RESEARCH

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Mr Chairman, and Members of the Highway Research Board of the Division of Engineering and Industrial Research, National Research Council·

I am glad to respond to your invitation to say a few words on RESEARCH on this occasion I have talked of little else in the past three years and shall probably continue to talk about it for several years to come. I am, however, simply adding my voice to the great chorus of voices from all over the world, representing industry, agriculture, commerce, education, and all who work for the public welfare

Research is the key that unlocks the gates to the unknown and gives us increasing knowledge and mastery of ourselves and our environment

All of the progress that has been made by humanity is the fruit of research, and yet we have only begun to learn how to proceed, and we have only begun to reap the benefits in store

The problems of training investigators and organizing research and getting public understanding of its vital importance and getting financial support for it are among our most pressing social problems of today

President Elect Hoover in his memorable address at Philadelphia before the Society of the Sigma Xi meeting with the American Association for the Advancement of Science, has summed up the general situation most admirably Let me quote a few paragraphs from that address·

"Business and Industry have realized the vivid values of the application of scientific discoveries To further it in twelve years our individual industries have increased their research laboratories from less than 100 to over 500 They are bringing such values that they are increasing monthly Our Federal and State Governments today support great laboratories, research departments, and experimental stations, all devoted to the applications of science to the many problems of industry and agriculture They are one of the great elements in our gigantic strides in national efficiency The results are magnificent "

"We are spending in industry, in government, national and local, probably $200,000,000 a year in search for applications of scientific knowledge, with perhaps 30,000 men engaged in the work

"I should like to emphasize this differentiation a little more to my non-scientific audience Faraday in the pursuit of fundamental law discovered that energy could be transformed into electricity through induction It remained for Edison, Thompson, Balle, Siemens, and many score of others to bring the great line of inventions which applied this discovery from dynamo to electric light, the electric railway, the telegraph, telephone, and a thousand other uses which have brought such blessings to all humanity It was Hertz who made the fundamental discovery that electric waves may traverse the ether It was Marconi and DeForest who transformed this discovery It was Becquerel who discovered the radio activity of certain substances, and Professor and Madam Curie who discovered and isolated radium It was Doctor Kelly who applied these discoveries to the healing art and to industrial service It was Perkins who discovered the colors in coal tar by-products It was German industrial chemists who made the inventions which developed our modern dye industry It was Pasteur who discovered that by the use of analine dyes he could secure differentiation in colors of different cells, and this led to the discovery of bacilli and germs, and it was Koch and Ehrlich who developed from this fundamental discovery the treatment of disease by antitoxins "

"For all the support of pure science research we have depended upon three sources—that the rest of the world would bear this burden of fundamental discovery for us, that Universities would carry it as a by-product of education, and that our men of great benevolence would occasionally endow a Smithsonian or a Carnegie Institution or a Rockefeller Institute Yet the whole sum which we have available to support pure science research is less than $10,000,000 a year, with probably less than 4,000 men engaged in it, most of them dividing their time between it and teaching "

"As a nation we must have this enlargement of stock if we would march foward And the point of application is more liberal appropriations to our National Bureaus for pure science research instead of the confinement, as today, of these undertakings for applied science work And we must have the more liberal support of pure science research in our State universities and other publicly supported institutions "

"A nation with an output of fifty billion annually in commodities which could not be produced but for the discoveries of pure science could well *afford, it would seem, to put back a hundredth of one per cent as an assurance of further progress*

"Nor is the interest of a particular industry confined to the science research which appears on its face to be directly in the line of that industry Practically all industry and all business gains by scientific discovery in any direction The discoveries which led to the invention of the internal-combustion engine and thus to the automobile have benefited every industry and every business in the United States Business and industry have an interest in the common pool of scientific research irrespective of its particular field Those fundamental discoveries of the germ basis of disease, with the load of mortality they have lifted from the race, have lowered the rates of insurance and thus contributed directly to business "

"And there is something beyond monetary returns in all this The progress of civilization, as all clear-thinking historians recognize, depends in large degree upon 'The increase and diffusion of knowledge among men ' Our nation must recognize that its future is not merely a question of applying present-day science to the development of our industries, or to reducing the cost of living, or to eradicating disease and multiplying our harvests, or even to increasing the general diffusion of knowledge We must add to knowledge, both for the intellectual and spiritual satisfaction that comes from widening the range of human understanding and for the direct practical utilization of these fundamental discoveries If we would command the advance of our material, and to a considerable degree of our spiritual life,we must maintain this earnest and organized search for truth I could base this appeal wholly upon moral and spiritual grounds, the unfolding of beauty, the aspiration after knowledge, the ever-widening penetration into the unknown, the discovery of truth, and finally, as Huxley says, 'the inculcation of veracity of thought

> "No greater challenge has been given to the American people since the Great War than that of our scientific men in the demand for greater facilities It is an opportunity to again demonstrate in our government, our business, and our private citizens the recognition of a responsibility to our people and the nation greater than that involved in the production of goods or trading in the market "

In respect to agriculture, Secretary Jardine has repeatedly emphasized the vital importance of fundamental research

In his last message to the Congress our great President, Calvin Coolidge, says

> "I can not too strongly commend, in the field of fact-finding, the research work of the Department of Agriculture and the State experiment stations The Department now receives annually $4,000,000 more for research than in 1921 In addition, the funds paid to the States for experimentation purposes under the Purnell Act constitute an annual increase in Federal payments to State agricultural experiment stations of $2,400,000 over the amount appropriated in 1921 The program of support for research may wisely be continued and expanded "

You will see therefore that our greatest leaders are alive to the need for research and that progress is being made

Here I want to take the opportunity to express my appreciation of the excellent work being done by the National Research Council in bringing about sound organization, coordination, and cooperation in research effort The work of this Highway Board is a good example that might be duplicated in almost every field

Tonight I want to review briefly for you the history of highway research in the Department of Agriculture I am indebted to my good friend Mr MacDonald for the material.

In 1893, when the Fifty-second Congress in its wisdom decided that the time had come to see what could be done to redeem the roads of the country after half a century of neglect, it called upon the Secretary of Agriculture to do four things (1) To make inquiries in regard to the systems of road management throughout the United States, (2) to make investigations in regard to the best method of road making, (3) to prepare publications on these subjects, and (4) to assist the agricultural colleges and experiment stations in disseminating the information obtained

Thus was begun a study of highway administration and construction by the Department of Agriculture, which has continued without cessation until today

How accurately the Congress adjudged the scope and importance of the investigation it then set in motion is indicated by the fact that the sum of money it appropriated for the first year to cover the cost of acquiring the information and publishing and disseminating it after it was acquired, was $10,000.

The Secretary of Agriculture who was thus richly endowed to carry out a research which after thirty-five years still finds some problems to be solved, was a Scotchman In appointing the special agent who in his person comprised the entire force of what is now the Bureau of Public Roads the good Secretary stated that "the work under the appropriation will need to be of gradual growth, conducted at all times economically " At that time there was only one other agency in the entire country that had enlisted in the search for road-building knowledge, that is the Massachusetts Highway Commission, led by the great Dean Shaler

Last year the expenditure for highway research by the Bureau of Public Roads alone was $400,000 Nearly an equal sum was required to support the investigations of the State Highway Departments, and still we have not counted the very substantial outlays by the various experiment stations and colleges Certainly the total expenditure was not far from a million dollars, and if one may judge from the excellence of the modern highways and the efficiency that characterizes their construction the million dollars was well spent

During the thirty-five year period of the Bureau's existence, in which it has grown from a one-man research and extension agency with a $10,000 program to the organization which today carries on efficiently an annual research program involving an expenditure of $400,000, there has been no change in the fundamental purposes of its work During all that time it has been trying to discover the best methods of road management and road making, and what it has found has been faithfully given to the country through its publications and by means of cooperation with the agricultural colleges and experiment stations

Notwithstanding the fact that the purposes of its study have not changed, the nature of the problems with which it has to deal has undergone remarkable alteration In 1893 the rural roads were a problem, but they were distinctly an agricultural and local problem The farmer was the largest and indeed almost the only road user The radius of highway travel was measured by the distance from the farm home to the railroad station or the county seat. The only vehicles were the farmer's buggy and crop wagon The gasoline motor and rubber tire were still beyond the future's horizon

Under these conditions we find the Bureau devoting its energies to the discovery of the methods of road making that would best meet the requirements of horse-drawn traffic, light in volume and weight, and narrowly limited in range—to types of improvement that could be accomplished cheaply and within the limits of cost which the light traffic of the day would justify

We find it experimenting with burnt clay as a surfacing material, studying the possibilities of sand-clay mixtures and developing these possibilities to their utmost usefulness, and passing on the knowledge gained to local road builders in all the States by the construction of object-lesson roads in thousands of localities all over the land We find it very much interested in improving the efficiency of the county and township road authorities, and yet in its first Annual Report it recognized the State Highway Department as probably the best hope for the future

For the roads of heaviest traffic we find the Bureau advocating the Macadam surface—not the careless rock-scattering that passed under the name of McAdam among the local road builders of the day, but a rolled road of two courses, with much emphasis on crown and drainage, and a little later an important rôle in the adaptation of the French tests of quality of rock as regards American requirements, developing where need was found entirely new tests, one of which bears the name of its former director, Mr Page, who was a close personal friend of most of us here tonight

From the earliest days the Bureau has been mindful that the chief end of road improvement is the facilitation of traffic, and so we find that very early it took a serious interest in determining the relative tractive resistance of the various types of surfacing then employed As early as 1896 it had constructed, in cooperation with the University of Tennessee, a recording instrument, which it called a tractograph, for the measurement of tractive power

Perhaps it was the records of this tractograph that led the Bureau to enter upon an investigation of the possibilities of steel roads Perhaps it was brought about simply by observation of the rapid wear of stone roads under the steel-tired wheels of the increased traffic which followed each road improvement At any rate we find that by 1898 it had put its idea to the test of practical experiment, by laying on the outskirts of Cleveland, Ohio, 500 feet of channel-bar trackway set in a macadam surface In the Bureau's report is the statement that "The road is laid in a street on which there is a large amount of heavy traffic and has already demonstrated the great value of steel in road construction "

That may seem a rather radical statement as the result of an investigation so limited in extent and time, but perhaps the Bureau was right, and may be we might all be traveling on steel tracks today had not another group of experimenters, all unknown to the Bureau, hit upon an idea which has made some rather radical changes in the character of vehicles and their tires

We must credit the Bureau at least with one quality which is no less commendable than prophetic vision, and that is the ability to adjust itself promptly to new circumstances and conditions As we turn the pages of successive Annual Reports we find no further mention of steel tracks, but two years later, just at the turn of the century, we find a description of the first experiment with oil

The Bureau had learned a lesson that it has not forgotten. It had discovered that it would be to the mutual advantage of the builders of tracks for vehicles and the builders of vehicles for the tracks to confer rather intimately in regard to their respective plans In the years since the World War especially that idea has borne some very excellent fruit, notably the development of pneumatic tires for trucks and the use of multiple axles on the larger trucks and busses

The Bureau's first experiment with oil was made in 1900 on the Queens Chapel Road in the District of Columbia This road was of earth without surface, and the experimental section, 4,650 feet long, was rounded up and treated to an application of oil in the amount of about a gallon to the square yard over a width varying from 9 to 12 feet The oil used was the residue of crude petroleum after the volatile naptha, kerosene, benzine, and gasoline had been extracted Referring to this test the Bureau's report says "It is claimed by some that the application of crude oil will make a surface impervious to water, and consequently comparatively free from frost and mud If this be the case oil will supersede gravel and stone in the improvement of country roads " Again there was a prophetic strain—but no, they would not be caught in that trap again, for they hasten to add: "The test of time alone can settle this very much-disputed question " And then, rather primly "It is deemed inexpedient, therefore, to discuss this phase of the subject until after the experiment has been tested by traffic, winter and spring rains, freezes, and thaws "

After the first experiment there is no further mention of oil treatments in the Annual Reports until 1905 Perhaps they were waiting for the winter and spring rains to thoroughly prove the first venture, and I rather suspect it was not a tremendous success. At any rate when we next find a reference to the use of a bituminous material it is to be used as a dust layer on a macadam road at Jackson, Tennessee That was in 1905, the year that my friend Dean A. N Johnson came to the Bureau as its chief engineer In the spring and summer of 1906 the experiments were conducted in cooperation with the city engineer of Jackson, Mr W S Keller, the brother of Miss Helen Keller, who as Chief Engineer of the highway department of Alabama, was long prominent as a highway engineer until his untimely death a few years ago

The experiments involved the use of both tars and oils, the latter of three weights—a light crude oil, a medium oil described as a "steamer oil from Texas," and a heavy residue, which was applied hot Seven months after the application of the tar the section so treated is described as still in excellent condition, hard, smooth, and resembling asphalt, except that it has a more gritty surface The light crude oil produced little if any permanent improvement, the steamer oil gave good results, but the best results were obtained with the heavy residue, which produced an entirely dustless road, which could "be cleaned or swept as well as the tarred road," and there was "but little noise, even from horses hoofs "

By this time the Division of Tests had been organized, with a program resembling in many respects the activities of a laboratory of the present day. There were routine tests of rock for macadam roads, of sand, cement, mortar, and concrete, of brick, wood block, tar, asphalt, and oil The laboratory began to standardize the abrasion, impact, and cementation tests for rock, and various tests of asphalt, oils, and tars

I infer that it was at about this time, or in 1905, that the really scientific investigational work of the Bureau began Each year thereafter at least one and in some cases several experimental roads were constructed, in which trials were made of various bituminous materials applied as surface treatments, as surface binders by the penetration method, and a little later by the mixing method—the beginning of bituminous concrete In conjunction with these field trials there was carried on in the laboratory an energetic analysis of the bituminous materials employed, and rapid strides were made in the development and standardization of tests which would indicate the qualities of the various materials and determine their suitability for road-building purposes

The work of this period resulted in the notable series of circulars under the title of "Dust Preventives and Road Binders," in the work under the same title by Mr Prevost Hubbard, and in a series of specifications for the various types of bituminous material, which played so important a rôle in standardizing these materials

The Bureau was now ready to begin the construction of its best-known experimental road on Connecticut Avenue from the Chevy Chase Circle to the Lake The construction was begun in 1911 with the bituminous macadam-sections from the Circle to Bradley Lane, and in 1912 and 1913 was continued with the building of the bituminous concrete, concrete, and brick sections between Bradley Lane and the Lake

This famous experimental road was built at a time when there were only about a million motor vehicles in the entire country At the date of construction the traffic was still preponderantly horse-drawn, and motor trucks, if there were any at all, were exceedingly few and far between This construction has lived to serve a constantly increasing traffic of automobiles and motor trucks to the present day For fifteen years these roads were carefully maintained by the Bureau and a record was kept of every expenditure and of the traffic they carried There is probably no other road anywhere in the word for which there is such a parallel record of cost and traffic covering so long a period Probably also there is no other road that has been studied by so many engineers or any whose behavior has been so closely studied

Following the Connecticut Avenue experiments the Bureau entered upon what may be called the modern period of its experimental work The bridge-slab tests were begun in 1912, the soil pressure tests in 1915, the earlier wear tests in 1919, and the impact experiments in the same year The analysis of sub-grade soils were begun in 1920, the traffic surveys in 1922, and coincidentally there were carried on many lesser tests and experiments, which most of you have followed in the pages of PUBLIC ROADS With these later investigations you are doubtless familiar and I shall not take time to recall them

Supplementing the work of the Bureau in more recent years there is the splendid body of investigational work by numerous other agencies—the State Highway Departments, the experiment stations and colleges, and others, all contributing to the excellence of the State and Federal Aid highways and the more important county roads as they are built today

So obviously fruitful has been this great program of testing and research conducted by all the agencies here represented that it may appear hypercritical to suggest that there has been one serious omission If so I ask you to charge it to a very keen interest in the fortunes and future of the American farmer.

From the time when the Bureau of Public Roads began its experiments with bituminous materials attention has been concentrated rather narrowly on the development of materials and processes which are applicable only upon the main heavily traveled highways, most of which are included in the Federal-aid and State highway systems In these systems there are no more than 300,000 of our 3,000,000 miles of public rural roads It would not be correct to say that the farmer is not interested in these great highways, but there is the evidence of the recent traffic surveys to show that his use of them is a very small percentage of their total utilization Far more than the farmer the city resident and the industries of the cities have benefited from the improvement of these essentially inter-city thoroughfares.

Outside of the main systems there are some 270,000,000 miles of local roads which lead directly to the farms The traffic they carry is not sufficient to support the types of improvement upon which your investigations have mainly been centered These roads are still administered by county and township officials, and I am informed that there are only about 1,700 of the 3,066 counties in which there is any provision whatever for engineering design and supervision and less than 1,000 in which the engineering point of view is adequately represented In nearly two-thirds of the counties of the United States and practically all the townships, in other words, there has been relatively little improvement in methods of road management and construction

It has long seemed to me that you gentlemen could render an exceedingly important service—one of greater importance perhaps than you have yet rendered—if you would devote at least a portion of your time and attention to the solution of the problems of these local roads, and because of that feeling I have been especially interested in the recent experiments with road improvement methods of low cost and in the success of the Bureau in bringing about a rather close cooperation of the various county and municipal authorities concerned with the administration of highways in the Cleveland metropolitan region

A somewhat similar coordination of the resources of groups of the more distinctly rural counties would, it seems to me, bring about a very decided improvement in the efficiency and economy of the local road work, especially if there were also an arrangement whereby the advice and assistance of the State highway departments could be made available

I am especially impressed with the methods of inexpensive road surfacing by the light-oil mixing processes which have been developed experimentally in the West and are now being applied to large mileage of roads in that section. The facts that these methods lend themselves to quantity production with a minimum of working force and mechanical equipment and that the surfaces can be maintained cheaply by means of blade machines makes them especially useful for the improvement of the large mileage of local roads

If I may be permitted the liberty of a suggestion it is this: That there is waiting your attention in this matter of local road construction methods and administration a bigger problem than any you have yet undertaken, one in which there is the opportunity to perform a service of the greatest importance to rural America The successes you have won in the improvement of the main highways inspire confidence that similar success will attend your careful study of this other and perhaps more difficult problem

It is my hope that you will continue the studies already begun and that your efforts in that direction will shortly be crowned with a success commensurate with that which you have attained in your studies of the higher types of construction