MEMORANDUM

TO: W. B. Drake
Assistant State Highway Engineer
Chairman, Kentucky Highway Research Committee

SUBJECT: Research Report, "Weighing Vehicles in Motion;"
KYHPR-61-27, Part II, HPS-HPR-1(26) and
HPR-1(1); CH 12695

The report submitted herewith presents further progress
toward the objectives outlined in my previous transmittal,
dated October 30, 1964. Whereas the previous submission sum­
marized the development of a suitable weighing platform, the
present report provides a vision of a fully-automated, weighing
system. In this sense, it is a prospectus which we plan to
implement in the continuation phase of the study. The work
herein completes the study plan which was mutually agreed upon
for the period beginning October 1, 1964, and ending September

The continuation plan has been approved by the Bureau of
Public Roads under Part II, HPR-1(1). A continuation agreement
is being prepared.

The drawings in the report are intended to be installation
plans. The platform has been fabricated and is ready for
installation in the roadway at the site designated therein. We
are hopeful that the installation can be accomplished in one
work day and that it will be possible to employ District forces
and equipment for the work. We hope to make the installation
before the onset of winter.

Copies of the report are being directed to the Research
Committee and to the Bureau of Public Roads. Comments and
suggestions are invited from all reviewers.

Respectfully submitted,

Jas. H. Havens
Director of Research
Secretary, Kentucky Highway
Research Committee

cc: Research Committee
R. O. Beauchamp
Russell Johnson
September 30, 1965

Mr. J. H. Havens, Director
Division of Research
Department of Highways
CAMPUS

RE: Annual Report
Weighing Vehicles
UKRF 201-05-00704-S3001
HPS-HPR-1(26)
KYHPR-61-27

Dear Jim:

Submitted herewith is the Annual Report on the subject research project. The Report covers project activities during the period October 1, 1964 - September 30, 1965 and is submitted in compliance with Section V of the Agreement between the Kentucky Department of Highways and the University of Kentucky Research Foundation, dated October 1, 1964.

Sincerely,

David K. Blythe, P.E.
Chairman
DKB/1h
ANNUAL REPORT

WEIGHING VEHICLES IN MOTION

CIVIL ENGINEERING DEPARTMENT

UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION

LEXINGTON, KENTUCKY

SEPTEMBER, 1965

SPONSORED BY:

THE KENTUCKY DEPARTMENT OF HIGHWAYS

and

THE BUREAU OF PUBLIC ROADS

United States Department of Commerce

KRF 201-05-00704-S3001
KYHPR -61-27
HPS-HPR -1 (26)
ANNUAL REPORT
Weighing Vehicles in Motion
Civil Engineering Department
University of Kentucky
Lexington, Kentucky

INTRODUCTION

An agreement between the Kentucky Department of Highways and the University of Kentucky Research Foundation dated October 1, 1964 defined the minimum objectives of the subject research project as follows:

A. Developing and furnishing plans for an in-stream transducer system for dynamic axle weighing with manufacturers' specifications for the components required.

B. Constructing and furnishing a scale having an optimum mechanical configuration and which would perform the dynamic axle-weighing function in an overall data-gathering system, as determined in A. above.

This report describes the way in which these objectives were attained by the project staff during the period October 1, 1964 - September 30, 1965. Other activities pertinent to the work are also described.

OBJECTIVE A

The results of previous research (1) and conferences with the Highway Department officials concerned indicated that dynamic weighing needs on Kentucky highways could best be met by an electronic scale of the "broken bridge" type. By a fortunate coincidence one of the developers of the original German broken bridge (2), Dr. Wolfgang Schwaderer, as an ASCE visiting foreign engineer, was on the University campus while the preliminary design of the present version was underway. His advice on the theoretical and practical aspects of the problem was most helpful.

1Blythe, D. K., Professor and Chairman, Civil Engineering Department; Dearinger, J. A., Associate Professor of Civil Engineering; Woodworth, Victur, Electrical Engineer; Cassidy, Robert, Laboratory Technician, University of Kentucky.

2Numbers in parentheses refer to references listed at end of report.
Working drawings and construction specifications for the scale, frames and platform were completed in February, 1965 (see Appendix 1). Emphasized in the design were comparative lightness of weight, ease of access to the load cells and stabilizing mechanism, ease of installation in the highway pavement and elimination of the deep pit used in previous experiments.

Necessary to the proper evaluation and useful operation of the proposed in-stream weighing device was the development of a dependable continuous recorder with an output format suited to further analysis on a high speed digital computer. Since Professor Puckett, our Electrical Engineer, is on leave to study for his Ph.D. Degree, arrangements were made by the University of Kentucky Research Foundation to employ Victor C. Woodworth, from Spindletop Research, Inc. to investigate the types of electronic equipment available and to work with the project staff in selecting a recording system. His investigation was based on the following requirements:

1. The vehicle may have from 2 to 10 axles.
2. The vehicle may travel at speeds as great as 70 mph.
3. Dynamic loads may range from 1,000 to 30,000 lb. per axle.
4. The dynamic measurement load accuracy must be recorded to a precision of ±200 lb. per axle.
5. The speed of the vehicle must be recorded or deduced to an accuracy of ±5 mph.
6. It is desirable to be able to deduce the number of axles per vehicle.
7. It is desirable to be able to deduce the spacing between axles to within ±0.5 ft.
8. It is desirable that the measurement system operate unattended over a 24 hour period with the maximum expected number of vehicle weighings not to exceed 10,000.

After discussions with various manufacturers of electronic gear and conferences with the project staff a system utilizing a multichannel analyzer was recommended. This configuration can be shown in a block diagram as follows:
Block I is already available from the Taller Cooper System used at the I-64 Test Site (1).

Block II is a low cost transitorized circuit which will condition the output signal from the strain guages to a form suitable for triggering the analyzer. This circuit is described by O. D. Sitler in *Review of Scientific Instruments* - Vol. 35, No. 7, pp. 872-74, July, 1964.

Block III is a 400-500 channel analyzer. Manufacturer's literature describing an analyzer of this type is in Appendix 2.

Block IV is a computer-compatible digital tape recorder of the type described in Appendix 2.

Data collected on the tape recorder would be processed through the University of Kentucky Computing Center to determine individual axle weight, gross weight per truck, number of axles, spacing of axles and speed of vehicle. The weights referred to here are the dynamic values as applied to the platform of the scales by a moving vehicle.

It should be noted that this recording system is an on-site installation, designed to be housed in the Bureau of Public Roads Instrument Van already in use at the project. It would be applicable in its presently described form only to a one-scale, one-lane installation. Expansion to a complete four-lane coverage would probably require an analog recorder with a larger data handling capacity. All equipment listed here could be utilized in an expanded system.

The electronic scale and recorder described above and in Appendices 1 and 2 constitute the "in-stream transducer system" required in the statement of Objective A.
OBJECTIVE B

A requisition was written and bids invited in early March, 1965 for the fabrication of the scale platform and frames. Certain small items were requisitioned separately or were built in the College of Engineering Machine Shop. The completed scale was assembled at the University in early August, 1965. Further machining of some critical parts and a few minor design changes have been completed and the scale is now ready for installation. Various views of the finished scale are shown in Figures 1, 2, 3, 4, and 5.

Other Activities

Additional staff activities during the period included the following:


(2) Presentation of the paper, "Variations in Axle Weights of Moving Trucks" at the May, 1965 meeting of the Society of Automotive Engineers.

(3) A visit to the Electronic Scale Test Site of the Michigan State Highway Department near Jackson, Michigan - a continuation of the cooperative exchange of ideas on dynamic weighing that began in 1961.

(4) A visit to the Railweight Office of the International Railroads Weighing Corporation in Northfield, Illinois and a conference (on the U. K. campus) with representatives of the Toledo Scale Company concerning commercial developments in the field.

Recommendations for Further Research

It is recommended that the project be continued and that funds be made available for accomplishing the following work during the period October 1, 1965 - September 30, 1966:

(1) After preliminary systems testing and calibration, institute a comprehensive data collection program designed to evaluate this platform as an in-stream dynamic scale. In order to do this the following will be necessary:
Figure 1 - Component Parts - Broken Bridge Dynamic Scale
Figure 2 - Two-Piece Platform (less covers) and Stabilizing Springs
Figure 5 - Detail - Hinged Connection Along Contiguous Edges of Two-piece Platform
(a) Install the new broken bridge scale in the outside east bound lane of Interstate Highway 64 at a point just east of the Bryan Station Road overpass near Lexington, Kentucky. This site provides good sight distances on a long, nearly level tangent and permits the instrument van and operating personnel to be hidden (by the abutment fill for the overpass bridge) from approaching traffic. Details of the proposed site are shown in Figures 6, 7, 8 and 9. Site layout and construction plans for the scale installation are in Appendix 3.

(b) Procure, assemble, test and install the above recommended recording system.

(c) Develop and test a data analysis program suitable to the input requirements of available digital computers and to the output desired by the operational units of the Kentucky Department of Highways.
Figure 7 - Close-up - Proposed Test Site, showing Scale Location;
Approximate Station - 335 + 12
Figure 8 - Approach To Proposed Test Site.
References


2. W. Schwaderer and W. Reimund, "Die Automatische Achlastwaage bei Grunbach", (Remstal), Strasse Und Autobahn, 1959 pages 41-47
BROKEN BRIDGE DYNAMIC SCALE
UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION
KENTUCKY DEPARTMENT OF HIGHWAYS
U. S. BUREAU OF PUBLIC ROADS
### Bill of Materials

**Broken Bridge Dynamic Scale**

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<th>MATERIAL</th>
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**Sheet 5 of 14**

**FINISHED BY**

**CHECKED BY**

**Date**

**2/10**
PLATFORM & FRAMES

BROKEN BRIDGE DYNAMIC SCALE

-SECTION-

PLATFORM & FRAMES

Note: "Pay to be Gravity Drained" drawn to standard side of highway.
APPENDIX II
Models 115 and 116 400-Channel Analyzers

Versatile new Multichannel Analyzers whose basic design has been tested and refined in over 500 instruments now at work in the world's leading research laboratories.

The kind of information obtainable from nuclear radiation detectors is largely determined by the electronic instruments used in conjunction with these detectors. With a single-channel analyzer, counts can be accumulated in a given energy range, and a complete energy spectrum can be built up by storing counts in successive ranges. Such a procedure requires many operations and the time taken may be prohibitively long, especially in the case of short-lived isotopes. Alternatively, a continuous scanning spectrometer may be used to sweep the position of each channel and give a record of the entire energy spectrum on a paper chart in one single operation. Here again, however, only a small percentage of the information available from the detector is obtained by this method, because the instrument is sensitive only to pulses lying in one small energy range at any given time.

With Packard Models 115 and 116 400-Channel Analyzers, pulses lying in 400 energy levels are simultaneously accumulated in a magnetic ferrite core memory. The stored spectra can be viewed on the built-in oscilloscope both during and after accumulation. Data in the memory can be read out manually or fed automatically to a printer or a recorder for more detailed study.

The circuitry of Models 115 and 116 Analyzers is fully transistorized and utilizes plug-in etched circuit boards. Some of the advantages of this design and construction include:

- Small size and weight
- Low power consumption
- Minimum heating with resultant longer-lived components
- Excellent reliability
- Ease of servicing by replacing easily accessible plug-in circuit boards

Packard Analyzers are an essential tool in any nuclear laboratory. Their versatile operation and modern design combine to provide what is, in effect, a "nuclear oscilloscope."

Principles of Operation

In an analog-to-digital converter, each pulse amplitude (or "energy") is converted into an equivalent time interval. The number of pulses (N) from a periodic oscillator which occur during this interval are counted by a scaler (Address Register). This gives a quantified digital measure of the amplitude of the input signal. The final position of this scaler or "address" identifies the channel (N) in which the pulse is stored in the magnetic core memory. In Model 115, each channel can store up to 10^5 counts. Model 116 allows storage of up to 10^6 counts in each channel. The contents of the memory can be viewed on the built-in oscilloscope, and may be read out on an external printer or recorder.
General Specifications

Analyzer

Number of Channels: 400
 Memory Type: Finite core
 Memory Capacity:
 Model 115: 10³ counts per channel
 Model 116: 10³ counts per channel
 Technology: 26 plug-in printed circuit boards, fully transistorized
 Temperature range: 50°F to 110°F ambient
 Long Term Stability: Less than 1 channel drift over 24 hours
 Zero Drift: Less than 0.4% of full scale per 20°F + Less than 0.3% of full scale per 10°F line change
 Gain Shift: Less than 0.5% change in the number of channels between two peaks per 20°F + Less than 0.2% change in the number of channels between two peaks per 10°F line change

Gain Shift: 
Less than ±0.25% over the top 98% of the range
 Differential Linearity: 
Better than ±2% over the top 98% of the range

Maximum counting rate: Less than 0.4% of full scale shift of last pulses injected at photomultiplier anode of 5 x 10⁶ pulses per sec. of 0.5-50 with 1.6 mev full scale

Live Timer Accuracy: Better than ±0.5% overall up to 50,000 cps

Power Failure Protection: Transistor sensing circuits protect against loss of data in memory in event of power failure.

D.C. Signal Input Characteristics
Input used for slowly-varying negative signals with amplitude not exceeding 5 volts maximum — to be sampled by an external time base generator (Model 51).

Conversion gain: 8. 6. 4. 2 and 1 volt/100 channels

Conversion time: Address selection by 4 mc pulses driven from 8 mc crystal oscillator

Upper Level Adjustment: 
0.2 to 10 volts by 10 turn helical potentiometer. (This adjustment permits rejection of pulses with energies higher than the region of interest, thus eliminating off-time caused by such pulses. The adjustment is useful for observation of low energy areas of spectra during high counting rates)

Threshold (Channel Zero) Adjustment: 
0 to 8 volts by a 10 turn helical potentiometer. (This adjustment shifts the origin of the energy scale and permits a detailed examination of the high energy region of a spectrum without overburdening the Analyzer with the dead times associated with low energy pulses)

Lower Level Adjustment: 
0.15 to 8.0 volts by means of a 10 turn helical potentiometer. (This adjustment eliminates pulses lower than the selected level, and the off-time due to these pulses without shifting the origin)

Converter blocking input: 
External positive pulses greater than 8 volts

Prompt coincidence (anticoincidence) input: 
External negative (positive) pulses greater than 8 volts

Delayed coincidence (anticoincidence) input: 
External negative (positive) pulses greater than 8 volts

Dead Time

12 × 10⁻¹ sec: read-write memory cycle
4.9 × 10⁻¹ sec: linearization circuit
4 × 10⁻¹ sec for channel number 1
Average dead-time meter reads 2 × 10⁻¹ sec dead time

General Features

Automatic Live Timer and Programming

Two mechanical registers, both driven by the same quartz oscillator, give preset storage and stop times which can be adjusted from 0 to 1,000 minutes in 0.1 minute steps.

Preset time can be true time or live time. With live time all dead times are automatically subtracted from the true elapsed time.

Preset Count Control

In addition to controlling the experiment on a preset time basis, a preset count facility is included in Models 115 and 116 Analyzers. The number of counts may be preset at 1,000, 2,000, 4,000, 8,000, 10,000, 20,000, 40,000, 80,000, (Model 115) and, additionally, for Model 116, at 100,000, 200,000, 400,000, and 800,000 counts.

This control permits the experimenter to utilize (a) any of the channels associated with the experiment as the controlling function,
TROTT ELECTRONICS, ROCHESTER, NEW YORK
INCREMENTAL MAGNETIC TAPE SUBSYSTEM

This subsystem accepts digital data in BCD code from counters, digital voltmeters, and other parallel data sources and drives a Precision Instruments 1107A Incremental Magnetic Tape Recorder. Operating at speeds up to 300 characters per second, data is recorded in IBM format with packing density of 556 bits per inch.
APPENDIX III
### Bill of Reinforcement

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</tr>
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<td>100%</td>
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### Pit Details

**Broken Bridge Dynamic Scale**

UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION
KY DEPARTMENT OF HIGHWAYS

Date: 9-20-68

Designed by: 999-9999

Checked by: 999-9999

Approved by: 999-9999

Sheet 2 of 6

Drawn by: 999-9999