

## Investigation of RADTRAN Stop Model Input Parameters for Truck Stops\*

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### ABSTRACT

RADTRAN is a computer code for estimating the risks and consequences associated with the transport of radioactive materials (RAM). RADTRAN was developed and is maintained by Sandia National Laboratories for the U.S. Department of Energy (DOE). For incident-free (i.e., no transportation accidents or off-normal occurrences) transportation, the dose to persons exposed while the shipment is stopped is frequently a major percentage of the overall dose. This dose is referred to as Stop Dose and is calculated by the Stop Model. Because stop dose is a significant portion of the overall dose associated with RAM transport, the values used as input for the Stop Model are important. Therefore, an investigation of typical values for RADTRAN Stop Parameters for truck stops was performed. The resulting data from these investigations were analyzed to provide mean values, standard deviations, and histograms. Hence, the mean values can be used when an analyst does not have a basis for selecting other input values for the Stop Model. In addition, the histograms and their characteristics can be used to guide statistical sampling techniques to measure sensitivity of the RADTRAN calculated Stop Dose to the uncertainties in the stop model input parameters. This paper discusses the details and presents the results of the investigation of stop model input parameters at truck stops. The current investigation was limited to refueling stops, but the methodology developed can be applied to stops with other purposes.

### INTRODUCTION

The objective of this investigation was to determine statistically meaningful estimates of the average values of the parameters which affect the calculation of stop dose at truck stops. Stop parameters observed for trucks in general are considered to be representative of RAM transportation trucks specifically because whether or not a truck actually carries RAM should not affect its time to refuel. This investigation has not attempted to characterize road-side stops or stops at any other location than truck stops.

To begin this investigation, it was necessary to identify which parameters affect the stop dose. This was accomplished by studying the documentation supporting the RADTRAN Stop Model [1] and an earlier investigation "Truck Transportation of Radioactive Materials" [2]. The parameters identified as most directly affecting stop dose are: the duration of the stop, which is referred to as Stop Time; the number of persons exposed to the truck while it is stopped, which is referred to as Number of Persons Exposed (NPE); and the distance from the truck to

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the exposed persons, which is referred to as Exposure Distance. The NPE can be divided into people outside at the truck stop (i.e., without radiation shielding), and people inside buildings at the truck stop (i.e., with radiation shielding). Thus, the NPE should be observed as two parameters: NPE-outside, and NPE-inside buildings. In addition, the building materials should be noted as they could affect shielding values.

The prototype RADTRAN 5.0 Stop Model allows two options for specifying the NPE at a stop: 1) User specified number of people at a fixed exposure distance from the RAM shipment; and 2) a user specified number of people within an annular region with user specified minimum and maximum exposure distances [3]. In addition, RADTRAN 5.0 allows for up to 20 distinct stops to be modeled in a single RADTRAN run. Hence, a refueling stop can be modeled with separate input values than a weigh station stop or a repair stop. A stop during peak time (with respect to congestion at the truck stop) can be modeled separately from a stop during off-hours.

To determine the range of values possible for the Stop Model input parameters, factors expected to affect these input values were identified. Factors possibly affecting Stop Time, NPE, and Exposure Distance include: truck stop location (i.e., rural, urban, or suburban, proximity to other commercial establishments, etc.); time of day; and purpose of the stop (i.e., refueling, service, etc.). Truck stop location is likely to affect the amount of business at that stop and, hence, the number of persons potentially exposed as well as the amount of time needed for service and potential for delays. Time of day was expected to have a similar effect. Truck stop location could also affect the configuration of the truck stop and, hence, the exposure distances. For example, land availability may affect the square footage occupied by metropolitan and rural truck stops, which could in turn, alter the distances between refueling bays, service bays, and restaurants, etc. The purpose of the stop is expected to affect the stop time. For example, a simple refueling stop is likely to be of shorter duration than a stop requiring repair service.

The stop times measured in this investigation were limited to refueling stops because all transports of sufficient distance must refuel, whereas a service stop may be unnecessary. Also, a refueling stop is most likely of shorter duration than a service stop. Therefore, a refueling stop is a reasonable representation of a routine minimum stop time. Because the RADTRAN 5.0 Stop Model allows for up to 20 distinct stops to be modeled in a single RADTRAN run, the RADTRAN analyst can select a larger stop time when modeling a service stop. The observations of exposure distance and NPE should be applicable to all stops that occur at truck stops.

The actual investigation included traveling to truck stops and measuring stop time, number of persons exposed, and exposure distance. Truck stops were selected in several locations and observations were made at various times of the day and on various days of the week to yield a representative sample of truck stop parameters.

## **TRUCK STOP OBSERVATION PROTOCOL**

A truck stop observation protocol was necessary to help ensure consistency in observation techniques between different truck stops, and to help ensure statistical soundness of the resulting data. We observed each truck stop anonymously so that our presence would not alter the data

(i.e., the fuel pump attendant doesn't alter his or her pace, etc.). To avoid any unintentional preferential treatment in selecting which trucks to observe, we decided to measure stop time for every truck that refueled during each observation period. Two persons were involved in performing these observations and were present at each observation. To help ensure uniformity, each person performed the same duties at each observation.

Preliminary truck-stop observations were performed at two truck stops in Albuquerque, New Mexico, and at one truck stop in rural Arizona (Holbrook). The purpose of these preliminary observations was to familiarize ourselves with the conditions at truck stops so that we could develop an efficient and uniform plan for observing data at various truck stops. Based on these preliminary observations, an observation ledger form was developed to help ensure consistency between observations at each stop. The observation form included columns for observing the following variables: truck stop location; observation date; day of week; time of day; stop time; NPE-outside; outside exposure distance; NPE-inside buildings at the truck stop; building material(s); number of trucks parked in the first row (with respect to the refueling bays); distance from the refueling bays to the first row of parked trucks; paving material; and a section for comments. A free-hand sketch of the configuration of each truck stop was also prepared for each truck stop. A video camera was used to record the truck stop observations and a stop watch was used to measure stop time. The video tapes and ledgers are part of the quality assurance file for this project. The observation data are stored in a spread-sheet file (Microsoft Excel) so that data can be added as additional observations are performed.

The number of parked trucks was noted because parked trucks may have one or more persons sleeping inside. These persons could be considered as a distinct subset of NPE-inside. All parked trucks were not counted because persons sleeping in the 2nd or further row of parked trucks would be shielded by the first row of parked trucks.

The exposure zone was defined as the area enclosed by major shielding objects such as building walls and the first row of parked trucks. Since most of the persons travelled from the parking areas to the buildings, the exposure zone was modelled as a circular region with the diameter being the distance between the buildings and the first row of parked trucks.

Preliminary observations indicated that tracking the exposure distance for each individual entering the exposure zone would be nearly impossible because most persons walked through the zone rather than occupying it in a stationary manner. The preliminary observations also indicated that the same individuals did not occupy the exposure zone during the entire stop time for any given truck: people entered and exited the exposure zone at various times during any given truck's refueling period. Therefore, the protocol for observing NPE was defined as follows: the number of persons in any portion of the exposure zone was observed, along with the approximate time that each person occupied the zone (which is referred to as residence time). Summing the residence time for each person observed in the exposure zone yields a time-integrated NPE, with units of NPE-time. Dividing the time-integrated NPE by the total observation time yields an equivalent number of persons occupying the exposure zone for the entire observation period, as if they were not travelling into and out of the exposure zone. With this method of calculating NPE, one person occupying the exposure zone for two minutes is counted the same as two persons occupying the exposure zone for only one minute. This is

consistent with RADTRAN methodology because RADTRAN calculates population dose rather than individual dose. Also, this definition of NPE is compatible with the NPE Input Option 2 in the RADTRAN 5.0 Stop Model, in which the NPE is expressed as the number of persons in an annular exposure zone with a user specified minimum and maximum radius. The two NPE Input Options available in RADTRAN 5.0 are discussed in the Introduction section of this report.

In practice, it proved impossible to observe NPE separately for every truck in the refueling area, because there were frequently numerous trucks refueling at the same time or in over-lapping time periods. Therefore, the protocol was adjusted to track the NPE for an observation time period during which many trucks were observed individually for stop time. Each observation period was approximately 60 minutes in duration. Therefore, the data presented in the Results section will show more observations of Stop Time than NPE.

## RESULTS

Upon completion of the Truck Stop Observation Protocol, the actual investigation was performed. The actual investigation included traveling to truck stops and measuring stop time, number of persons exposed, and exposure distance. Two metropolitan truck stops in Albuquerque, New Mexico (Fina and Union 76) and one rural truck stop in Tucumcari, New Mexico (Shell) were observed.

The Fina observations were performed on July 24 (Monday), July 27 (Thursday), July 28 (Friday), August 1 (Tuesday), and August 2 (Wednesday) 1995. To provide a sampling of times-of-day, these observations were performed in the mornings and afternoons. The Union 76 observations were performed in the mornings of August 29 (Tuesday), September 6 (Wednesday), and September 7 (Thursday) 1995. The Shell observations were performed in the afternoon of October 23 (Monday) 1995. The average values, standard deviations, and number of observations for stop time, NPE-inside, and NPE-outside for each truck stop individually and for all three trucks stops as a composite, are listed in Table I. The number of trucks parked in the first row (with respect to the refueling bays) and the exposure distance for each truck stop individually and for the composite are also listed in Table I. The number of trucks parked in the first row is not presented as a statistical observation with numerous observations because the value appeared to be constant for each truck stop; the first row was always observed to be full and, therefore, limited by the number of parking spaces in that row. The exposure distance for each truck stop is also not presented as a statistical observation because that value is constant for each truck stop, but depends on site-specific factors.

Histograms of the stop times for each individual truck stop and for the composite are shown in Figures 1-4. The histograms and their characteristics can be used to guide statistical sampling techniques to measure sensitivity of the RADTRAN calculated Stop Dose to the uncertainties in the stop model input parameters.

Table I. Average Observed Values for Stop Model Input Parameters

Parameter	Fina Albuquerque, NM	Union 76 Albuquerque, NM	Shell Tucumcari, NM	Composite
Stop Time Avg (min:sec)	19:05	18:53	14:39	18:18
Stop Time $\sigma$ (min:sec)	5:56	8:27	4:40	7:27
Stop Time # observations	16	35	9	60
NPE-inside Avg (persons)	33.4	65	44.3	44.5
NPE-in $\sigma$ (persons)	8.4	15.5	3.2	9.75
NPE-inside # observations	11	6	3	20
NPE-Outside Avg (persons)	6.9	6.8	4.7	6.4
NPE-Outside $\sigma$ (persons)	0.2	2.6	0.5	2
NPE-Outside # observations	3	6	2	11
Parked Trucks (number)	8	13	11	10.7
Exposure Distance (feet)	75	75	150	

Figure 1. Stop Time Histogram for the Fina-Albuquerque Truck Stop

Figure 2. Stop Time Histogram for the Union 76-Albuquerque Truck Stop

Figure 3. Stop Time Histogram for the Shell-Tucumcari Truck Stop

Figure 4. Stop Time Histogram for the Composite Truck Stop Data

## Discussion

The results listed in Table I indicate that the two metropolitan truck stops (Fina and Union 76) have nearly identical average stop times, average NPE-outside, and exposure distances, whereas the rural truck stop (Shell) has a lower average stop time, a lower average NPE-outside, and a larger exposure distance.

The exposure distances at both Albuquerque truck stops seem to be practical minimums because they represent the minimum distance needed to accommodate the number of refueling bays and a minimum lane width. The exposure distance at the Tucumcari truck stop is, indeed, larger than that at the Albuquerque truck stops.

Qualitative observations are useful for helping the analyst to design and perform analyses of truck stops. The first qualitative observations concern the refueling process. A general

observation is that the truck stop employees work efficiently to refuel all of the trucks quickly. Dual fuel tanks were usually filled simultaneously; a separate fuel pump was used to fill each tank. Also, most of the truck drivers removed their trucks from the refueling bays promptly after the refueling was completed. All of these factors combine to minimize waiting time at the refueling bays. This is consistent with industry practice, as most truck drivers are concerned with travel time and strive to minimize their own delays and those of other truck drivers.

A second qualitative observation is that truck stops, in general, are quite busy. People concentrate around the restaurant, fueling area, mechanical shops, pay stations, and gift/supply stores. Numerous automobiles were observed parked at the restaurants at both Albuquerque truck stops, the Tucumcari truck stop, and the Holbrook truck stop. This indicates that people not associated with truck transport (i.e., local residents, automobile travellers, etc.) patronize the restaurants and other truck stop amenities. In addition, at the Albuquerque truck stops, people were observed walking through the exposure zone in route from one neighboring business to another; these people were not using truck stop services.

A third qualitative observation concerns trucks parked at the truck stop. The majority, approximately 90%, were equipped with "sleeper" cabins located aft of the crew cabin. This supports the concern that each parked truck could potentially contain at least one sleeping person who could be exposed to a RAM transport. However, these persons would be significantly shielded by the tractor cab and engine compartment.

A last qualitative observation concerns building materials because they may affect shielding. Most of the buildings were of concrete cinder-block construction. However, some associated out-buildings such as the weigh-station booth, fuel payment-booths, etc., might be constructed of different materials providing less shielding.

## SUMMARY

This paper discusses an investigation of stop model input parameters at truck stops. The parameters of stop time, number of persons exposed (inside building), and the number of persons exposed outside are presented as average values with standard deviations. Histograms of the stop data are presented as an aid for the analyst who may want to use statistical sampling techniques. The results presented in this report indicate that a metropolitan truck stop has a longer average stop time, larger average NPE, and closer exposure distances than the rural truck stop. However, fewer observations of the rural truck stop were performed than for the metropolitan truck stops. These data are stored in a spread-sheet file (Microsoft Excel). This format will allow new data to be added to the database as additional observations are performed.

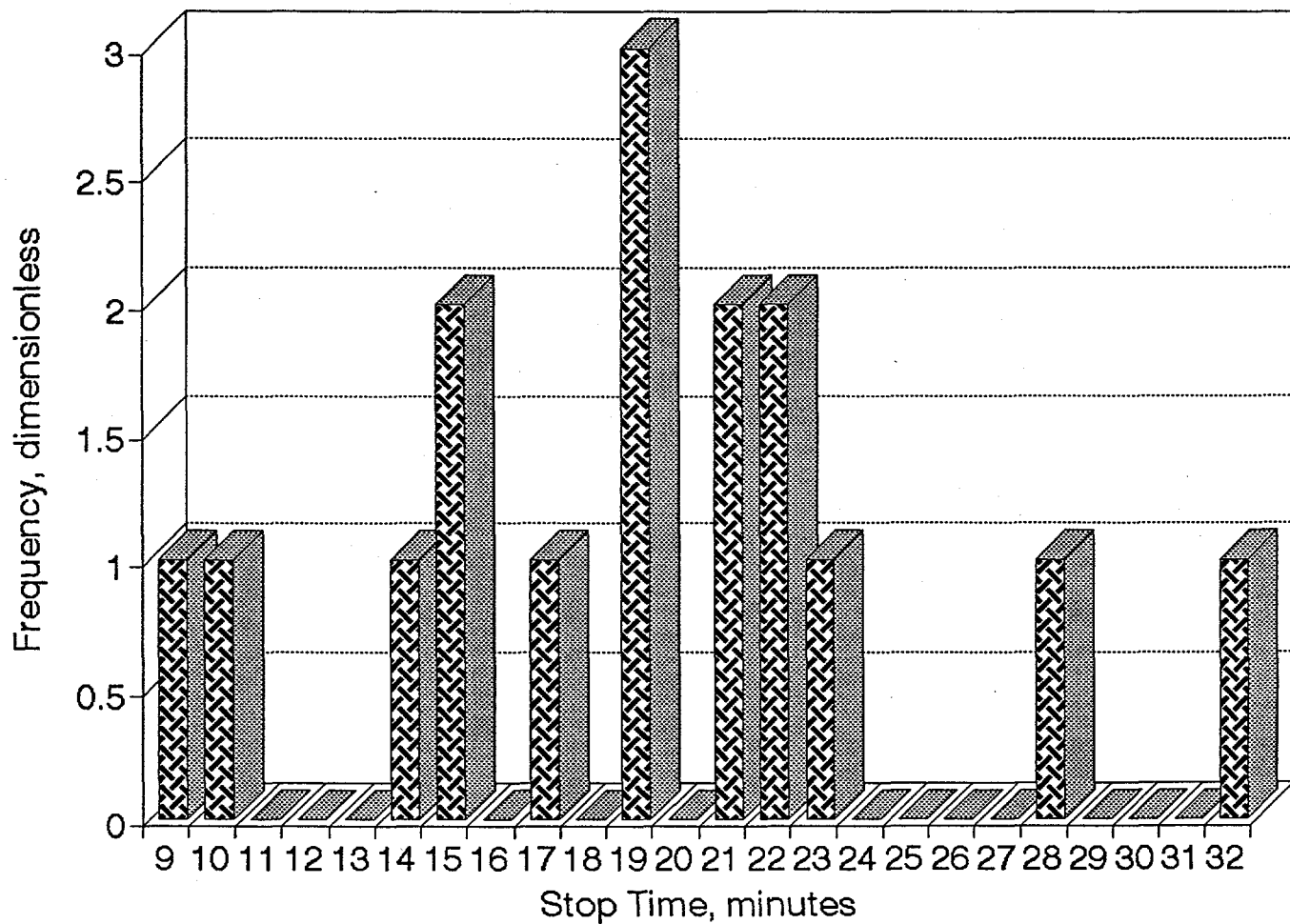
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2. Madsen, M.M., and Wilmot, E.L. "Truck Transportation of Radioactive Materials," PATRAM Conference Proceedings, Volume 3, 1983.

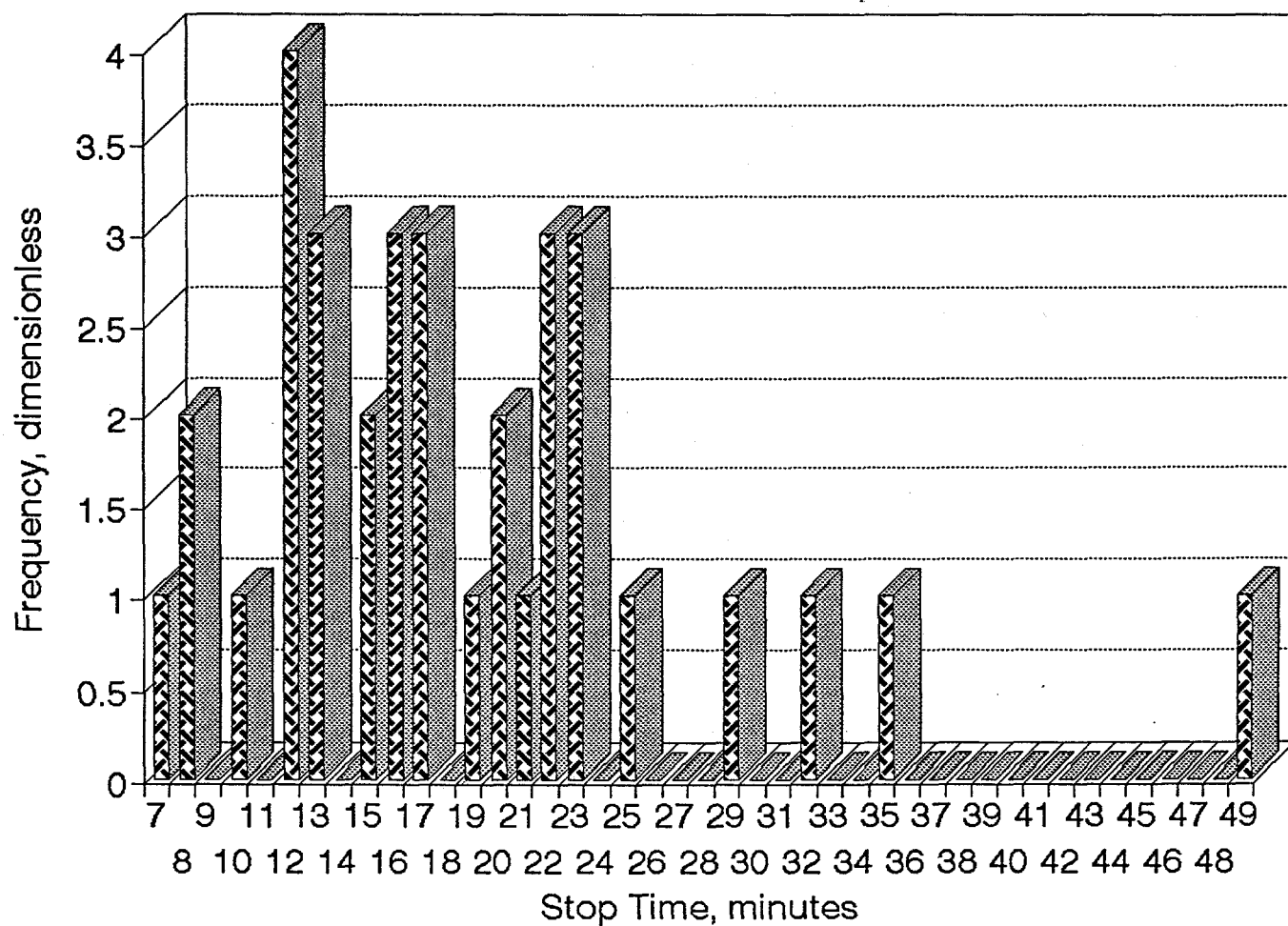
3. Kanipe, F.L. Private Communications, July 10, 1995.



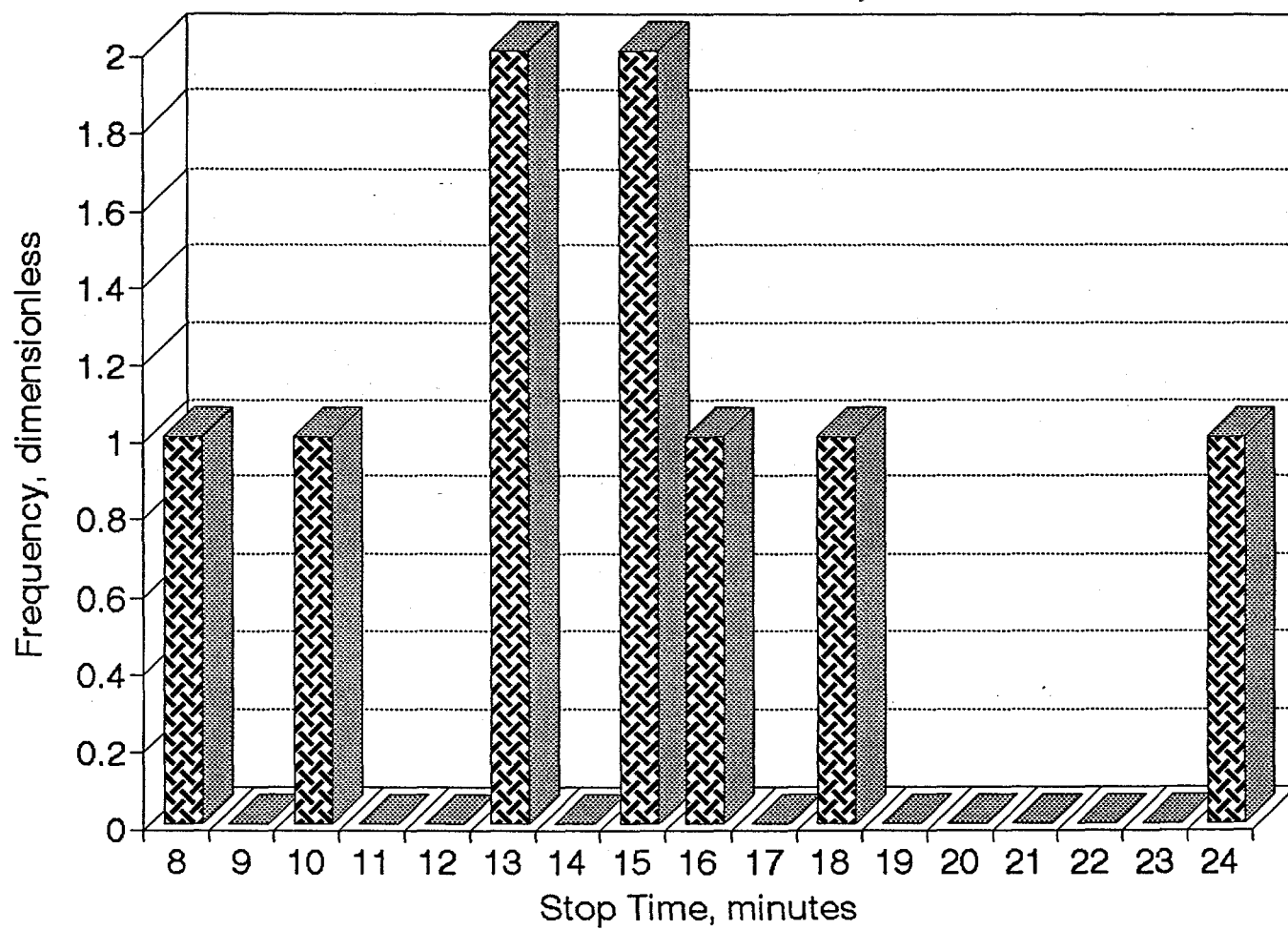
## Fina - Albuquerque, NM



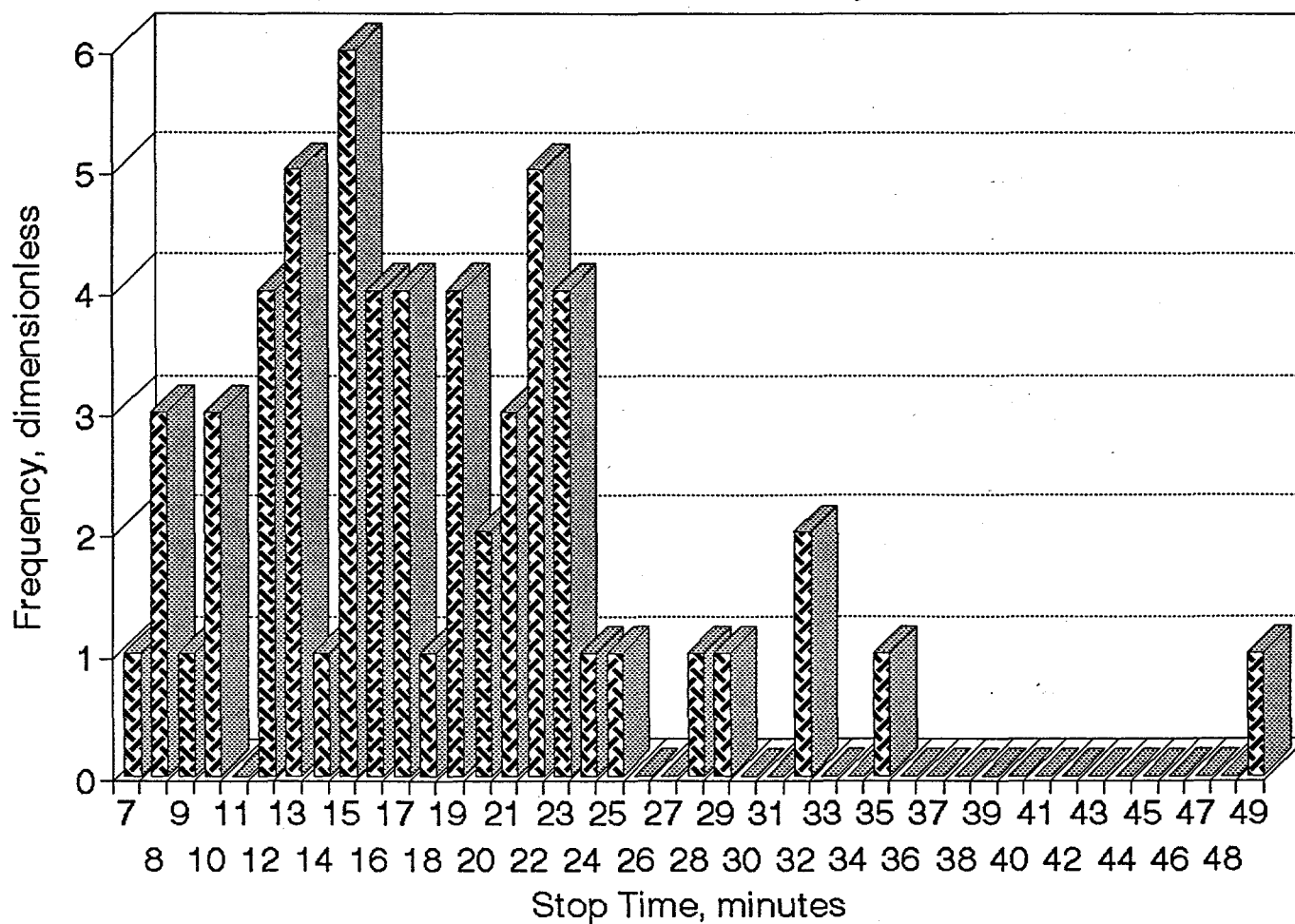
## Union 76 - Albuquerque, NM



## Shell - Tucumcari, NM



# Composite: Fina, Union 76, Shell



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