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Application of Sensors for Design Improvements

Mansour A. Ahmadshahi
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ABSTRACT

An In-Vehicle Data Acquisition/Monitoring Device (Data Logger) has been developed to be used for evaluating the performance of alternators during vehicle operation. It can be linked to other controllers and electronic devices for exchange of information through the use of a serial communication port. By utilizing a microcontroller, eight analog and three TTL level signals are measured and recorded in non-volatile EEPROM memory devices. The system measures temperatures of critical components, system voltage and rotational speed.

INTRODUCTION

Design engineers are often faced with the question "what are the field operating conditions under which their design is expected to last?" Such vital information can be used to improve and optimize their designs. Failure analysis engineers are also troubled with the lack of information in what led to the final catastrophic failure. More often than not, there are insufficient clues to accurately determine the sequence of events which caused the final catastrophic failure. In both cases, a data logger may be used to record and store digital data to be used for future analysis. A similar device has been used for years aboard commercial jetliners and is commonly referred to as the black box.

IN-VEHICLE DATA ACQUISITION/MONITORING DEVICE (DATA LOGGER)

A microcontroller-based In-Vehicle Data Acquisition/ Monitoring Device referred to as the data logger has been developed to record and store digital data to be used to evaluate the performance of alternators in real-world conditions. Furthermore, the device is capable of transferring digital data, through the use of a serial communication port, to other various controllers and electronic devices aboard the vehicle. By utilizing a microcontroller, eight analog and three TTL level signals are measured and recorded in non-volatile EEPROM memory devices. The system contains thermistor sensors which are used to measure bearings, stators, and ambient air temperatures. Rotational speed of alternator is also measured by sensing the phase terminal which outputs an AC signal whose frequency is proportional to the RPM of alternator. The system is capable of determining the vehicle engine RPM assuming there is no belt slippage between alternator and drive pulleys. Alternatively, the system can compare alternator and engine RPM and generate a warning signal to the vehicle indicating excessive belt slippage.

Hardware Design - The device uses a 8-bit microcontroller which contains an analog-to-digital converter to digitize the signals generated by various negative temperature coefficient (NTC) thermistors. In order to improve the level of accuracy, these thermistors are in direct contact with the surface of components whose temperatures are to be measured, such as the outer raceway of a rolling bearing. The resistance of a NTC thermistor is inversely proportional to its temperature and when used in a voltage divider circuit the voltage across the thermistor is proportional to its temperature which is subsequently measured by the microcontroller and recorded in the EEPROM memory devices. There are 8 such memory devices in the system which are used to store the data obtained and processed by the microcontroller throughout the operating time of alternator. There are 3 TTL level input lines which are used to measure periods of periodic waveforms. Similar to the analog input lines, the voltage at the phase terminal is fed to a voltage divider and the voltage across one of the resistors is input to the microcontroller. The system is capable of detecting the rising and/or falling edges of the corresponding waveform which is used to determine the period and subsequently the frequency of the signal. Since the AC voltage across the phase terminal of alternator is related to the rotational speed, the measured frequency of the waveform is in direct proportion to alternator RPM. Since there are 3 such input lines, the frequency of 3 such signals can be detected and analyzed. For example, if one of the input lines is connected to a signal proportional to engine RPM, its frequency can be measured and compared to that of alternator's. In case of mismatch, a warning signal can be generated to indicate possible belt slippage. Consequently, if one assumes there is no belt slippage, engine RPM can be determined from the ratio between the drive and driven pulleys. There is a standard 9-pin D-connector available in this system which can be used to transmit and/or receive data (parameters such as alternator/engine RPM, under-the-hood temperature, alternator voltage, etc.) between alternator and a master processor (for example, vehicle central processor) through the use of asynchronous Serial Communication Interface (SCI). The same connector is used to download and/or upload data to the 8 EEPROM memory devices using synchronous Serial Peripheral Interface (SPI). This port is modularized so that it can be connected to PC's and Laptops.

Software Design - There are all together 11 input lines which are used to measure waveform and frequencies of external signals. Eight input lines are connected to A/D converter with a sampling rate of 31.25 kHz and are multiplexed into 8 input channels of the microcontroller. The signals are contaminated by noise and require further processing before they can be analyzed. Lowpass digital filters are applied to the signals to remove random noise and improve signal to noise ratio. In the case of the waveform frequency, bandpass digital filters are implemented in the software to eliminate spurious frequencies generated by circuit noise. The software also uses smart algorithms which are based on physical and mechanical principles in order to eliminate deterministic noise in the signals. Finally, the software uses a 2-wire I^2C protocol to communicate with the 8 EEPROM memory devices. Other protocols such as SAE J1850 or CAN are adaptable to the system as a mean for information exchange.

Special Features - The software has been designed to transmit real-time data to an external device such as a personal computer or a laptop. Various temperatures, alternator RPM, and system voltage can be viewed in a real-time bar graph on a monitor. This is quite beneficial during sensor calibration and/or alternator diagnostics. The software is also monitoring over-voltage levels and time of occurrence, which are both stored in the internal EEPROM of the microcontroller. Total operating time of the alternator is also stored in the internal EEPROM of the microcontroller. These data are also downloaded to a personal computer or a laptop for future analysis.

<u>Application</u> - A 24V/400A alternator manufactured by C. E. Niehoff & Co. equipped with a data logger was installed in a transit bus. Five NTC thermistors were embedded in the alternator and connected to five corresponding analog input lines of the data logger to obtain the temperatures of ambient air, front and rear bearings, and front and rear stators. the output of the phase terminal of the associated regulator was fed to one of the TTL level input lines to obtain the alternator RPM. Finally, the energize terminal of the regulator was connected to the sixth analog input line to record and monitor the system voltage. The data logger was programmed such that the sampling rate was set to 7.5 minutes. In this manner 6 of the EEPROMS, each containing 8192 memory locations, could store the temperatures and the alternator voltage for 1024 hrs. The remaining 2 EEPROMS stored the alternator RPM during the same time. The stored data was downloaded to a Laptop after 654 hours. Figure 1 shows the profile of the ambient air temperature stored during 500 hours of operation. Figures 2 and 3 show the distributions of ambient air temperature and alternator RPM. Figure 4 shows the profile of the alternator voltage during the 500 hours of operation.

Temperature and rpm are two important parameters which are used to determine bearing life. The distribution (duty cycle) of bearing temperature and alternator rpm provided by the data logger is being used to more accurately estimate bearing life. The distribution of ambient temperature and alternator rpm obtained from the data logger will also be used in determining conditions for in-house endurance tests.

An interesting revelation from the downloaded data of the data logger has been that different applications such as coach and transit have different effects on alternator performance. For example, the rpm distribution obtained from the data logger is used to determine whether the alternator was used in a coach application where the average rpm is high or transit application where the engine is mostly in idle conditions. Different applications and their effects on alternator life may help constitute new or refine old warranty issues of value to the marketing of future products.

CONCLUSION

A microcontroller-based In-Vehicle Data Acquisition/ Monitoring Device (Data Logger) has been developed to record and store digital data to be used for evaluation of performance of alternators during field operation. A 24V/400A alternator manufactured by C. E. Niehoff & Co. equipped with such a data logger was installed in a commercial transit bus. The data logger obtained the temperatures of ambient air, front and rear bearings, and front and rear stators. It also recorded and stored the alternator voltage and RPM for a total of 640 hrs of operation. Some of the results are depicted in Figures 1 through 4. These results are used by design engineers to better understand the field conditions and consequently improve their designs. Furthermore, the data logger has a serial communication port which may be connected to various other controllers and electronic devices aboard the vehicle for exchange of information.

ACKNOWLEDGMENTS

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assistance of Mr. Manny Binyamin and Roberto Ceron is greatly appreciated.

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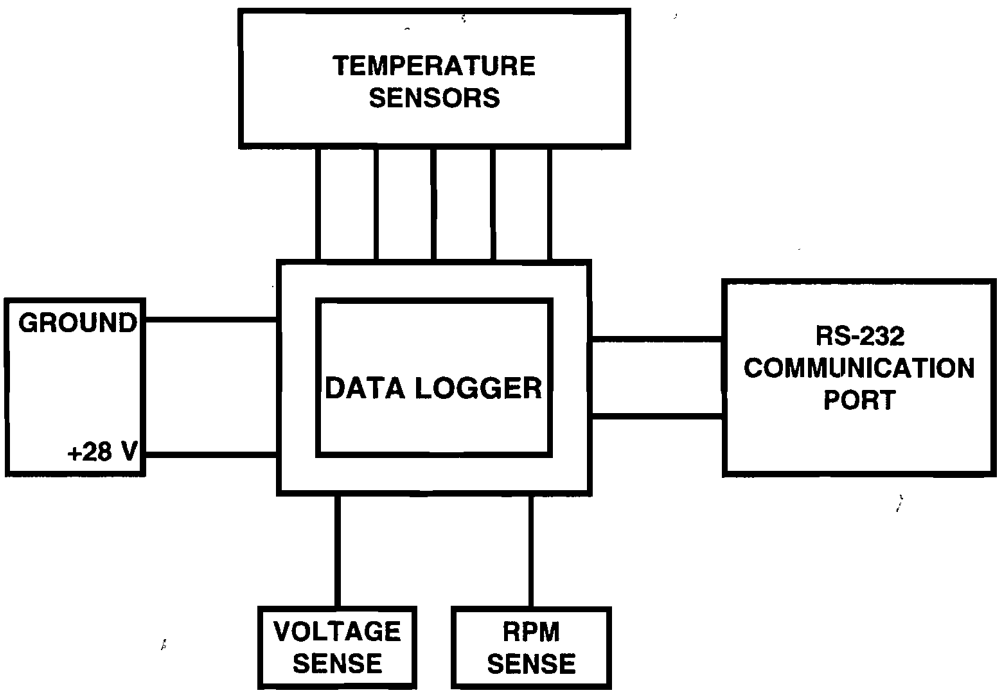
1. Motorola, HC11 Reference Manual.
2. Motorola, HC11 Technical Data.



BLOCK DIAGRAM OF DATA LOGGER

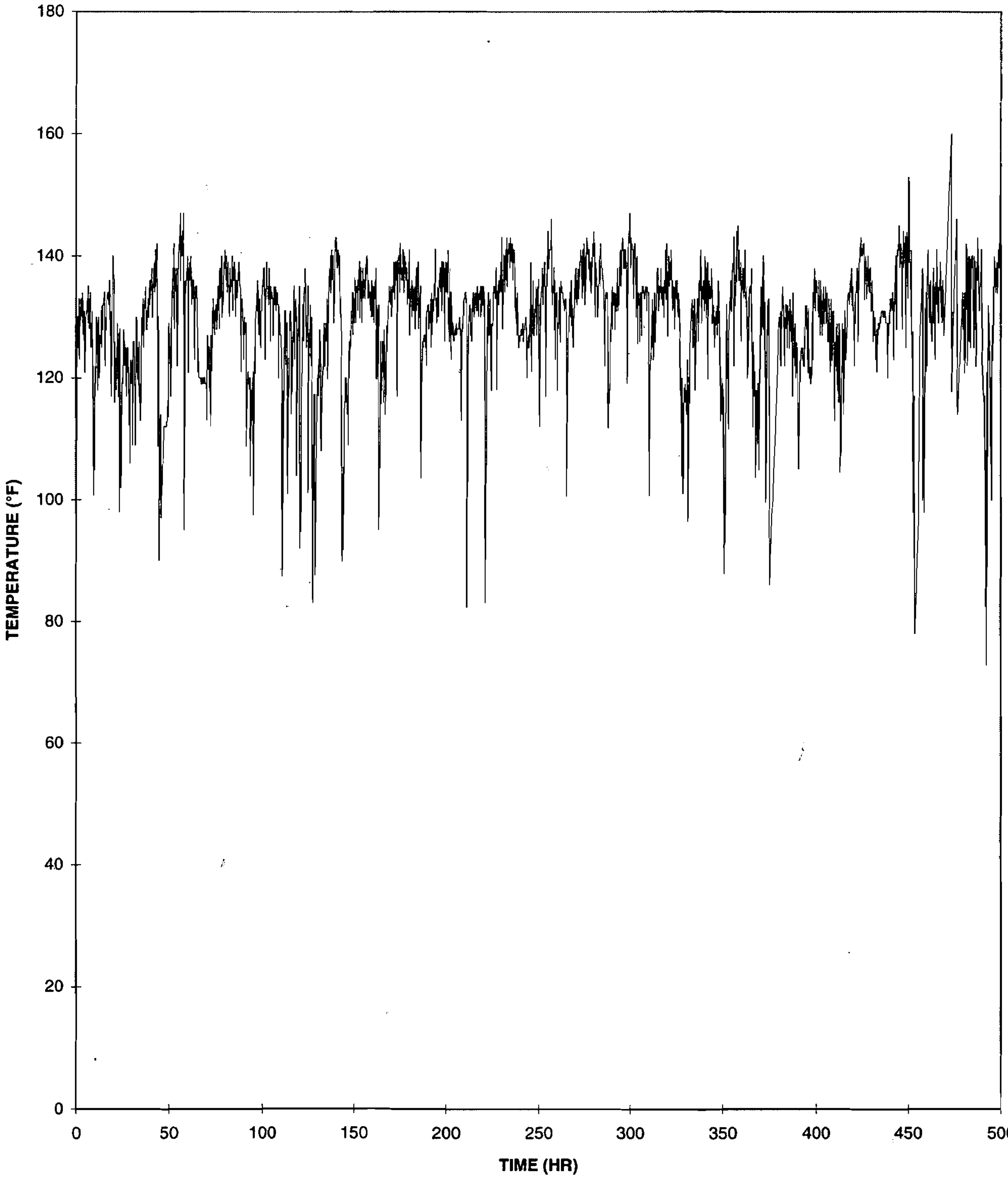


Figure 1. Ambient Air Temperature During 500 Hours of Operation.

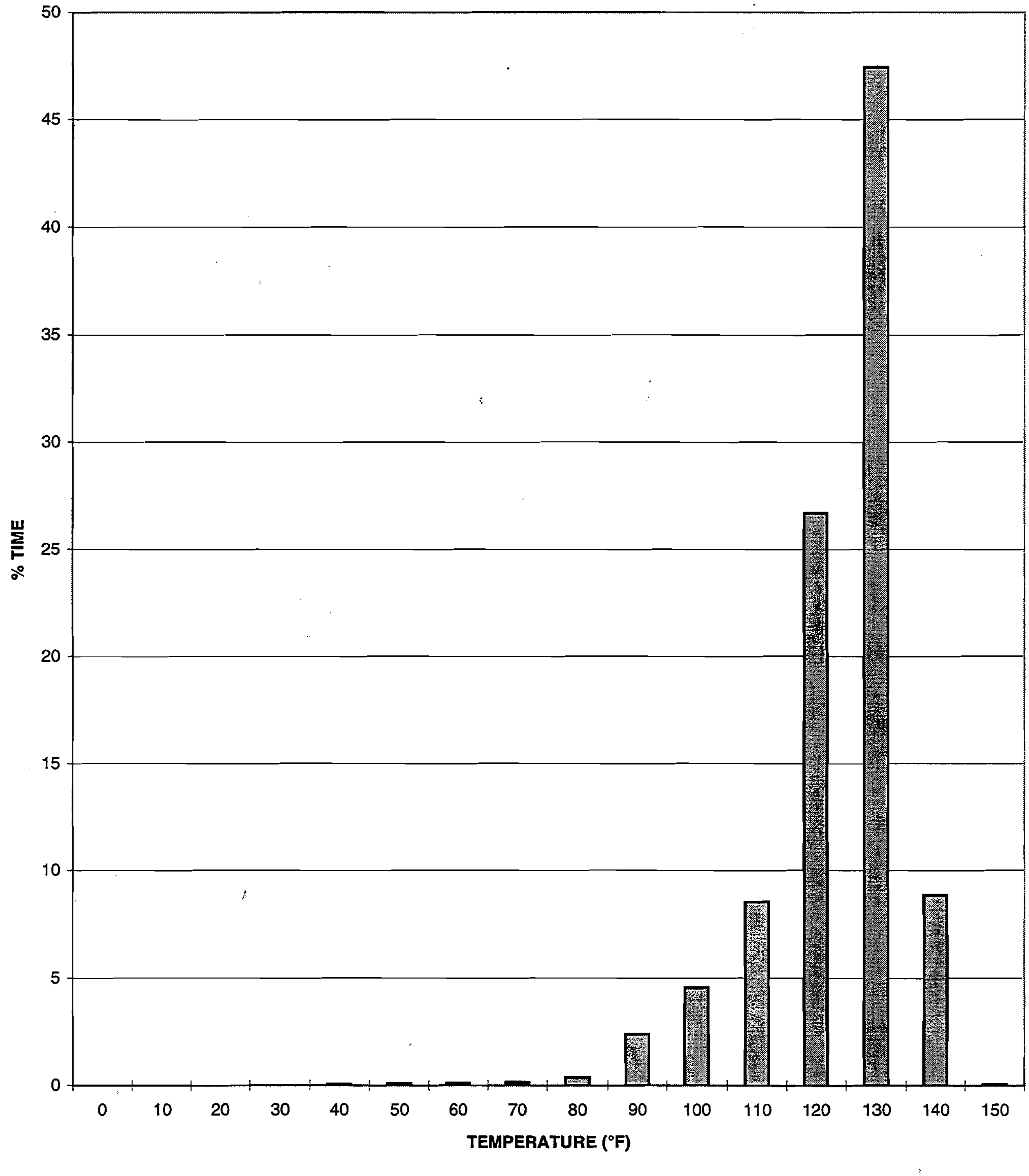


Figure 2. Distribution of Ambient Air Temperature During 500 Hours of Operation

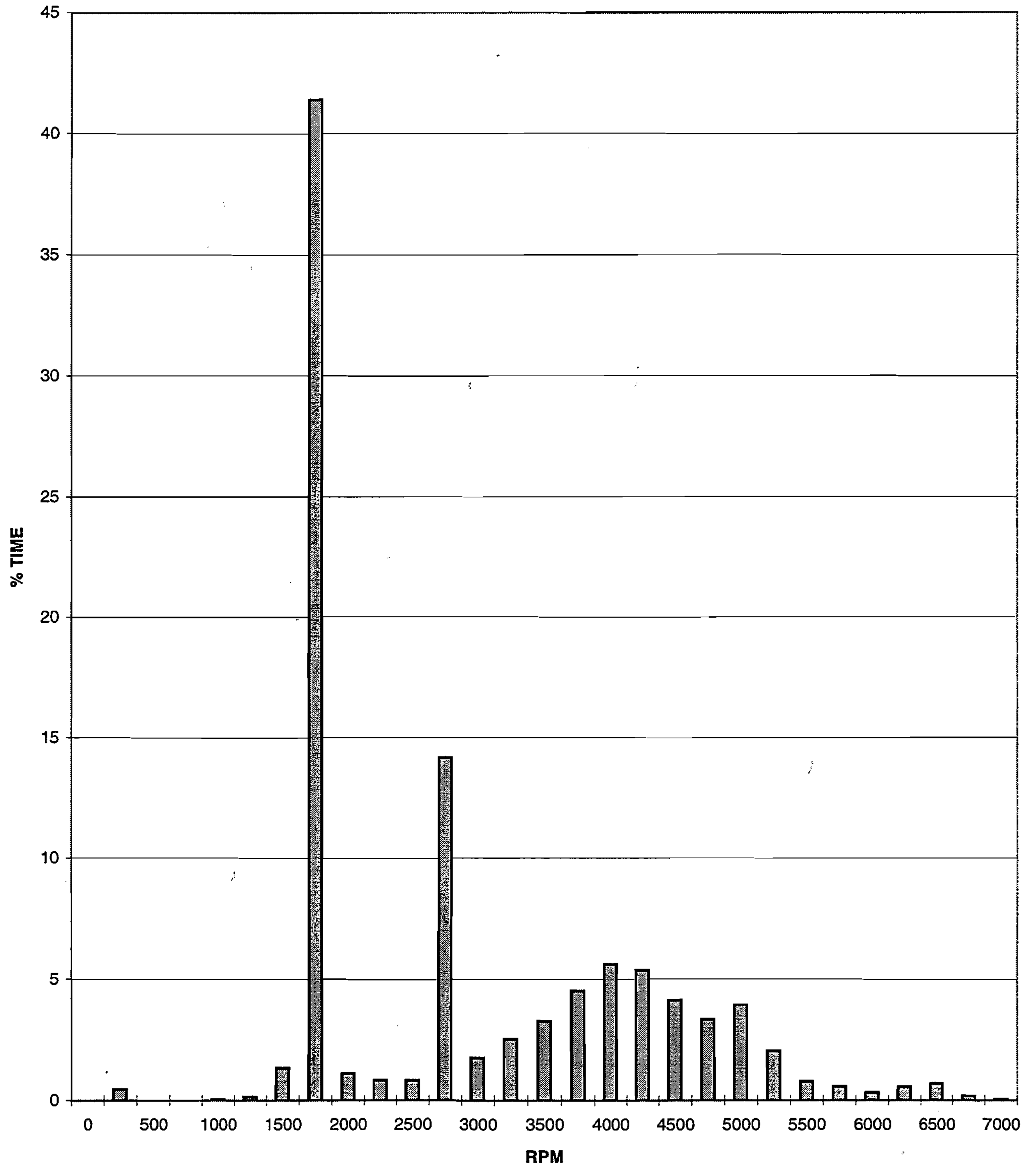


Figure 3. Distribution of Alternator RPM During 500 Hours of Operation

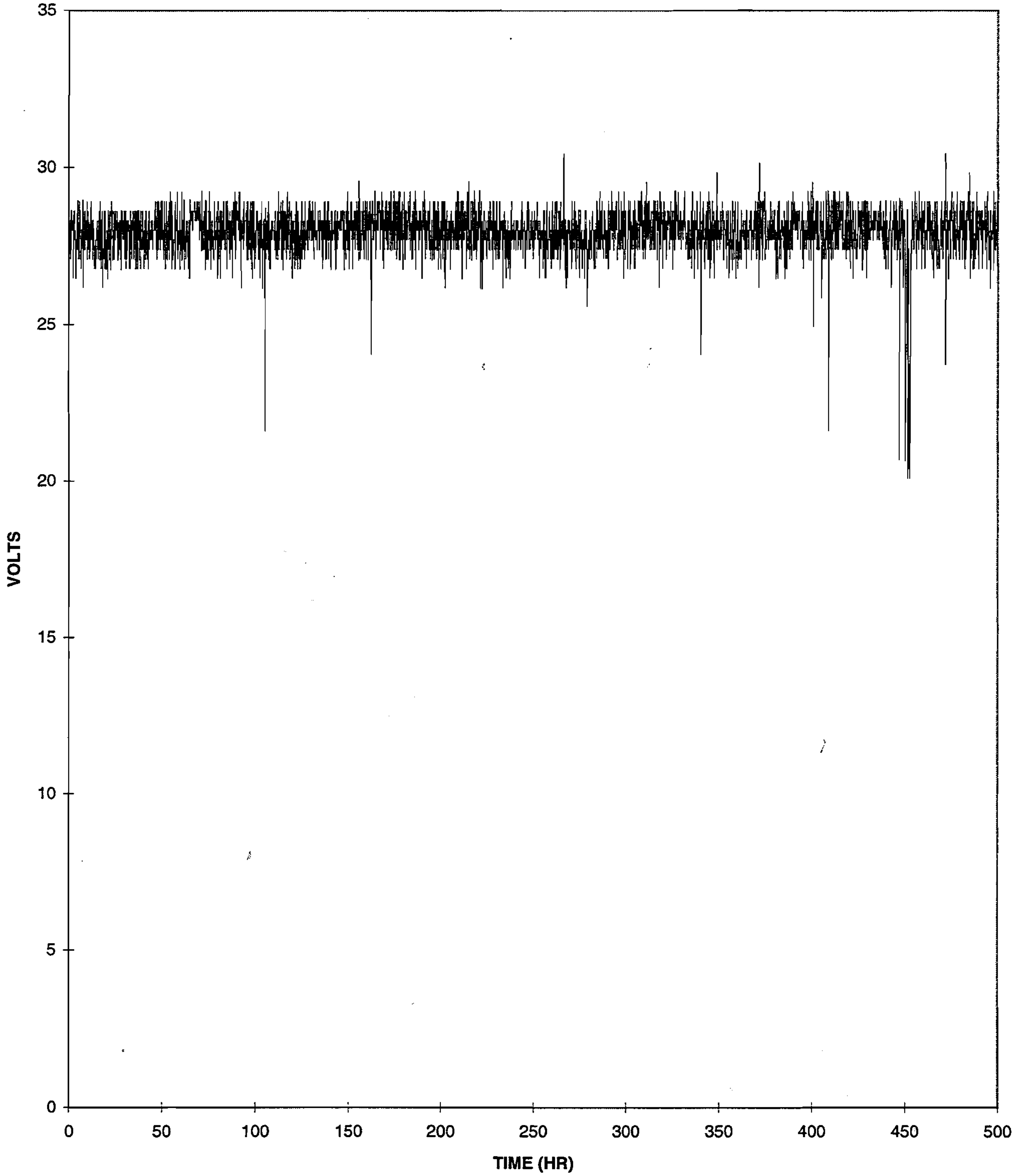


Figure 4. System Voltage During 500 Hours of Operation.