2008

Air Compressor Systems for Passenger Rail Applications

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Abstract

Passenger transit rail systems rely on compressed air for brake and suspension systems. These applications pose design challenges for the compressor system not usually faced by industrial applications. The air supply is packaged as a self-contained system generally containing a compressor, electric drive motor, air dryer system, and controls.

The air system supplier initially furnishes the system to a car builder under contract to a transit authority. Both the car builder and the transit authorities publish specifications for package size, materials, and workmanship constraints making each compressor system custom designed for the application.

General trends in the industry include the extension of overhaul and maintenance on the air system. In order to meet these new requirements, it was necessary to determine exactly how these systems operate in the field in terms of running time and cycle rate. To this end, air supply systems were instrumented with simple logging systems to monitor compressor operation. A summary from field studies from various locations is presented.

1. Introduction

Passenger rail systems rely on compressed air for brake and suspension systems. The friction brake systems are similar to those initiated by George Westinghouse over a century ago. Although some smaller systems use hydraulic systems, compressed air is the most common system. One of the major advantages stems from the unlimited fluid supply available in the event of system leaks.

Compressed air comes from a packaged air system consisting of an air compressor, electric drive motor, control system, adsorption air dryer system all attached to a frame system with the entire package designed for simple replacement in maintenance facilities. A large main air reservoir holds the compressed air needed by the various subsystems on the passenger cars that include not only the friction brake system, but also suspension systems as well as the door operation. A transit train usually consists of several mated cars the number depending upon the needs of the transit authority. In the interest of safety, redundant compressors are employed on each train.

When designing the air compressor system, a manufacturer considers many factors including vibration, noise, air volume, operating environment, debris damage, car builder and transit authority specifications. On top of these, the system must meet maintainability and reliability objectives set by customers. Design engineers will assume operating information, such as ambient conditions and duty cycle, the percentage of time a compressor runs in any given period, for reliable equipment.

Ambient conditions are reasonably well known based upon the geographical location the equipment will serve. Design criteria for temperature and humidity will frequently be included in the technical specification published by either the car builder or the transit authority operating the equipment. If not that information is readily available in climatological data.

Design engineers estimate duty cycle based on the calculated usage for all pneumatic equipment plus leakage. Engineers calculate the air requirements for the brake system, secondary pneumatic systems, such as air springs and doors, account for air leakage rates and apply these in simulated train runs based on speeds and distance between stations. Determination of the number and size of the air compressors on a train is based on a number of factors, including compressor duty cycle. A train consists of several cars depending upon the needs of the transit authority managing the system. In the interest of safety, redundant compressors occur on each train. By interconnecting the pneumatic lines across cars, air is shared as needed between cars assuring the train remains in service until the inoperative compressor can be serviced.

Each compressor is equipped with an independent control system to maintain pressure in a main supply reservoir by running the air compressor as needed. Depending upon the design of the train, the individual air compressors may operate autonomously, synchronized so all will operate at the same time, or in some form of a rotating selection of air compressor to even operating time among all air systems on the train. Autonomous control is by use of a two-position pressure switch that closes contacts at, or below, some set pressure and opens these contacts at a higher pressure. Common values in the United States are between 130 and 150 psig. These values ensure air system pressure above the 100 psig needed to actuate the braking system.

Rating of air compressor systems is for continuous service, as designed, they will generally see far less. A common engineering assumption is to the system will see a 50% duty cycle over the course of a service day. This assumption influences selection of compressor components as well as recommended maintenance and inspection intervals. The transportation industry trend is to extend major and minor overhauls on equipment.

2. Synchronization Operation

Synchronization will be the first method considered. For this system, each compressor on the train includes a pressure switch and circuitry to operate autonomously. In addition, another compressor on the train can also generate the run signal and that will control the entire car. For these trains the compressor with the highest set pressure will trigger all compressors on the train to run. This control system is common and as a rule will even out the operation time of all compressors on the train. At the same time, this system produces shorter run times for each compressor.

3. Autonomous Operation

The second method, strictly autonomous operation, does have drawbacks. In operation one compressor, the one with the highest reset pressure begins operation first. Depending on the ability of this compressor to satisfy the required air load and the reset pressures of the remaining compressors, this scheme can lead to one compressor accumulating significantly more hours than the remaining compressors on the train. Premature wear on this one compressor can occur well before the expected calendar time to overhaul. Excessive wear can cause disproportionate oil consumption, loading the oil separators included on the compressor unit or air dryer. Excessive oil in these components leads to loading of the desiccant packs and decreases air quality for the car systems.

4. Network Selection

The final method monitored employs the use of a car wide computer network to control the air system. In this system, the compressor maintains autonomous controls with a pressure switch, but now includes a signal line not unlike the synchronization line; only the compressors are not interconnected. The car network monitors pressure transducers in the main reservoirs. At the set pressure, established slightly above the internal pressure switch value, the car network starts one compressor, designated the master. The master compressor supplies air demands for the train for twenty-minute after which another compressor is designated the master. The network also designates an alternate compressor as the slave and operates if the master cannot meet the air requirements. This sequencing evens out individual compressor operation times, while increasing each average on cycle time. The compressors run for about the same total time, but each run cycle is longer.

5. Field Results

One simple, effective method to acquire operating time and duty cycle is to install a simple two-stage data system to log the date and time each time the control either starts or stops the compressor. The loggers chosen were small enough to fit into the control box sizes used across several transit authorities. In addition, they have the ability to fill non-volatile memory then stop collection to protect the data. This is important, as the trains may not be available in a maintenance facility to transfer data from the logger on anything less than a 30-day inspection cycle.

This paper examines data collected from the three different control methods referred to above. It is important to remember that the data comes from either different locations, or different car classes running on different lines and routes. We can infer generalities from the data, but need to exercise care with comparisons. The data displayed here is from different localities, car designs and seasons.

Data visualization is perhaps one of the most difficult tasks for the analyst. We first viewed the data using histograms, but found the desired detail was not apparent. Selection of a 2D histogram presentation is by far the easiest visual method to begin to see trends in the data. For these displays, we grouped the data by hour, based on a twenty-four hour clock, and created run time histograms for each hour. It then becomes easier to separate revenue service time from layover time in one of the marshalling yards. Run time, in all cases, is in minutes.

Due to the simple collection method, sometimes long run times may erroneous. The compressor requires both a low voltage control circuit and a high voltage power circuit for operation. In a marshalling yard, the low voltage circuit may be active when there is no high voltage available to power the compressor. In these cases, the compressor control may call for operation, but the unit does not have the high voltage necessary to run.

One of the first interesting observations drawn is the run time histogram of the compressor does not vary greatly between revenue service and yard layover. What does change is the down time between starts. During revenue service the off or rest time is diminished as the train air requirements increase.

In the data are displays, all the data are shown. When the run time exceeds the highest bin value, it is counted and the time recorded under the moniker ‘more’. In this approach, all data are displayed for review.

5.1. Synchronization Operation

When the compressors operate in a synchronous mode, there is no need to monitor all compressors on the train. One data logger gives all the information available for the operation. Initial deployments verified this by monitoring all three units to verify all ran concurrently. Figure 1 displays data collected from two deployments of the data logger.

In figure 1, several run times, exceeding 1 hour, we attribute to lack of high voltage in marshalling yard, and were not included within the duty cycle determining. For the first deployment, the duty cycle was 13% while the second was 5% with a combined average of 7%.

5.2. Autonomous Operation

In the autonomous mode, all compressors on the train need monitoring. Figures 2 through 4 show the data collected from three compressors on one train. It is obvious that the first compressor is supplying most of the air requirements for the train. The second and third units only run when the first cannot keep up with the air demands. The running time mode of the first compressor was about three and a half minutes, while the next one was closer to one minute.

The duty cycle determination of these compressors was 74%, 22%, and 11% respectively. From the data, in most cases the first compressor will handle the load only requiring the second about one third of the time and the final compressor only about one seventh. During one maintenance cycle, the first unit will exceed the recommended hours while the second and third units will still be under the recommended maintenance time.

5.3. Network Selection

In the case of car network selection, we again monitor all compressors on the train to compare operation. Figures 4 and 5 are two displays from one train controlling the compressors using a car network collected from the same deployment. For these computers it seems the compressor run times are longer but with a duty cycle of 7-8%, do not exceed those of synchronous operation. The advantage of this type of operation is a reduced number of starts on each compressor.

5.4. Comparison

Similarities appear between the autonomous and selection run time modes. Both are longer durations than the synchromous, which we expect as fewer compressors are trying to satisfy the air demand. The key difference lies in the total time accumulated by any one compressor. Since one compressor in autonomous operation provides most of the air, it accumulates most of the time.

CONCLUSIONS

Either synchronized operation or some form of load leveling such as computer network assignment leads to more uniform run time on the compressors. It will be easier to schedule maintenance and overhaul to best maximize use of consumables and extend the overhaul cycle.

The common assumption that the passenger rail air compressors operate at a 50% duty cycle through out the day appears to be overly pessimistic with a more reasonable estimate might be 15 to 25%.

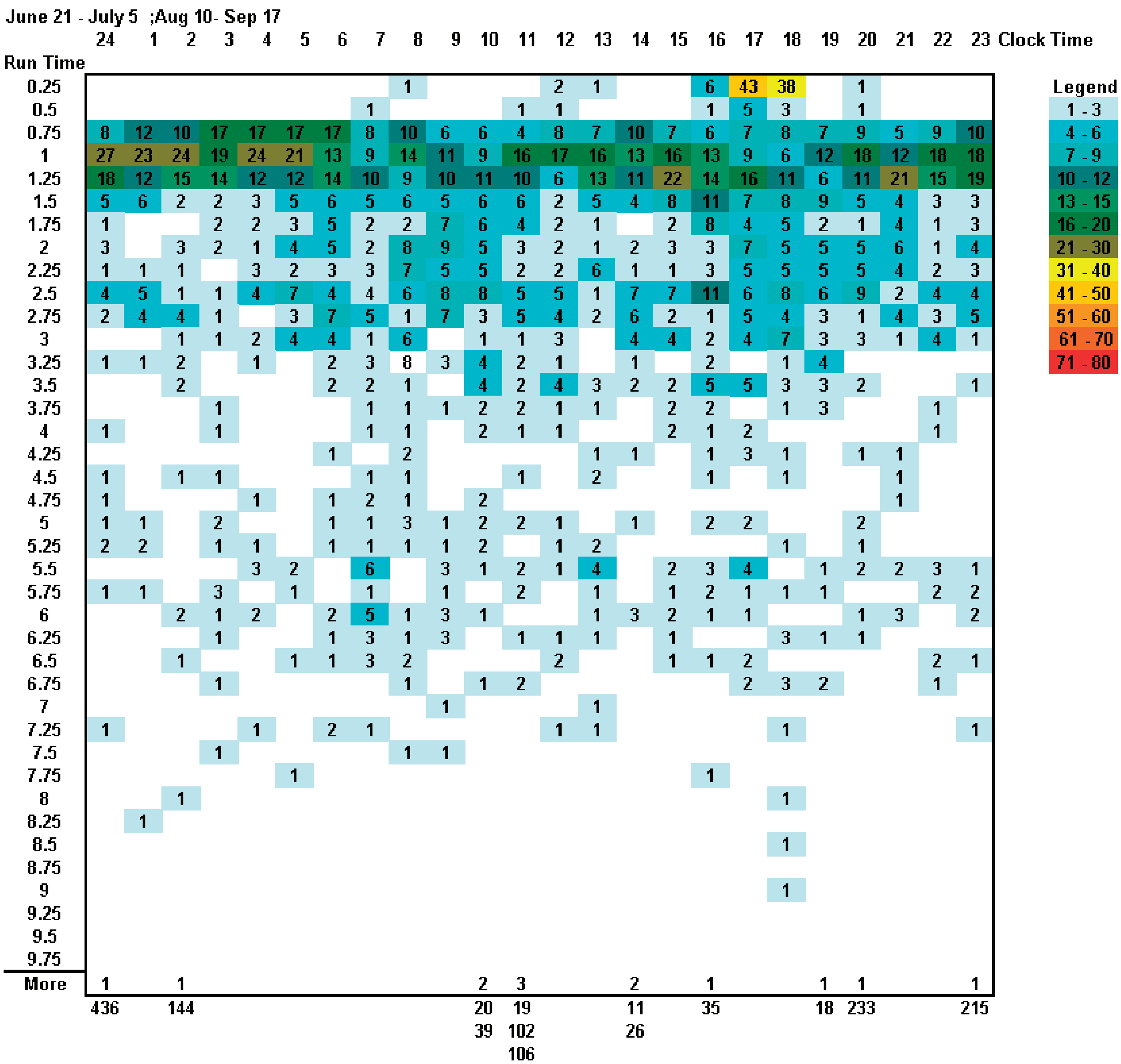

Figure 1 – Compressor Run Time Histogram
Synchronous Operation

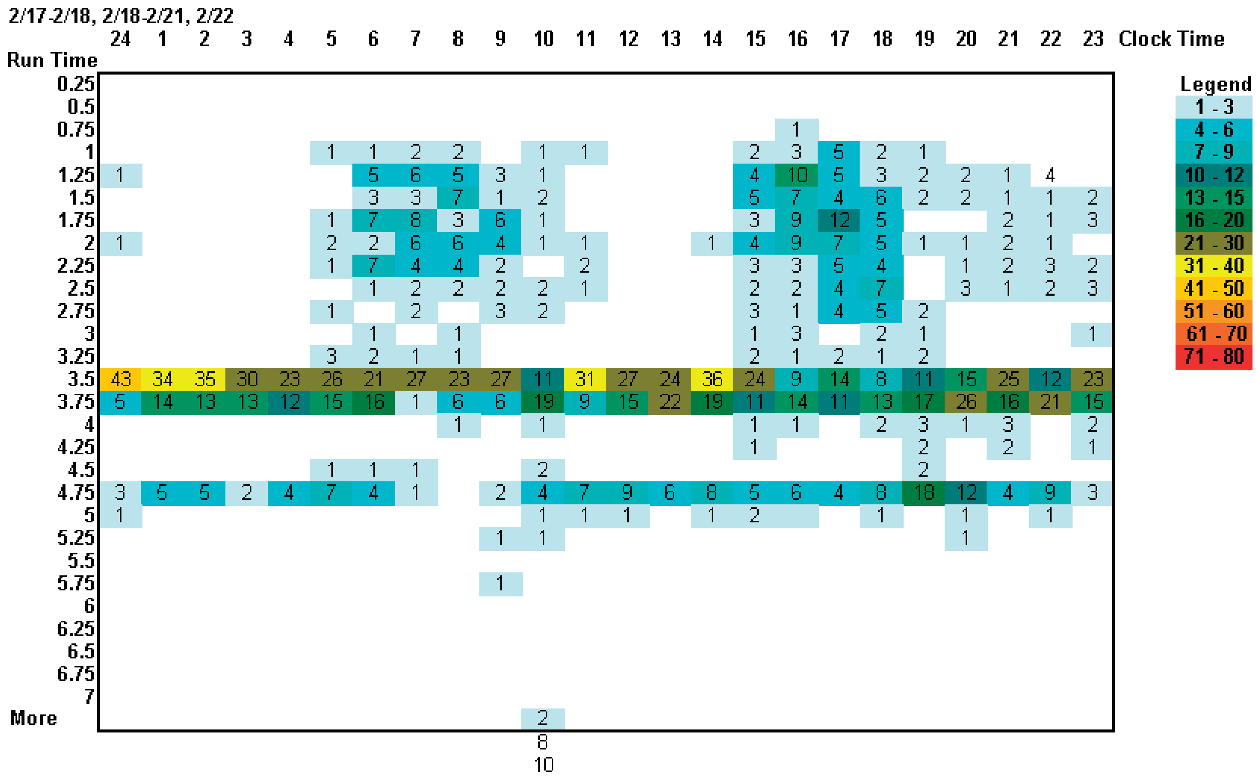

Figure 2 – Compressor Run Time Histogram
Autonomous Operation – Compressor One

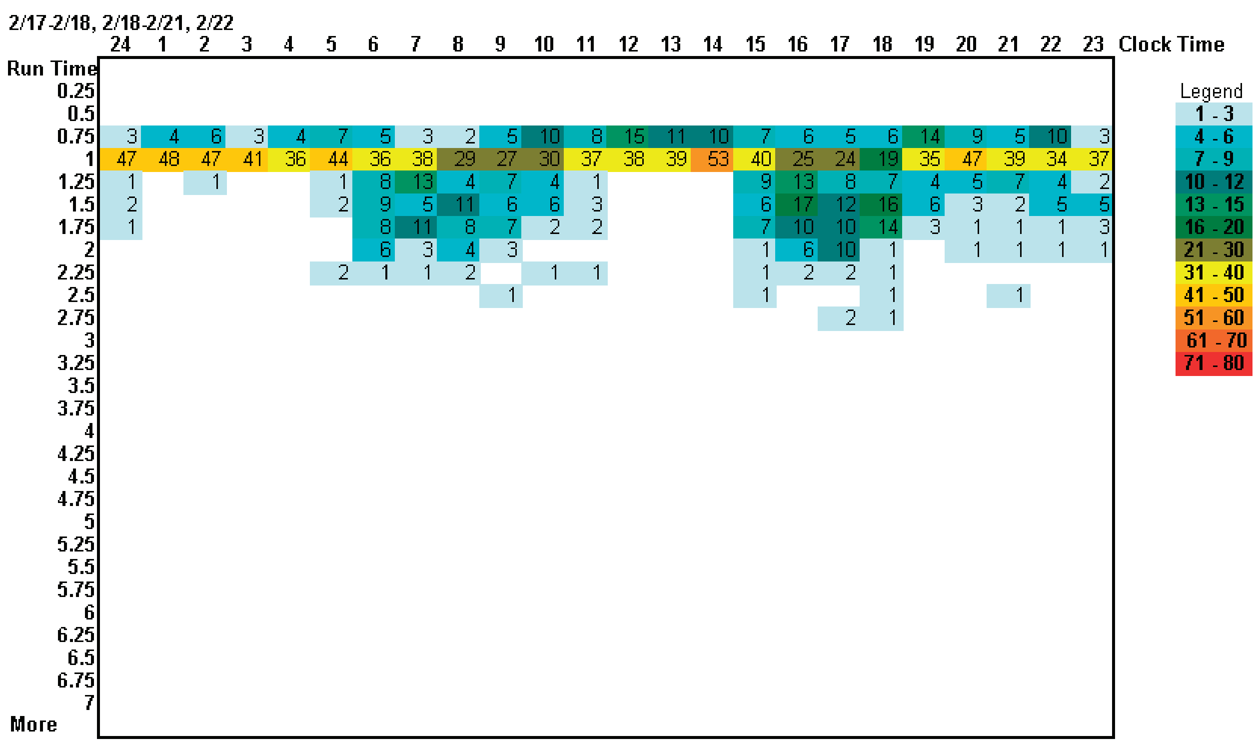

Figure 3 – Compressor Run Time Histogram
Autonomous Operation – Compressor Two

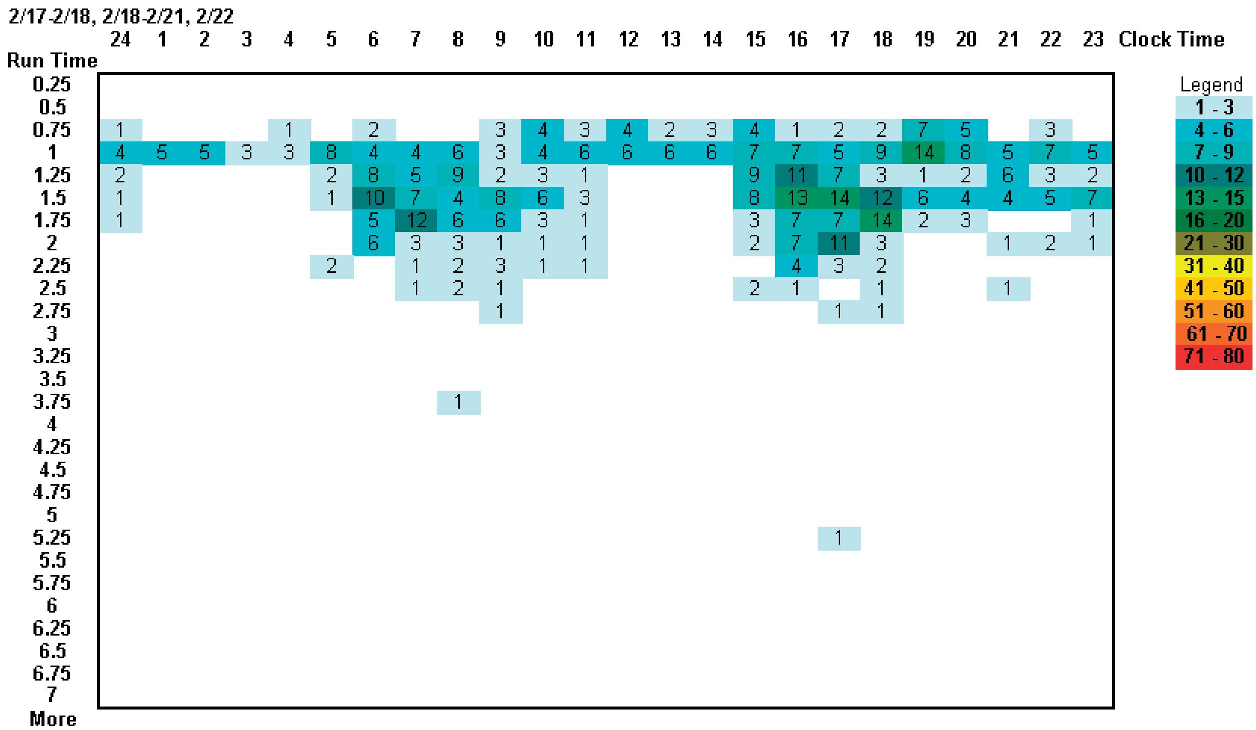

Figure 4 – Compressor Run Time Histogram
Autonomous Operation – Compressor Three

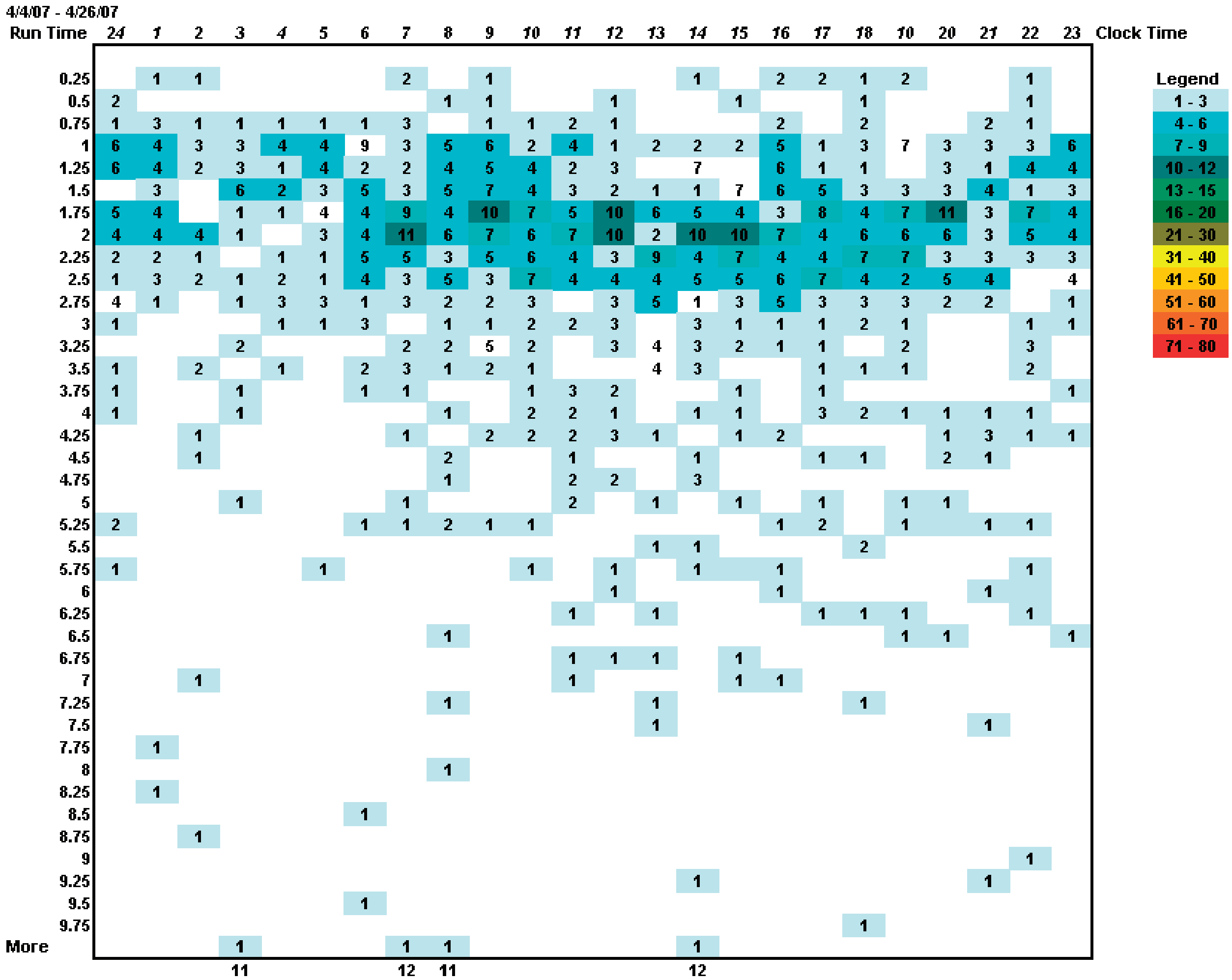

Figure 5 – Compressor Run Time Histogram
Network Selection – Compressor One

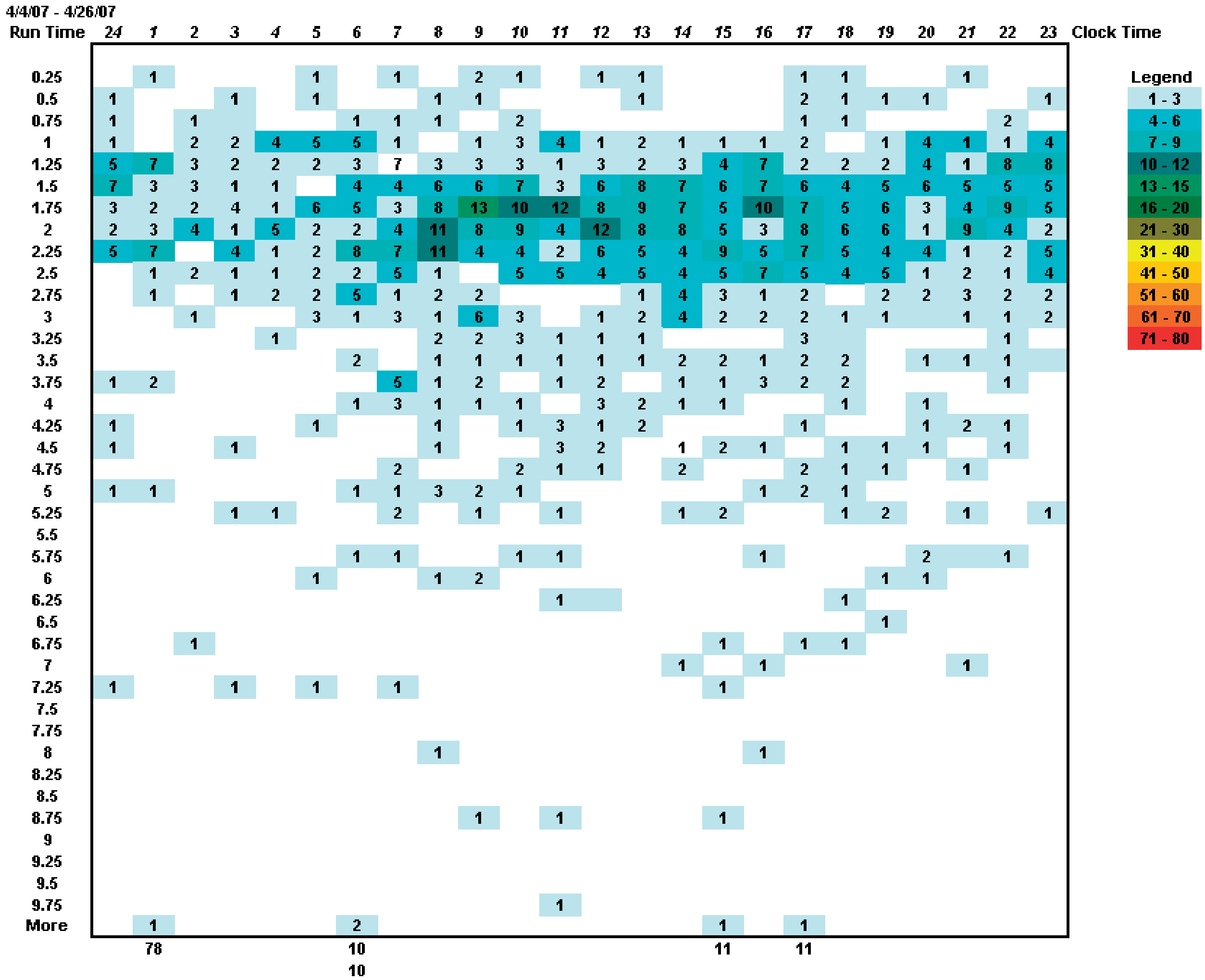

Figure 6 – Compressor Run Time Histogram
Network Selection – Compressor Two

ACKNOWLEDGEMENTS

The author wishes to thank the following transit authorities for their assistance in the data collection: Metropolitan Transit Authority - New York City Transit, Metropolitan Atlanta Rapid Transit Authority, and the Washington Metropolitan Area Transit Authority.