In any case, the "German" EMS today has a clear developmental head start on the "Japanese" EDS, but that should not lead to an undervaluation of the great developmental potential of the EDS, especially in connection with further happy surprises in the development of superconductors (see *EIR*, May 11, 1990, "Mag-lev Technology Could Rebuild U.S. Transportation," and May 18, 1990, "U.S. Could Leapfrog Europe, Japan, in Mag-lev Technology.").

The support system of Transrapid consists of a chain of support magnets that attract the rail from below. The vehicle completely surrounds the rail, which contributes to traffic safety since the magnet train cannot be derailed. Because the chain of magnets distributes the weight of the vehicle along the entire length of the car, only a technically advantageous load area has to be dealt with, and not a point load, with which rail-wheel systems load the roadway. How decisively this roadway-protecting construction can affect operational costs can be seen in the fact that the operational velocity of the Japanese Shinkansen was reduced from 280 kmh to 220 kmh, in order to keep repair times and costs within tolerable limits.

Guidance of the Transrapid is ensured by laterally mounted magnets. The drive system is integrated with these support and guidance magnets.

What drive system a magnetic train uses can be solved in two different ways, and the most promising of the two was chosen for Transrapid. To make that clear, it is best to consider the manner in which a normal electric motor functions. It consists of two components: a fixed magnetic field and a mobile magnetic field, which is pulled step-by-step along the stationary field, like a hamster on its exercise wheel. At first, the magnetic north pole of the mobile magnet is attracted to the south pole of the stationary field, and moves in that direction. When it reaches that point, the electromagnetic field of the mobile field is reversed, so that the stationary north pole is next to a repulsing north pole, and the next south pole of the mobile field can be attracted.

A linear motor functions in much the same way, as the name suggests, "linearly," and not in a circle. Our hamster runs around on a long, linear exercise ladder extending through the entire house. With linear drive systems, the decision can be made whether the active mobile field will be on the vehicle or on the roadway. For the hamster, the second solution seems paradoxical, since it would appear that many hamsters, one placed beside the other, would represent the active part of the route, and a short piece of linear ladder would be passed along beneath each, which gives it a few shoves with its feet as it comes by. Technically, however, the choice of the active roadway is very interesting, since it allows us to shift the drive out of the vehicle to the roadway.

With Transrapid, therefore, it is not necessary, as it is with the ICE, to install a drive motor in the vehicle, which has the advantage that drive energy does not have to be carried on board the vehicle. Current collectors such as the ICE needs are thus no longer necessary. Ferromagnetic stator packets with three-phase mobile field windings are attached to the underside of the roadway as the drive component of the Transrapid. These mobile fields draw the magnets, which are in any case necessary for lift-support of the Transrapid, along the roadway. The Transrapid thus actually "surfs" with its support magnets on the alternating magnetic field generated in the roadway. Braking is also performed without contact, with the mobile field simply reversing in polarity, and, finally, the energy necessary for on-board systems can be drawn by induction from the mobile field. Everything fits together.

This construction concept is convincing. On the other hand, the speed records of wheel-rail systems on specially prepared tracks are about as convincing as the habit that aging U.S. Presidents have of jogging in public to prove their fitness. The magnetic train can travel at more than 500 kmh, and without any structural changes. The operational speed of the Transrapid was limited in previous plans to 500 kmh, because the sharply increasing energy costs made that kind of self-limitation seem sensible. Since the energy use of the magnetic train is clearly below that of an airplane, it can be

Robert H. Goddard's 'High-Speed Bet'

Our story begins in 1904. On Dec. 20 of that year, Robert H. Goddard—freshman physics student at Worcester Polytechnic Institute in Massachusetts and future great American rocket scientist and pioneer—read an essay before the freshman class, responding to the assigned English theme of Prof. Zelotes W. Coombs, "Traveling in 1950." Goddard's essay created considerable discussion and a good deal of skepticism. Enough interest was shown, however, to give Goddard the courage to present the idea in the form of a story, and send it in 1906 to prominent magazines, such as *Scientific American*. The editors, however, were fully as skeptical as some of the students, and "The High-Speed Bet"—as Goddard titled his story—did not find its way into print.

What method of travel did the young Goddard propose in his essay? He presented a scheme for Earth travel, addressing the three impediments to rapid surface transit:

- Friction between the rails—to be eliminated by raising the cars off the rails by electromagnetic repulsion roadbeds;
- Friction against the air—to be eliminated by propelling the cars through at least a partial vacuum;

• The time of transit—to be reduced to a minimum by speeding the cars faster and faster up to the middle of the journey, and then reversing the power and slowing down until the destination has been reached.

The train Goddard projected for the year 1950 seemed fantastic to his engineering classmates. Cars were suspended inside a steel vacuum tube, floating and driven by the attraction and repulsion of electromagnets—what is now referred to as magnetic levitation.

At the time of Goddard's essay in 1904, no patents had been issued for mag-lev rapid transit schemes. In fact, it was not until April 2, 1910, that Emile Bachelet applied for a patent on the use of alternating-current electromagnets in a car for purposes of levitation, and of solenoids at intervals along a road-bed for purposes of propulsion.

In Goddard's scheme, the train's electromagnetic speed would be limited only by the force of acceleration on the passengers, who would be strapped securely in reclining and reversible seats—the idea he patented some 40 years later. At the outset, the train would accelerate rapidly, reaching maximum velocity of two times the average velocity at mid-journey, then would decelerate at the same rate as the initial acceleration for the last half of the journey. Some 200 miles between New York and Boston would be covered in 10 minutes, an average speed of 1,200 miles per hour. Goddard's mag-lev train was to compete against conventional trains "running at the frightful speed of 180 miles an hour, but with great waste of energy and much danger. The people were not satisfied; greater speed and greater safety was their demand. Most insatiable were the rich and influential men."

According to biographer Milton Lehman, Goddard barely concealed himself in "The High-Speed Bet" as his hero, Maurice Sibley, who proposed the bet on a rainy afternoon in late November 1948 during an animated discussion at the Engineers' Club in New York. Sibley wagered $1,000 that by 1958 he would build a rapid transit system which would permit travel from Boston to New York in 10 minutes. The bet was accepted by another engineer, Charles Adams, who was invited to ride on the maiden voyage of Sibley's rapid transit wonder. The train reached New York a full three seconds faster than the wagered 10 minutes.

Eventually, *Scientific American* paid Goddard $5 for the use of his article based on "The High-Speed Bet," titled "On Future Rapid Transit," which the magazine converted into an unsigned editorial, "The Limit of Rapid Transit," for the Nov. 20, 1909 issue—four months before Bachelet applied for his patent.

—Robert D. Allen

Robert D. Allen, a mechanical engineer with experience in nuclear energy and aerospace development projects, contributed a fuller discussion on Goddard's mag-lev project to the Fall 1991 issue of 21st Century Science & Technology.

expected that it will be driven on some routes at more than 500 kmh. If we wanted to technically soup up the magnetic system, as is done with the wheel-rail system today, it could even be faster than air traffic, for example, by laying some of the track inside a vacuum tunnel.

The development history of the magnetic train

Mag-lev technology is very new, and yet, as with every important development, there were brilliant anticipations of it long before (see box). For example, the Frenchman Emile Bachelet experimented in 1912 with a model of a levitation train that worked according to electromagnetic principles. The energy use was so great, however, that the project necessarily failed. The German engineer Hermann Klemper began to work with mag-lev technology in 1922, and demonstrated in 1935 that levitation must be achievable with economical power input, and on Aug. 11, 1934 received national patent No. 643316 for a "levitation train with wheel-less cars that travels by means of magnetic fields on iron guide tracks."

Then came the Second World War, and nothing happened then or afterward for quite some time. Only in 1969, after the success of the Japanese Shinkansen astonished the world, did the German Federal Transportation Ministry issue a contract for the HBS study, and research on rail-bound rapid transport was again picked up. In the same year, Krauss-Maffei presented the first basic model with magnetic support and guidance systems and with a linear motor, and in October 1972, the experimental vehicle Transrapid 02 was conceived on the basis of the electromagnetic system. At the MBB firm, a test magnetic sled was put into operation.

At that time, the electrodynamic system was also being researched in Germany. In 1973, AEG, BBC, and Siemens began work on Project Group Mag-Lev Train with the test vehicle EET 01 in Erlange. In the following year, Krauss-Maffei and MBB formed the Transrapid-EMS Corporation. In 1975, this corporation operated the magnetically supported and guided component test vehicle KOMET, which was accelerated on a short experimental track with a hot-water drive system. The vehicle attained even at that time a speed of 401.4 kmh. In the same year, the construction of Transrapid 04 could begin. This vehicle was a "purebred" magnetic train, and in 1977 set the world record of 253.2 kmh for a mag-lev train with linear motor carrying passengers.