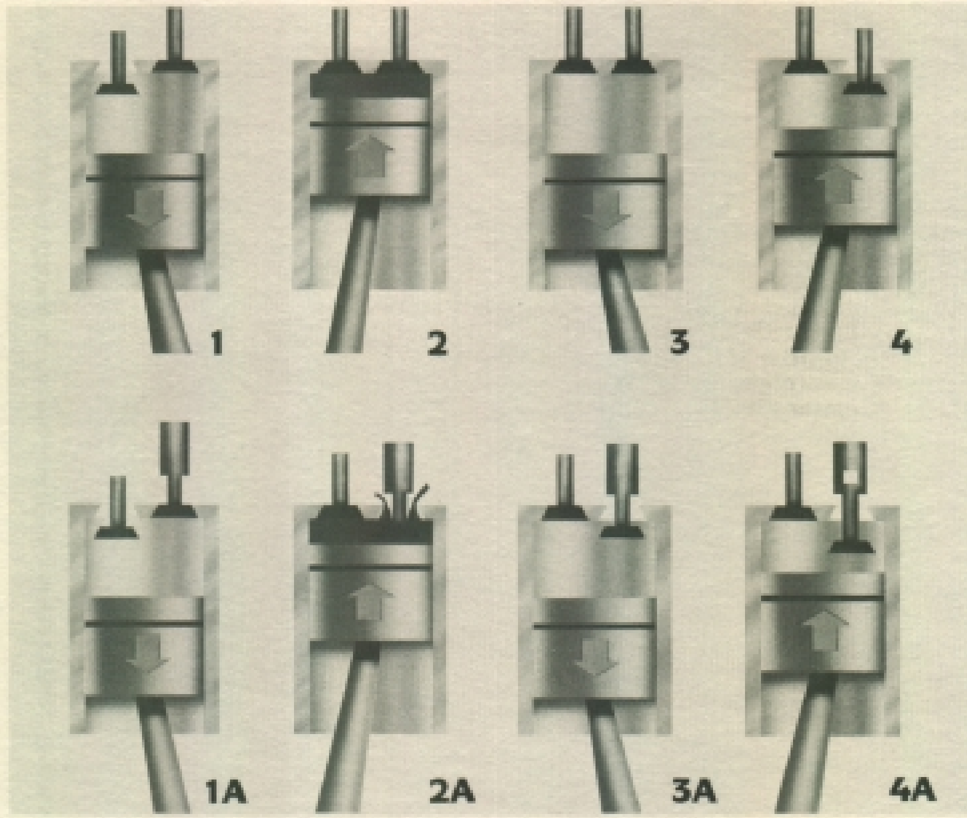
As we raced inexorably toward the crossing and doom, the train's caboose loomed out of the darkness. Its red lights cleared the highway just as we reached the tracks We had escaped certain death by Inches."

The memory of the dark night was never forgotten. The venerable diesel-powered Indiana did set a new coast-to-coast truck speed record of 97 hours, 20 minutes running time for the 3,214 miles, and one of its drivers vowed someday to make his engine work when going downhill just as well as going uphill.

Twenty-four years later, in 1955, Clessie Cummins' inventive genius again addressed the engine retarding question. In retirement in Sausalito, California, he began studying what might be done to turn his engine into an effective "brake."

It was also in 1955 that Clessie enticed his youngest son Lyle, a graduate mechanical engineer, to join forces and form the large concern which he named Centco (short for Cummins Enterprises Company), a name chosen to keep the household accounts separate from Clessie's ventures in the basement. The basement was actually an area that included an office with a view, a soon to be equipped machine shop with the usual lathes, milling machine, etc. and a four-car garage. Another member of the Centco team, added in 1957, was Ray Hansen. Hansen was an able machinist,

An American Automobile Association official (with flag at left) begins countdown for a December, 1931 endurance run at Indianapolis Speedway. The Cummins Diesel-powered Indiana truck had been used in an August, 1931 cross-country trip which demonstrated the need for an engine brake. Clessie L. Cummins, Ford Moyer, Dave Evans and T. E. Myers (Speedway Vice President) are poised in readiness for the run.



The Engine without a Jake Brake
During the piston's normal compression stroke (2), air compressed in the cylinders raises internal heat to almost 1,000°F. At this point, fuel is injected and combustion occurs, raising temperature even further. Pressure from this expanded gas forces the piston down (3). The engine has thus produced the positive power necessary to turn the crankshaft.

welder, and sheet metal bender whose hobby was building and racing sports cars.

Lyle's initial effort was expended on thermodynamic analyses to prove the Clessie's idea of turning the engine into a compressor really would provide sufficient retarding potential. The answer was an unqualified "yes," but how to do it? One scheme was to clutch-in a high pressure pump and a timed distributor to carry hydraulic force to a slave piston, which in turn would act on the exhaust valve to open it at the proper point on the compression stroke. A second method considered was to use a multi-plunger pump hydraulically timed to act on the slave piston. While both of these methods could be made to work, neither was considered a best solution.

An idea for a practical method, emphasizing the heat of the invention, came to Clessie in 1957 during a sleepless night in a Phoenix, Arizona hotel room. The idea that hit Clessie revolved around taking advantage of perfectly timed motion already built into Cummins and Detroit Diesel engines; these engines have a third cam on the main camshaft that activates the fuel injector of each cylinder. A simple retrofit mechanism should be able to transfer this motion to open the exhaust valve. The idea was jotted down on a bed-side scratch pad and was telephoned back to son Lyle in Sausalito early the next morning. By the time the vacationing Stella and Clessie Cummins returned home, layouts of possible design solutions were waiting, albeit in retrospect, they were more complicated than proved to be necessary.

An important subtlety of the invention made it novel enough that a very broad patent was ultimately granted, affording strong patent protection dating from the time of its application. The application was in the U.S. Patent Office for seven years due to new pertinent additions being twice added after the original filing in 1957.

A very thorough patent search made prior to filing Clessie's patent showed that the idea of opening a valve, exhaust or otherwise, at or near the end of the compression stroke was not a new one, some related patents dated back to 1918. These were either for the purpose of easing the cranking load during starting or for actual engine retarding.

A vital point had always been overlooked, however; this prevented any of the old braking patents from becoming commercially feasible products. None of the prior art made the conversion to the braking mode without altering in some way the existing valve train, i.e., cam, pushrod, rocker lever, etc. Clessie's idea was to

The Engine with the Jake Brake
The key to the Jake Brake's performance is the slave piston. Hydraulically actuated, the slave piston opens the engine's exhaust valve (2A) near the end of the compression stroke. The compressed air, which normally forces the piston down even though no fuel is added, is vented through the exhaust system (2A). By releasing this energy, the Jake prevents any positive power being exerted on the piston. The vehicle's forward momentum provides the energy needed to return the piston to its bottom position (3A), thus completing the process of generating maximum retarding power with a Jake Brake.

superimpose onto the existing exhaust valve motion an already available and correctly timed motion (the injector cam, for example, but not limited to this cam) *without* preventing the exhaust cam from acting to open and close the exhaust valve as it normally would during non-braking times.

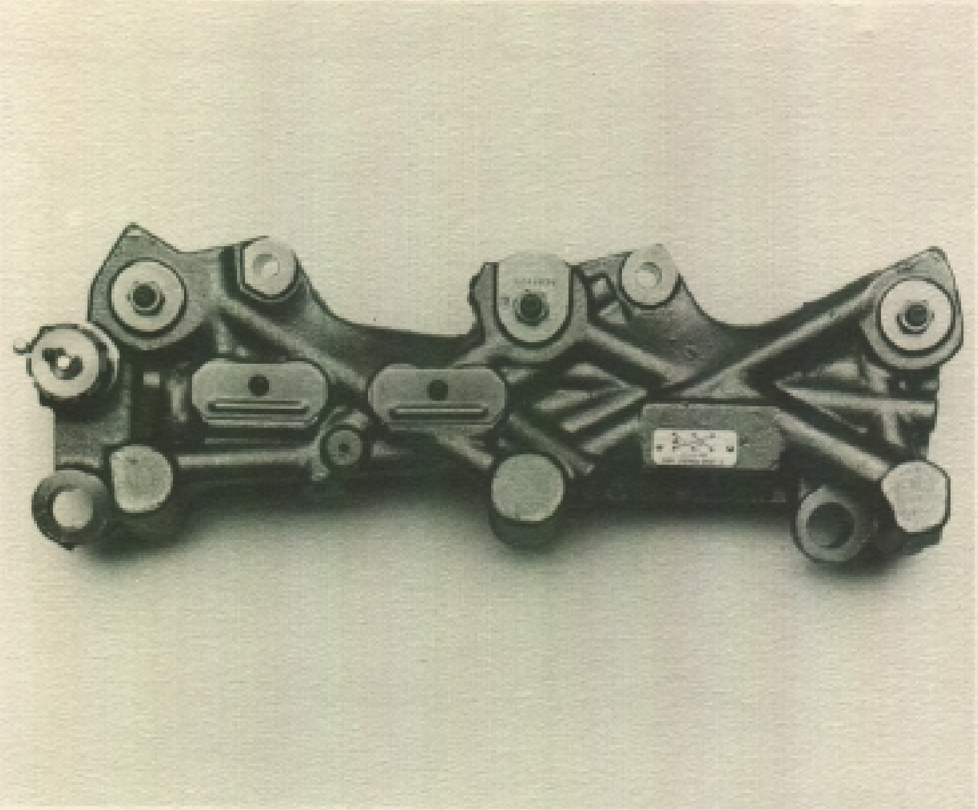
How best to transfer the injector cam motion was developed during the next two years. The simplest method was to tie together mechanically the injector and exhaust rocker levers with a one-way locking connection so that the injector cam could open the exhaust valve, but the exhaust cam could not actuate the injector plunger. The experimental construction consisted of blocks welded to standard rocker levers over the rocker shaft bosses. The injector rocker block had a deep curved slot open to the rear. Engine oil pressure, controlled by a three-way solenoid valve and acting through a hydraulic piston, forced the pin into the exhaust rocker lever slot. Engagement occurred during the exhaust, intake, and part of the compression strokes on a catch-as-catch-can basis.

Because the Cummins fuel system at the time tended to inject some fuel into the cylinder, even during coasting conditions, it was necessary to add another hydraulically-operated piston to hold the injector plunger seated whenever the locking pin was engaged. This piston had a wedge-shaped outer end acting against an extension to the injector plunger spring retainer and bridging around the injector rocker level.

The vehicle selected for first field tests of the completed device was a 1955 GMC "Suburban" station wagon repowered with a Cummins JN-6 diesel engine. The purchase and conversion were made in early 1956 when the vehicle was used for some investigative work prior to the final "assault" with the engine brake prototype. The Cummins JN-6 diesel engine had a displacement of 401 cubic inches and was rated at 125 BHP at 2,500 rpm. Because of additional engine weight and length, as well as accessibility reasons, heavier springs were added in the front and the Suburban's frame, fenders, and hood were lengthened by some eleven inches. The sheet metal work and modifications were done in the body shop of British Motors, the Rolls Royce dealer in San Francisco. Clessie's friend Kjell Qvale, who owned the dealership, suggested that the shop would be a good place to perform the "surgery." Needless to say the work was beautiful, but expensive! The longer wheelbase and additional weight helped the suburban's riding characteristics, yet handling was far from that of a sports car!

Downhill braking performance of the 6,500-pound test wagon with its cylinders acting in the mode of air compressors was most encouraging. Second gear allowed the diesel engine to slow down from governed speed to an idle in less than 200 yards on a thirty percent grade. Considerable retardation was also easily obtained on direct drive on six percent hills. After recovering from their fright at the way the vehicle began its downhill test runs in San Francisco, riders witnessing the operation of the invention as invited guests came away pale but visibly impressed.

Since the major market potential was in the Cummins NH series diesels at that time, the engine brake mechanism was scaled up and adapted to a Cummins NHRS supercharged model of 300 BHP at 2,100 rpm. The chief reason for selecting this model was simply because a pair of these diesel engines were installed in Clessie's 96-foot yacht *Canim* based at the Sausalito harbor! Clessie saw no reason to invest large sums of money in a test facility with a motoring dynamometer when one of his boat engines could tell almost as much! By powering the front four cylinders to drive the rear two, continuous downhill braking conditions were simulated on the two acting as com-



The Jake Brake today.

pressors, without the boat (truck!) even leaving the dock. (In the Cummins NH series six-cylinder engine, each head covers two cylinders.)

Although the principles were proved by mechanically transferring the injector motion, a more practical method was to use a fully hydraulic motion and force transfer. A test was next made with the rudiments of a final hydraulic design that later became the production prototype. The first retarder housings of the prototype design were installed on a Cummins diesel engine in a truck owned and operated by the Sheldon Oil Company. The work was done at Sheldon's shop in Suisun, California during August 1959. Sheldon Oil Company trucks were then hauling 400°F asphaltic oil to "batch plants" making highway paving material.

The initial run with the engine brake was to one of these plants just at the eastern base of the grade, down the Sierras on U.S. Highway 50 near Lake Tahoe. Bill Hill, an eighteen-year veteran driver for Sheldon, said he normally was forced to pass the turnoff onto the job site because of faded brakes; he would come back when he could slow down enough to turn around! With the engine brake he needed to use his wheel brakes briefly only two times on the descent from the summit. The turnoff was easily made, and the brake drums were barely warm to the touch. Bill said he never wanted to drive a truck again unless it was equipped with Clessie Cummins' new invention!

Marketing of the engine brake began while the design and patent processes were still being completed. As a result of a prior contractual arrangement, Clessie was obligated to show his ideas first to Cummins Engine Company. This was done three times during the engine brake development because of the patent refilings. The novelty of the idea, which broke into untried mechanical areas, plus the uncertainty of its commercial merit caused it to be rejected by Cummins Engine Company. Lest incorrect surmises drawn, all of the other major manufacturers contacted, who either built or used "three cam" diesel engines in their trucks, also turned down the opportunity to license or buy the idea. Nonetheless, Clessie was not discouraged, because he also was thinking about starting a small company to manufacture the brake himself. At seventy years of age, he was just getting his second (or tenth) wind!

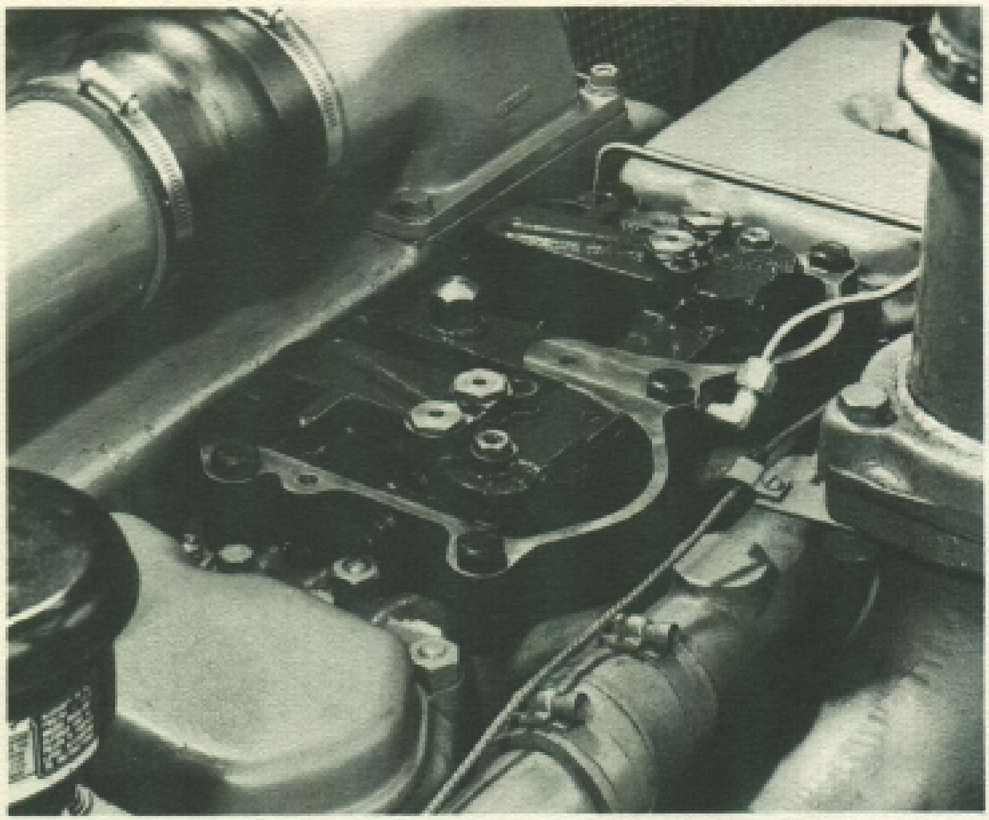
The story of how Clessie Cummins' engine brake became the Jacobs Brake retarder is the tracing of an improbable and complicated set of circumstances. Follow this through if you will: Clessie's brother Deloss Cummins, once service manager of Cummins Engine Company, lived in Phoenix, where he and a partner ran a successful Cummins engine distributorship. He visited Clessie occassionally in Sausalito and knew of the ongoing "basement" activities. Deloss' son Don was serving in the U.S. Coast Guard, with one of his last stations being in New London, Connecticut. The Cummins Engine Company distributor in nearby Hartford was a good friend of Deloss and had known Don Cummins for years. This resulted in an invitation to Don to come to Hartford; naturally the visit would be more pleasant if Don could also spend some time there with a person more his age (especially a person of the opposite sex). Thus a blind date was arranged with the daughter of a good friend. The girl's father, Bob Englund, also happened to be a Vice President of Jacobs Manufacturing Company, the world's leading manufacturer of drill chucks. There was a mutual attraction between Don Cummins and Roberta

Englund, and in due course wedding bells were heard.

Don knew through his dad that Uncle Clessie was working on some kind of engine brake as one of his retirement projects, and the word eventually reached the ears of Jacobs Manufacturing Company's President Louis Stoner and his brother Arthur, then head of engineering at Jacobs (The description of what was going on in California by this time was rather remote from any relationship to the actual device!) Since Jacobs was actively seeking new projects in order to diversify its operations, the "air compressor" brake that Bob Englund's son-in-law's uncle was working on might be worth looking into! Just weeks before the Sheldon Oil Company test began, a letter was received in Sausalito asking if the Stoner brothers and Page Wodel, a capable young Jacobs salesman, could come to California to see what invention Clessie had under development. A demonstration of the brake on the boat engine, plus the infectiousness of Clessie Cummins' determination and foresight experienced during a yacht ride on San Francisco Bay, excited the visitors to the point that agreement was soon reached to build brake assemblies for ten engines as quickly as possible from drawings that Lyle provided.

An option agreement between Clessie Cummins and Jacobs Manufacturing Company was entered into in December of 1959. Based on the results of Centco-conducted tests with trucks using the Jacobs-made units, along with market surveys and independent tests, Jacobs would then be allowed to make their decision as to whether or not they would exercise the option. Consolidated Freightways, Pacific Intermountain Express, Willig, Sheldon, O-N-C, and other trucking firms kindly furnished test trucks. While several minor problems appeared, the tests demonstrated conclusively the engine brake's improved, safer operation, as well as a large potential cost savings in brake linings and drums.

Increased engine life, due to the fact that the engine remained hot on long downhill runs, was an advantage proven later, though assumed by Clessie from the very beginning. In April of 1960, Jacobs Mfg. Company made the decisions to establish its new Clessie L. Cummins Division (now named Vehicle Equipment Division) for manufacture of the engine brake.



An early Jake Brake.

Although there was never any doubt on Clessie's part as to the quality of the product that Jacobs would build, he did have reservations that they could succeed in a new market totally foreign to their previous experience. Thus, while he was selling Jacobs on the value of his engine retarder, they in turn were wooing him on their ability to make it a commercial success.

The "Clessie L. Cummins Division" title was chosen to show that it had a tie to the man whose name was on the diesel engines for which the product made by that division was to be used. The final contract between Clessie and Jacobs Mfg. Company specified that he would also be willing to act in an advisory capacity when either party felt the need. This clause was actively exercised during the first few years. Others in the Cummins family also participated. Deloss Cummins assisted Page Wodell in establishing a dealer network. (For a number of years, all sales were on an aftermarket basis.) Don Cummins, now a mechanical engineer, went to work for Jacobs, and, in addition to his official title of sales and service engineer, provided practical know-how for many years in more areas than his title indicated

Lyle Cummins was also involved with Jacobs Mfg. Company, first while on loan from Centco, and later in the Jacob engineering department working in product design. Methods used by Lyle and Don were sometimes unorthodox, but sudden situations arising with a new product, in a company unfamiliar with the market where the product was used, often called for direct and "interesting" approaches to problem solving!

Nevertheless, the Jacobs organization, particularly under the direction and dedication of Page Wodell in sales and Gerry Haviland (Chief Engineer after Arthur Stoner's retirement), rose to the occasion and a competent team was the result.

The first production units for the Cummins NH series engines left the factory in 1961, followed shortly by a brake for the Detroit 71 series. Today Jake Brake retarders are available for the major U.S. heavy duty diesel truck engines; Caterpillar, Cummins, Detroit Diesel and Mack. Military applications have also become significant with Jacobs retarders, being standard on several U.S. military vehicles.

Clessie Cummins' idea for making a diesel engine work downhill as well as uphill has thus been implemented. The Jake Brake retarder has become a major contributor to greater control and safer operation of heavy trucks worldwide.

The text of this brochure is based on an article by C. Lyle Cummins, Jr., from Diesel Car Digest, Vol. 6, No. 4, Winter, 1981, reprinted here with the kind permission of its editor, Robert E. Flock, Diesel Car Journals, P.O. Box 160253, Sacramento, CA 95816.

The Jacobs Engine Brake is the 81st National Historic Mechanical Engineering Landmark designated since the program began in 1973. In addition 18 International and 9 Regional Landmarks have been recognized by the Society. Each represents a progressive step in the evolution of mechanical engineering, and each reflects an influence on society. Forfurther information contact ASME, Public Information Dept., 345 East 47th St., New York, N.Y.

The American Society ofMechanical Engineers
345 East 47th Street
NewYork NewYork 10017

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