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The California/New York

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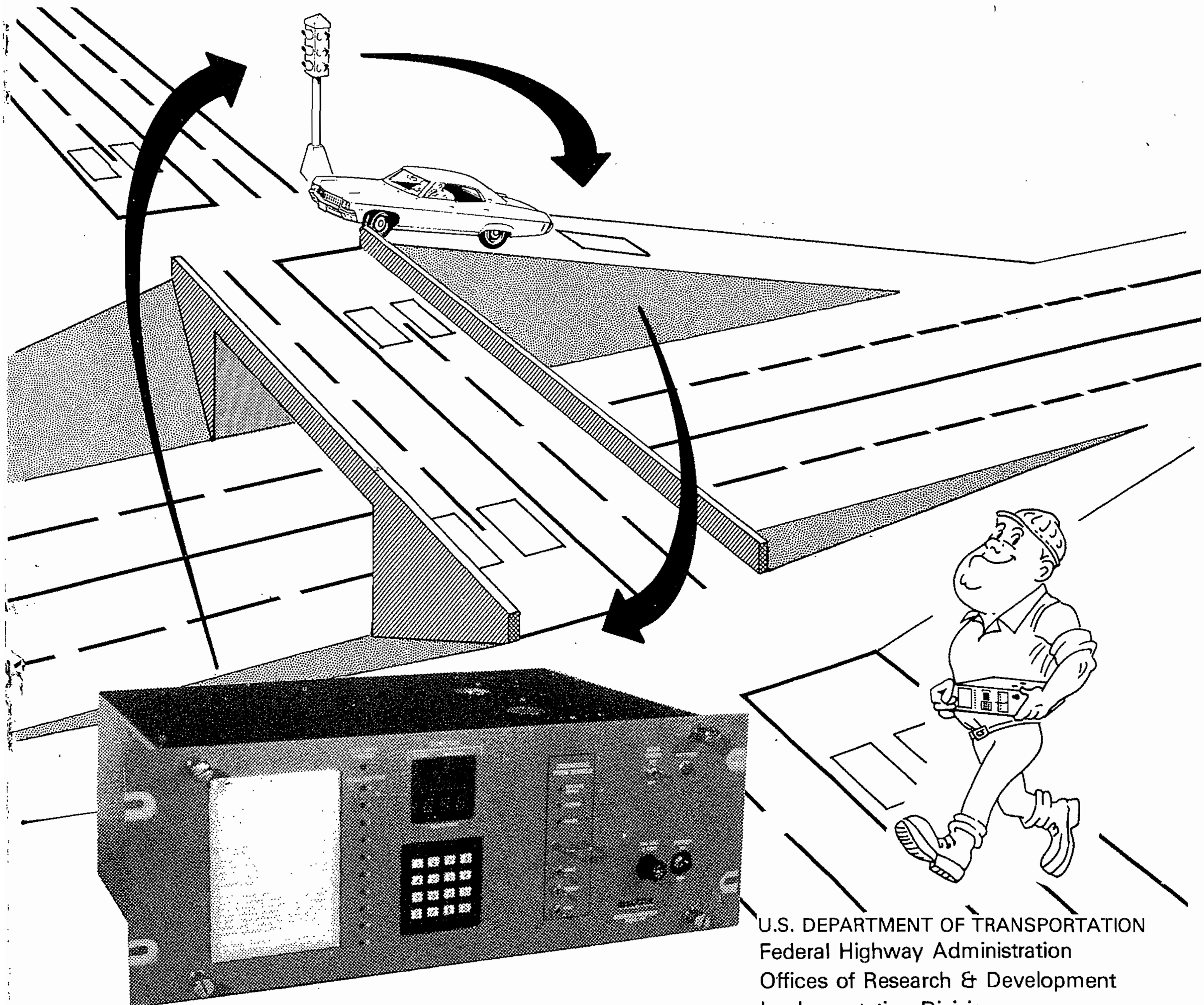
Type 170 Traffic Signal Controller System – Microcomputer Based Intersection Controller



U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Offices of Research & Development
Implementation Division

Caltrans

NOTICE

Diamond Interchange Traffic Signal Controller

An Aid to the Preparation of Procurement Specifications for Microprocessor Based Traffic Signal Controllers

December 1978

Prepared by the State of California

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Offices of Research and Development
Implementation Division

FOREWORD

This TechShare package presents the application of the Type 170 traffic signal controller to diamond interchanges. The specifications for this controller were developed jointly by the States of California and New York as a user-oriented controller specification. The purpose of this report is to show the flexibility of the controller, its low cost, and its ease of use.

The report first compares the 170 microcomputer-based controller to the minicomputer equipment and to the hardwired equipment for diamond interchange control to show how much capability has been placed in this small controller. It then explains the user orientation of the controller and compares the three alternatives of microcomputer control, minicomputer control, and hardwired equipment control to demonstrate that microcomputer controllers such as the 170 are the logical choice. The logic behind the design of the 170 hardware and its use of proven technology are then explained as are the cost effectiveness and benefits which derive from the 170 design. Software considerations such as man-machine interface features are briefly described, and the report concludes with a recommendation that the 170 controller be considered as a standard controller for all traffic signal control application and that it is so specified by the States of California and New York. A copy of the 170 specification is attached.

While the report is being written from the viewpoint of the diamond interchange control project performed for the FHWA by the State of California, it must be noted that its conclusions apply to most signalized intersections and ramps.

In publishing this document the FHWA intent is to provide technical information which may serve a useful purpose in system development similar to other reports and manuals produced by FHWA research and development in this area. NO POLICY ASPECTS OR IMPLICATIONS ARE INTENDED. The United States Government assumes no liability for its contents or use thereof. The specification is currently being used by the States of California and New York, and further questions should be directed to these States.

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A. INTRODUCTION

1. Background Information

Diamond interchanges are a simple and relatively inexpensive type of interchange. Traffic demands at some urban diamond interchanges have grown at increasing rates. In many instances, the urban areas served by the diamond have grown much faster than originally forecast. This growth has led to increased traffic on the ramps of the diamond and the adjacent street system. At present, many urban diamond interchanges operate at a very low level of service during the a.m. and p.m. rush periods. Frequently, the traffic signal control disrupts signal progression on the adjacent arterial street and vehicle delays to all users are lengthy.

There has been considerable work done on real-time control of diamond interchanges in an attempt to optimize traffic flow throughout the interchange and retain smooth flow on adjacent corridors. (A typical diamond interchange is shown in Figure 1.) A recently completed research effort, "Control and Geometric Design of Diamond Interchanges," sponsored by the Federal Highway Administration and performed by System Development Corporation (SDC), resulted in a promising strategy for control of these interchanges. Their report indicated a 20 to 30 percent reduction in delay when this strategy was temporarily implemented on Western Avenue in Los Angeles, California. The hardware used for this test was expensive, bulky, and not suitable for a permanent installation. It consisted of a Varian 620 I minicomputer with 8 thousand words of memory, a 7-track magnetic tape unit, a punched card reader and a display panel all housed in an air conditioned office trailer and is shown in Figure 2. This strategy utilizes numerous detectors and a computer for real-time traffic responsive control of offset, split and cycle length.

Work on control of signalized intersections by use of minicomputers along lines similar to the SDC work had been done by both California and Texas. However, this had not been "reduced-to-practice" to create a controller suitable for mass production and easy application of advanced control techniques. It was, therefore, important that followup work be done to develop standard hardware and application criteria to enable the practicing traffic engineer to properly apply cybernetic technology to traffic control.

The State of California, under contract to the FHWA, undertook to design low cost standard hardware and to demonstrate it in a real-world environment. In the process, it cooperated with the State of New York to produce the 170 specification for a standard, general purpose traffic signal controller. Figure 3 shows a 170 controller operating a

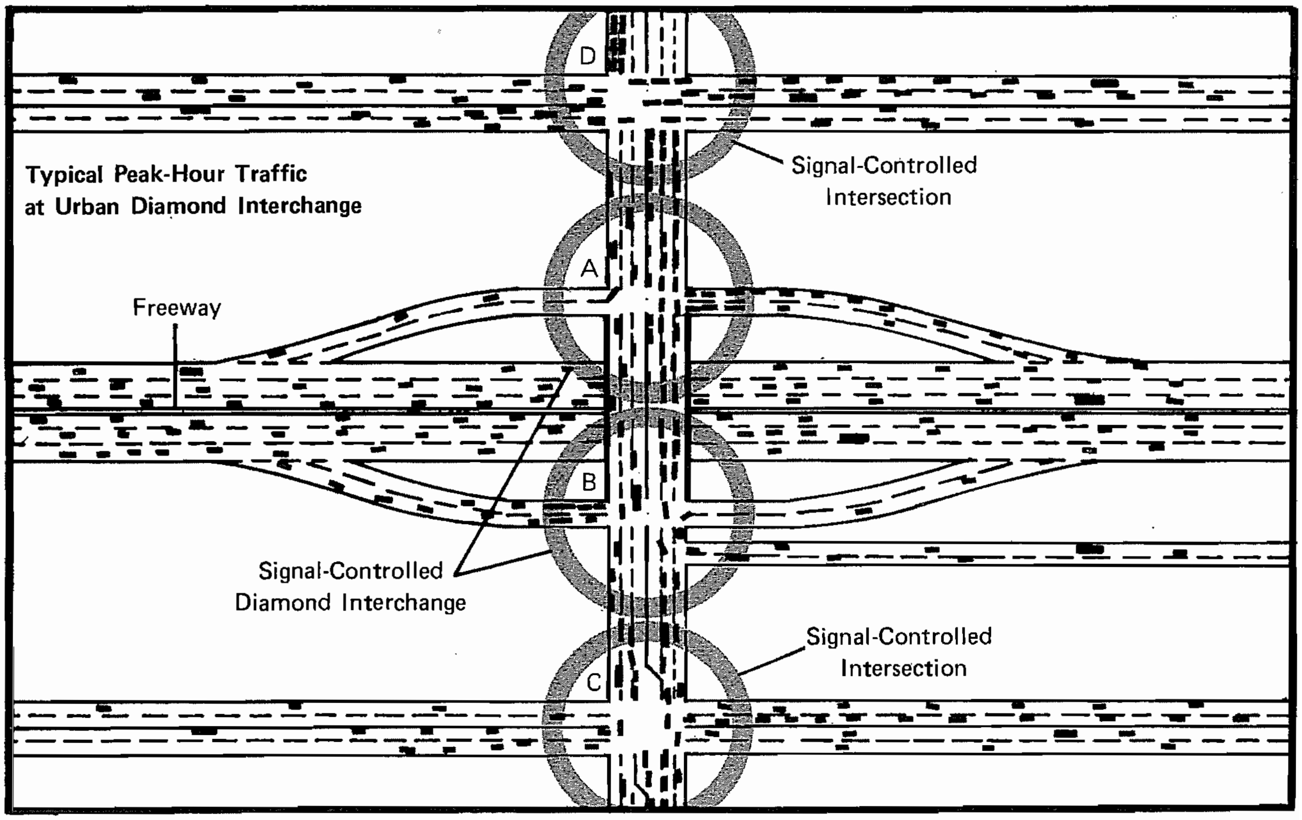


Figure 1 The Diamond Interchange at Western Avenue, on the Santa Monica Freeway, at Los Angeles, California, Is Depicted Here as an Approximation. A Peak-Hour Traffic Situation Is Illustrated To Show That Without Real-Time Control Good Operation Timing of the Diamond and Nearby Intersections May Be Difficult To Achieve. Build-Ups at the Off-Ramps (A and B) Are Caused by Uncoordinated Timing at the Major Intersections (C and D), Which Hinder Right and Left Turns onto Western Avenue.

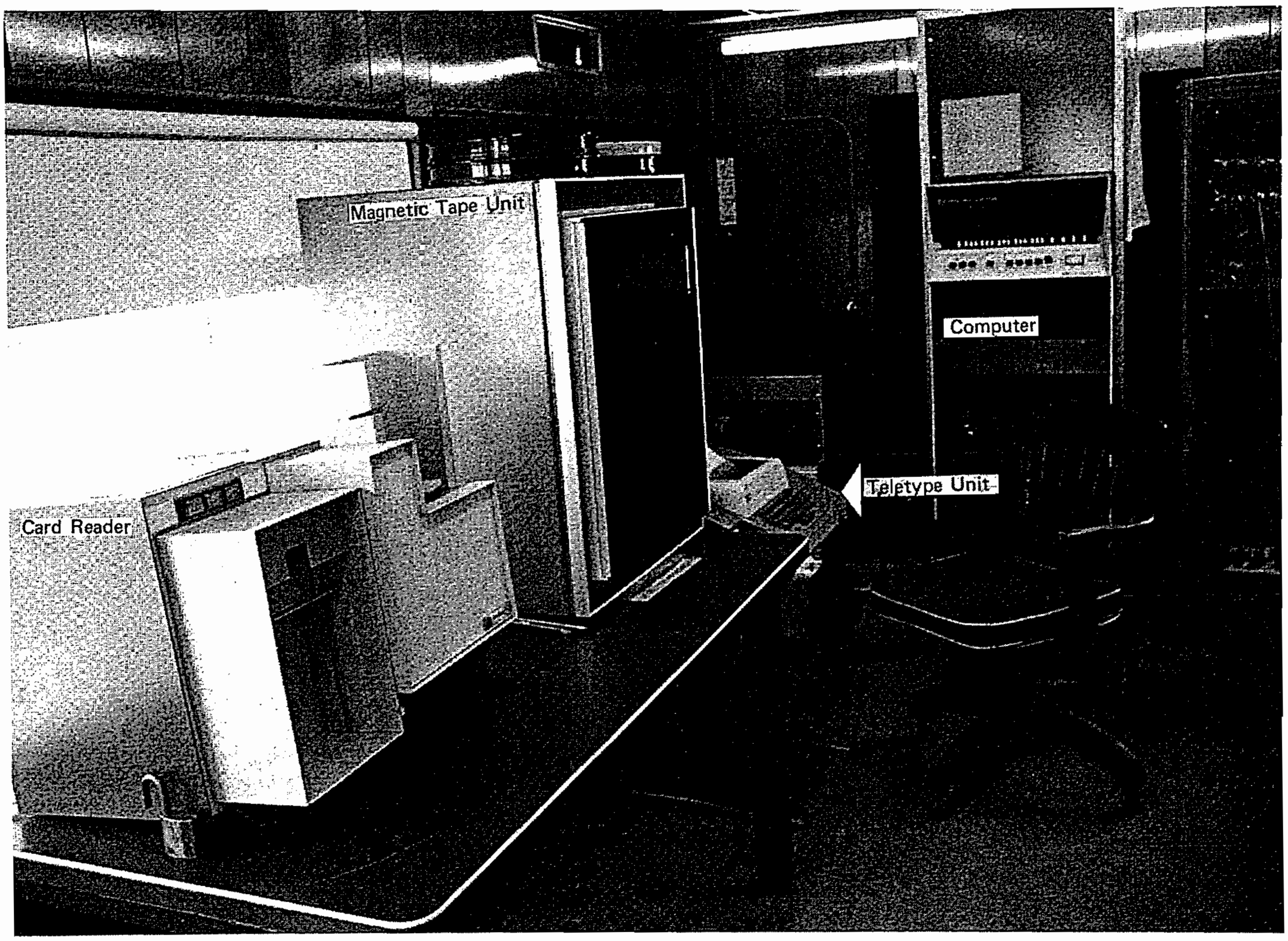


Figure 2 Trailer Control Center

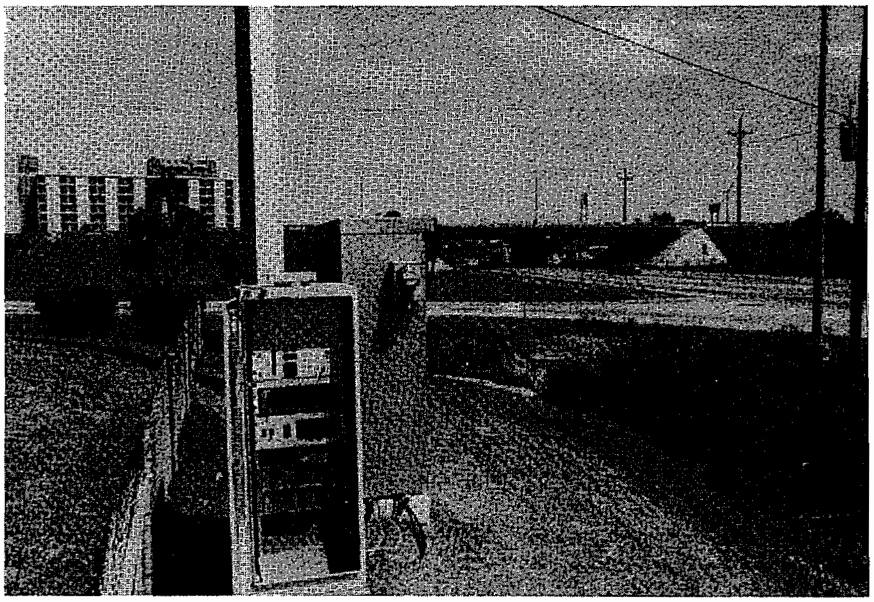


Figure 3 Type 170 Controller Operating Traffic Signals for a Diamond Interchange in Jacksonville, Florida. Side View of Old Controller in Background.

diamond interchange in Jacksonville as part of the field demonstration of the controller's ease of use by signal engineers and technicians who had not previously been trained on it. This controller has the same capabilities as the equipment shown in Figure 2.

B. DESIGN OF THE CONTROLLER

1. User Orientation of the Controller

To develop a diamond interchange controller that will be generally used, it must be acceptable to the potential users of such a device. The investigators reviewed typical signal controller specifications of several potential users of computer controllers for diamond interchanges. The State of New York has a detailed and thorough specification for traffic signal controllers. The investigators met with New York Department of Transportation personnel in Albany, New York, and discussed operational and maintenance considerations of solid-state traffic signal controllers. New York State contributed greatly to the appreciation of the capabilities of maintenance personnel and the controller operating environments in the State of New York. The operating environments in New York differed considerably from other areas reviewed in temperature, humidity, lightning and electrical power brown-out considerations. The hardware developed as a result of this task order will consider the needs of various States.

The review of control strategies and hardware almost universally indicated a preferred phase sequence called, "four-phase overlap" (Figure 4A). However, despite the overwhelming preference for one sequence, there was a demonstrated need for other sequences. Texas prefers the four-phase overlap sequence, but also uses a three-phase sequence when needed to maintain progression along adjacent frontage roads (Figure 4B). The Florida installation used a sequence utilizing lagging left turn phases. Fully actuated strategies are also used for very light traffic at some locations. In some locations the preferred phase sequence is varied based on time of day to permit progression along the frontage roads connecting diamond interchanges. Thus, the present hardware to implement signal control often lags behind modern technology. The hardware used varies from drum and dial controllers to uniquely wired minicomputer cabinets (see Figure 5). The status of the various software packages is described in Appendix A.

2. Analysis of Hardware Systems for Diamond Interchange Control

Three alternate hardware systems for controlling a diamond interchange have been developed. The three systems

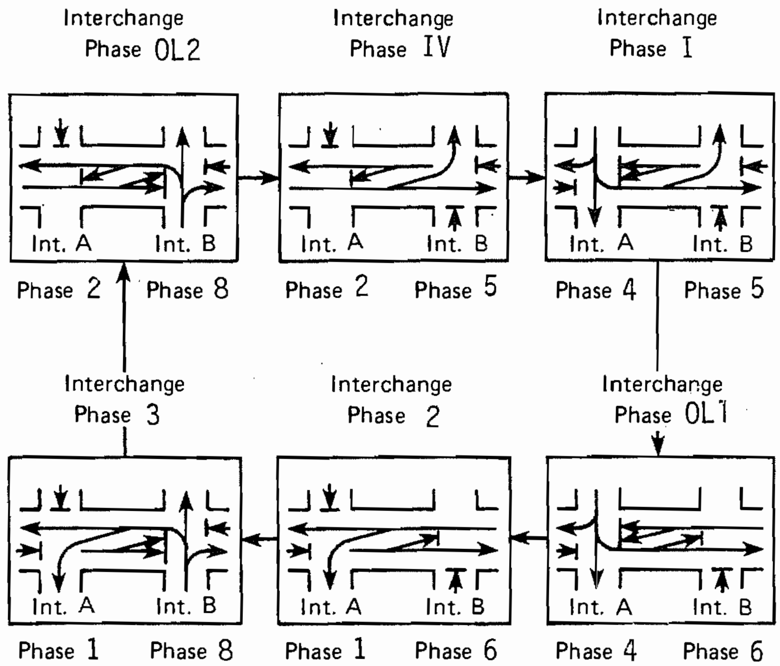


Figure 4A The Leading-Leading (Four-Phase-With-Two-Overlap) Phasing Pattern for a Diamond Interchange.

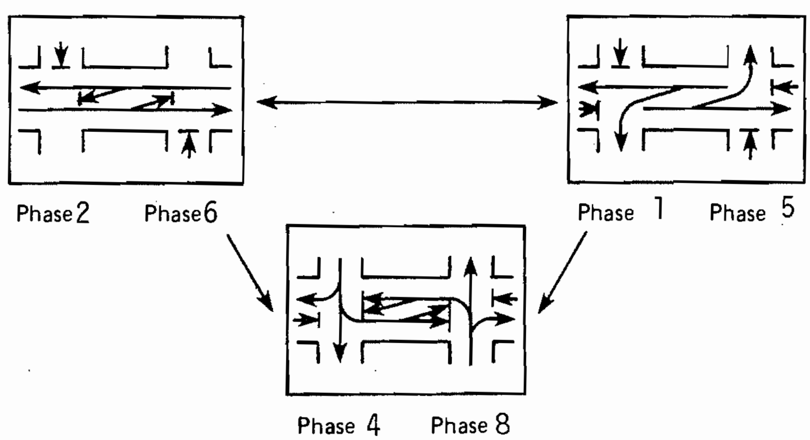
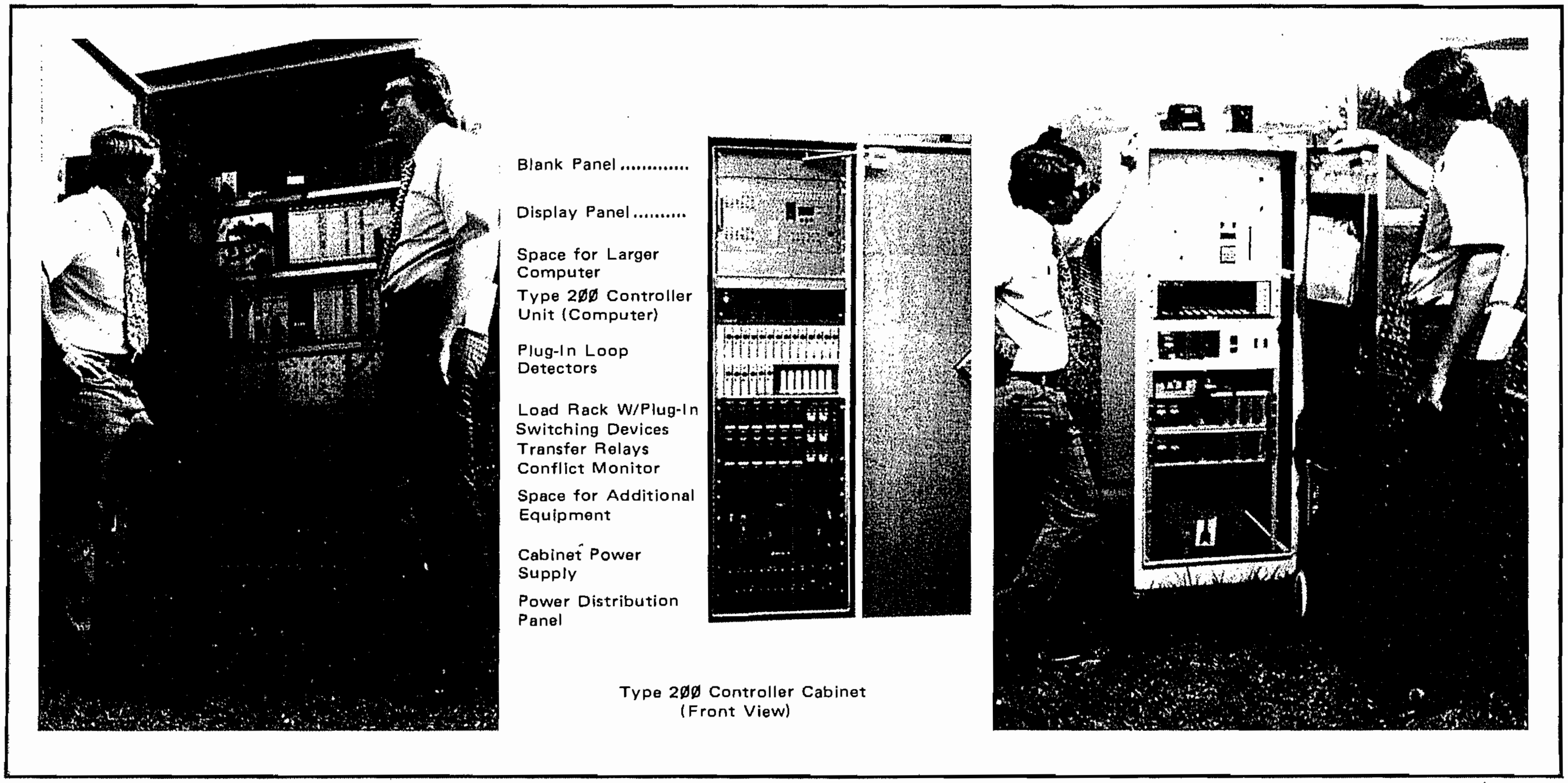


Figure 4B The Lagging-Lagging (Three-Phase)Phasing Pattern Fully Symetrical for a Diamond Interchange Which May Be Used to Facilitate Progression Along Frontage Roads.



5A Hardwired | **5B Minicomputer Based** | **5C Microcomputer Based**

Figure 5 Alternative Hardware Configurations for Diamond Interchange Control (5A and 5B at Jacksonville, Florida Site)

are based on the use of a 1) minicomputer, 2) microcomputer, and 3) typical industry hardwired logic. The three alternate systems are shown in block diagram Figures 6, 7, and 8. Examples of these controllers are in Figure 5.

Note that loop detectors, power supply, load switches, power distribution panel, conflict monitor and the field terminations are all common to all three alternate systems (see block diagrams Figures 6, 7, and 8). The microprocessor and hardwired logic controllers both need a vent fan whereas the minicomputer requires climatic controls which include heating and air conditioning.

Cost comparisons and materials list for the three alternate systems are listed in Figure 9. Relative benefits are listed in Figure 10. Estimated cost* in ascending order is as follows:

1)	Microcomputer alternate	$ 9,145.00
2)	Minicomputer alternate	$12,550.00
3)	Hardwired logic alternate	$31,214.00

* based on 1975 prices.

Programing - Software
(First Cost)

Computer programing for the minicomputer and microcomputer is estimated to be $5,000. The hardwired alternate will not have software cost associated with it.

The microcomputer is recommended for use as a diamond interchange traffic controller because of its program flexibility, low cost and because it can operate in a cabinet without air conditioning and heating.

The major equipment items resulting in the large cost differences are as follows:

Cabinet

The hardwired alternate requires a double cabinet with a representative cost of about $1,650 whereas the minicomputer and microcomputer require only a single cabinet ($700 - $750).

Climatic Control

The minicomputer alternate is deficient in this respect as it needs close temperature control. Thus, air conditioning and heating is required within its cabinet at an approximate cost of $500. Maintenance and breakdown of the

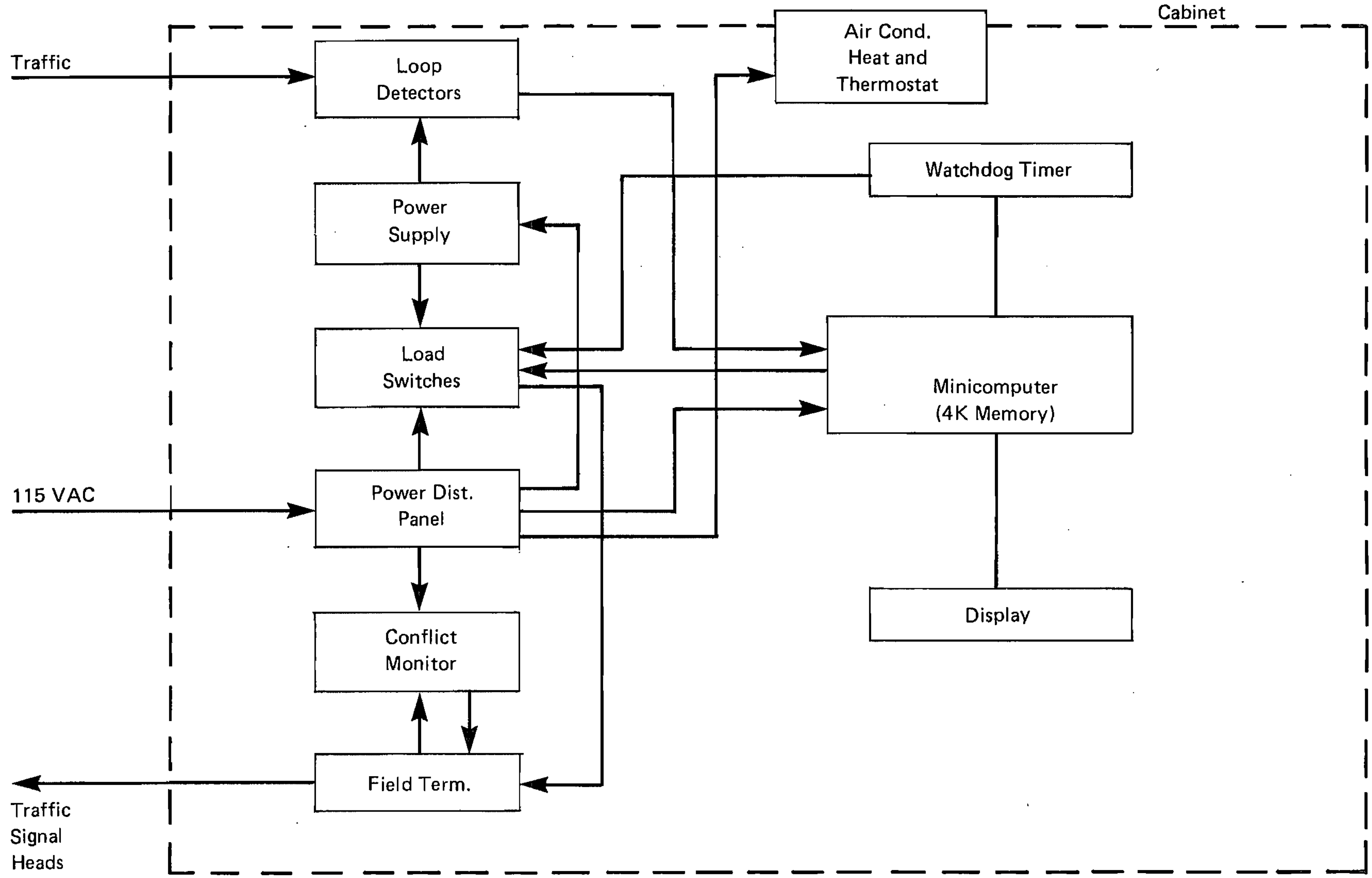


Figure 6 Diamond Interchange Traffic Controller With Minicomputer

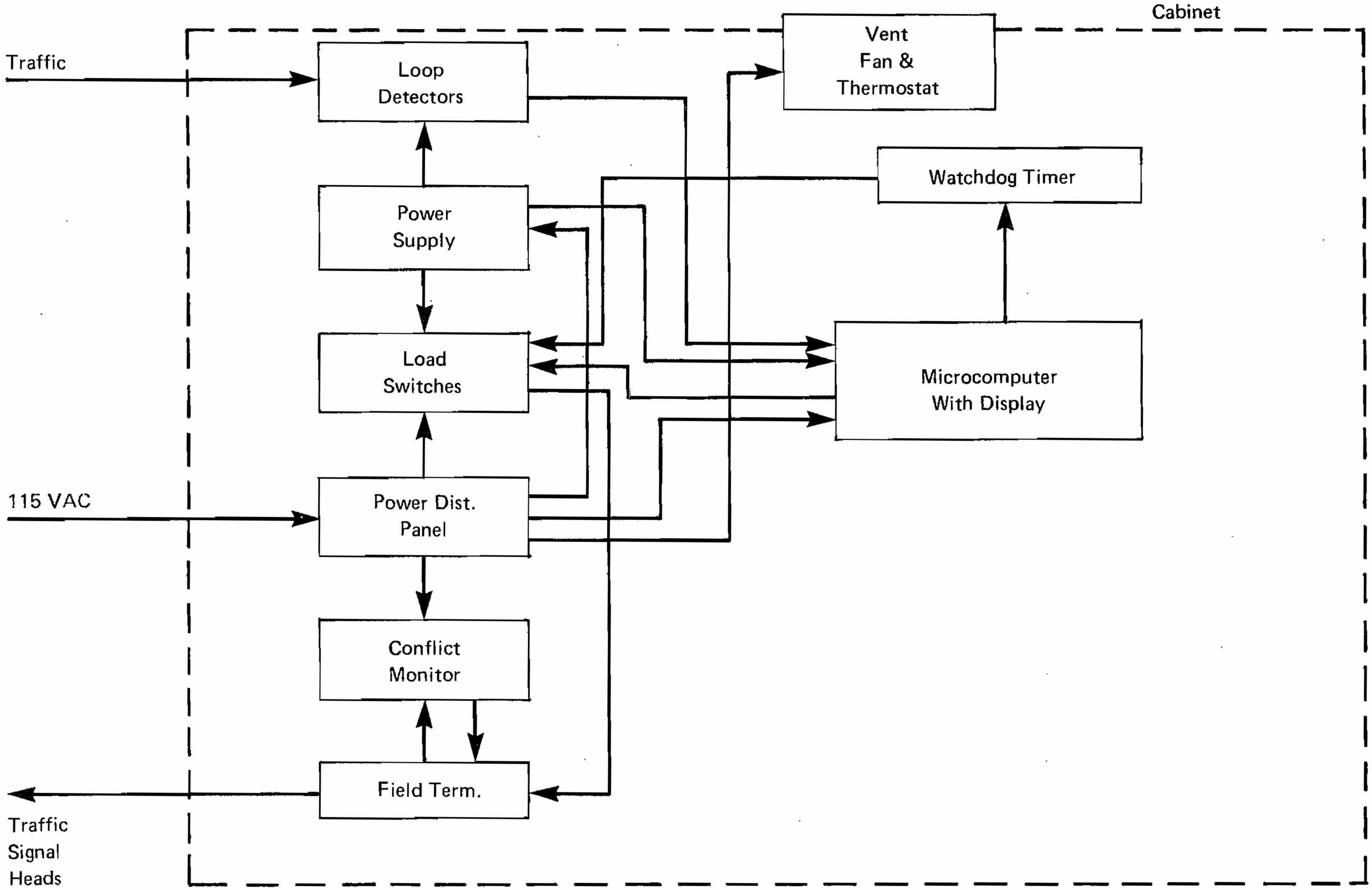


Figure 7 Diamond Interchange Traffic Controller with Microcomputer

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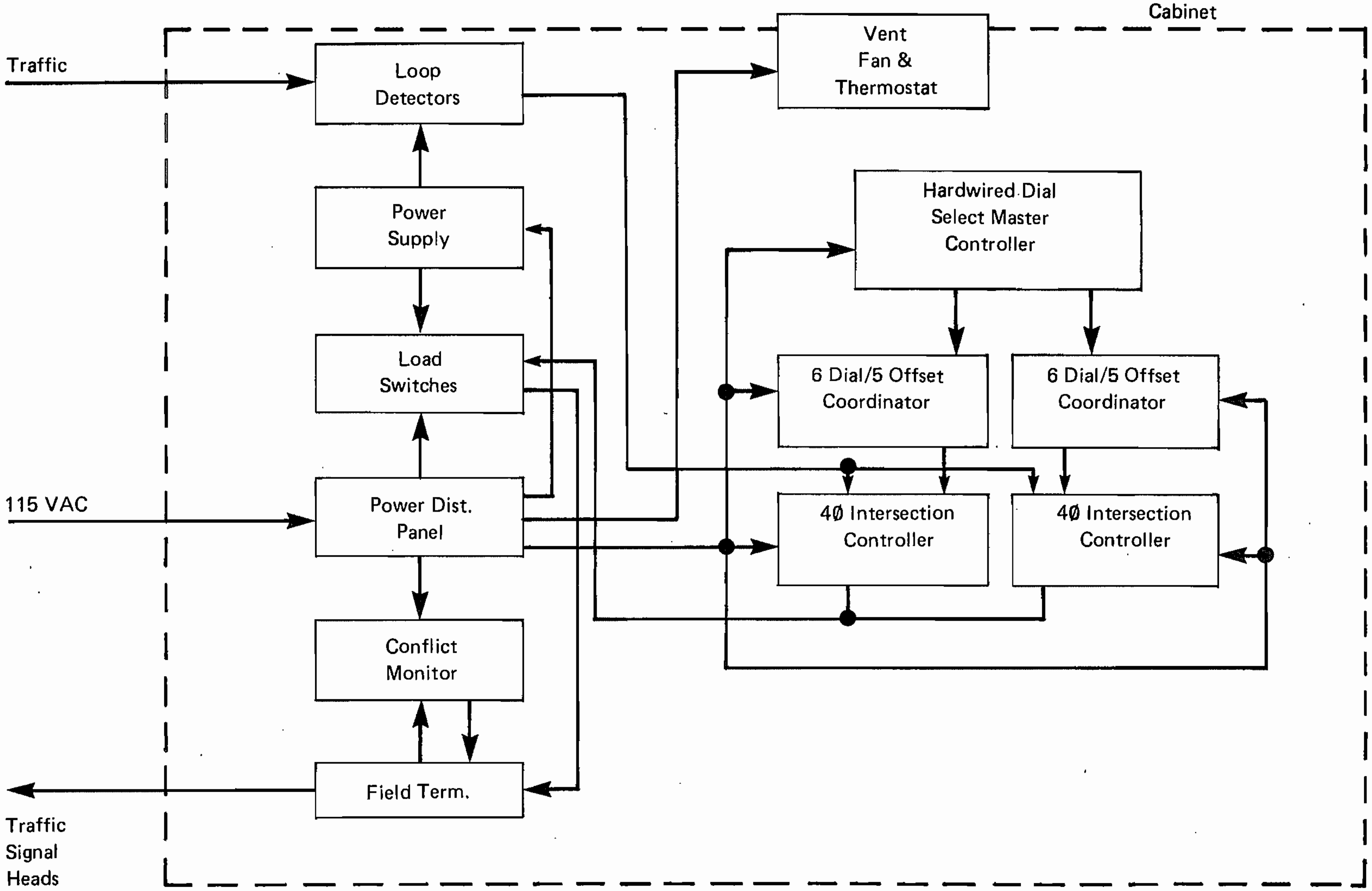

Figure 8 Diamond Interchange Hardwired Traffic Controller

	Alternate Hardware Systems, $		
	Minicomputer	Microcomputer	Hardwired
Cabinet	$ 750	$ 700	$ 1,650
Power Supply	300	300	300
Display	800	-	-
Detectors (20 req'd)	1,300	1,300	1,300
Load Rack (12 load switches)	1,300	1,300	1,300
Air Conditioning & Heating	500	-	-
Ventilation Fan	-	45	90
Wiring & Assembly (including parts)	2,000	1,900	3,000
Power Distribution Panel	600	600	600
Monitor	500	500	500
Computer	4,500	2,500	-
Dial Select Master Controller	-	-	7,200
6 Dial/5 Offset Coordinator (2 req'd)	-	-	7,600
Traffic Semi-actuated Controller (2 req'd)	-	-	7,574
Test Panel	-	-	100
TOTAL	$12,550	$ 9,145	$31,214
*Programing Amortized over 10 units	5,000	5,000	-
	$17,550	$14,145	$31,214

Figure 9. Equipment and programing cost comparison for three alternate hardware systems (based on 1975 State of California costs).

A=Best B=Satisfactory C=Adequate

	Minicomputer	Microcomputer	Hardwired
Cost	B ($12,550)	A ($9,145)	C ($31,214)
Software	C (needed)	C (needed)	A (none needed)
Flexibility	A (completely flexible)	A (completely flexible)	C (inflexible)
Maintenance (training)	C	B	A
Maintenance (actual)	C	B (limited field experience)	C (needs mechanical maintenance)
Climatic Control	C (needs climatic control)	A (vent fan only)	A (vent fan only)
Support Systems	A (operates independently)	A (operates independently)	C (requires master controller)
AC Power Req'd	C (uses most energy)	A (uses least energy)	B
Housing Size	B	A	C
MTBF	B	A	B
Field Installation	B	B	B
Centralized Control	A	A	B
Control Strategy Expansion	A	A	C

Figure 10. Comparison of relative benefits of three alternate hardware configurations for traffic control of diamond interchanges.

air conditioning and heating systems are an added detriment, whereas the microcomputer and hardwired alternates require only vent fans for $45 - $90.

Wiring and Assembly

Wiring and assembly costs the most for the hardwired alternative ($3,000) whereas it will be the least expensive ($1,900) for the microcomputer. This is because minicomputer and microprocessor alternatives do not utilize external logic controls; consequently, less cabinet wiring is required.

Logic Controls

The major cost difference is the logic control equipment for the traffic signals. Note that the hardwired alternate requires master controllers, offset coordinators and a test panel which aggregates $22,474, whereas a minicomputer or a microcomputer doing the same job costs $4,500 and $2,500, respectively.

3. Design of Selected Hardware

Once the microcomputer approach had been selected, a detailed design of this equipment was undertaken. Major consideration in the hardware design was given to the following factors:

(i) Utilization of standard traffic control components where applicable and cost-effective.

(ii) The most prominent diamond signalization strategies must be implementable with the controller design.

(iii) Components should be readily accessible for field maintenance and removable for shop maintenance.

(iv) The controller should be adaptable to operation within a system. Communications with other controllers or a master controller should be readily implementable.

(v) The operator interface should be simple and engineered in a manner that allows traffic engineers to adjust timing and change and display parameters with a minimum of training.

(vi) Cost must be kept to a minimum consistent with adequate operational capability, maintainability and reliability.

(vii) Proven technology must be utilized.

(viii) Maintainability and reliability should be emphasized.

The final design (see Figure 7) incorporates load switches, flasher, flash and flash transfer relays, detector amplifiers, and mercury contacts which are off-the-shelf standard components presently in use by the traffic control industry.

The specifications for the microcomputer controller were developed in cooperation with the State of New York. Comments on the draft specifications have been received from other States, cities, and industry. A copy of the specification is attached as Appendix B of this package.

Unlike the controller proposed by SDC, this unit directly switches the signals for both ramp intersections. Local controllers for those intersections are then not needed. The controller unit is housed in a ground-mounted cabinet located within the interchange complex. Local controllers may be employed at adjacent intersections. With appropriate software, various types of interconnect hardware can be accommodated. Fifty-four 120-volt output circuits can be switched by the microcomputer. A normal diamond interchange using the "four-phase overlap" sequence with pedestrian signals utilizes 36 output circuits, exclusive of any needed for interconnect, right-turn green arrows or other special needs. Forty-two detector inputs can also be accommodated. These may be vehicle detectors, pedestrian push-buttons, preempts or special interconnect signals.

The cabinet permits 36 output circuits and 44 input circuits in its basic configuration. More outputs can be utilized by installing an additional output file.

Time display and changes are accomplished by means of a readout and keyboard similar to electronic hand-held calculators which are now so popular. Vehicle counts, flow rates, etc., can also be displayed with this versatile arrangement.

The flexibility of this controller unit arrangement is illustrated by the fact that the prototype unit was installed at a diamond interchange in California that employed the four-phase overlap sequence with full pedestrian signals. The controller unit was then installed in Florida on March 19, 1976, in a configuration that had no pedestrian signals, a different phase sequence and an adjacent coordinated intersection. It remained in operation there until September 6, 1976, at which time it was returned to California.

Several program changes were made while the controller was in Florida. These changes necessitated changing a memory chip in the controller unit and changing various timing intervals. These changes were accomplished in Florida by personnel who had no special training on microprocessors.

4. Cost-Effectiveness and Cost Benefits

Traffic engineers know that changes in traffic operations must benefit the public and must be cost-effective to be considered worthwhile. Some of the benefits include reduced number of stops, fuel consumption, pollutants emitted and increased safety. In order to properly evaluate benefits they must be equated to the costs involved. Several benefits are difficult to evaluate.

A value can be placed on safety, but a large sample size is needed to determine the effect on vehicle accidents of various changes. Traffic engineers know that installing a left-turn pocket reduces rear-end accidents, installing signals reduces intersecting accidents but may increase rear-end accidents, installing a protected left-turn signal phase reduces approach-turn accidents, etc. The list can go on and on. The investigators are unaware of any studies quantifying the effects of vehicular stops and delay on accidents. A reasonable assumption might be that less stops would result in less rear-end accidents. It is the opinion of the investigators that a protected left-turn movement is safer than the permissive movement as utilized in Jacksonville. For the purpose of this analysis, the investigators feel that insufficient data exists to properly quantify safety considerations.

Numerous studies are currently in progress to determine the costs of the effects of air pollution. When those studies are complete, traffic engineers will be able to quantify the economic benefits of improvement alternatives. Unfortunately, at this time the investigators are unaware of results from any of these studies. Consequently, analysis does not consider the effects on air pollution of alternative signal strategies.

The benefits analysis has been limited to savings in delay and fuel because of the above-mentioned difficulties in evaluating safety and pollution. In determining the costs involved, it was assumed that traffic signals were warranted; the question the traffic engineer was faced with was what kind of signals should be installed and how should they operate?

The microcomputer controller has previously been shown to be the more cost-effective alternative for all types of real-time and actuated control strategies. The cost-effectiveness of installing these strategies versus

Table 1. Estimated life cycle costs*
for various strategies.

Signalized Diamond Interchange

	Real-time or full-actuated	Semi-actuated	3-Dial pre-timed
Controller type	Microprocessor	Microprocessor	Drum & Dial
Site Preparation	$15,000	$15,000	$15,000
Loop Detectors	3,850	1,650	-0-
Controller Unit	7,845	7,845	5,000
Subtotal Construction Costs	26,695	24,495	20,000
Interest 15 years at 6 percent	38,800	35,700	29,100
Maintenance (callout)	1,472	1,104	368
Maintenance (bench repair)	3,030	2,400	1,410
Inspection (monthly)	2,850	2,850	2,850
TOTAL	$72,847	$66,549	$54,728
Average Annual Cost	$ 4,856	$ 4,435	$ 3,648

*This table considers equipment and site costs only. For stops, delay and fuel consumption data see Tables II and III.

other types of control, such as fixed-time or stop sign, can only be determined by an analysis of the potential benefits in a given location.

The estimated cost of signalizing a diamond interchange (Table 1) assumes the use of the microcomputer controller for all real-time or traffic actuated control alternatives. A life of 15 years is assumed for the installation. Maintenance costs were taken from the California Department of Transportation, Maintenance Management System, dated February 17, 1976. The cost of a real-time control or full traffic actuated installation is estimated to be approximately one-third higher than a three-dial pretimed installation.

It is assumed the cost of programing is amortized over a large enough quantity to become negligible. If special programing is required, the cost could range to as much as $5,000.

The value of delay savings has traditionally been used by traffic engineers to justify operational improvements. The California Department of Transportation currently uses 8 cents per vehicle-minute for the value of vehicle time. This value considers only the value of drivers' and passengers' time for a mix of commercial and noncommercial trips.

Any value placed on delay of noncommercial trips is highly subjective and open to question. Time saving to someone on a social/recreational trip does not provide more money to the economy. It does not provide more income to the driver. However, because it is a means familiar to traffic engineers, the investigators have included it in this analysis.

A study was conducted by SDC of the relative benefit of operation vs. traffic responsive fixed-time operation. The results indicated a reduction of 20 - 30 percent in both stops and delay for the traffic responsive operation. Using information from NCHRP Report #111 and the data reported by SDC, the fuel consumption savings at the Western Avenue diamond interchange in Los Angeles, California, is estimated to be 100,000 gallons per year.

Data received from Harland Bartholomew and Associates from its study of timing control strategies for diamond interchanges (Reference 6) in Jacksonville, Florida, indicated decreased delay and increased number of stops for the actuated strategy when compared with the fixed-time. Table 2 shows this data.

Table 2. Stops and delay for fixed-time and actuated diamond strategies.

Period	Aver. # Veh.	Stops/Veh. Fixed Time	Stops/Veh. Actuated	Delay/Veh. (seconds) Fixed Time	Delay/Veh. (seconds) Actuated
2-hour AM peak	1289	0.63	0.83	15.26	9.6
2-hour PM peak	2203	0.60	0.91	14.28	12.95
1-hour Offpeak	659	0.59	0.74	13.8	9.46

Table 3. Delay and excess gasoline consumption for fixed-time and actuated diamond strategies.

	Annual Delay at $.08 Min.	Annual Excess Gas Consumption
Fixed Time	$66,667	29,555 gallons
Actuated	$48,136	33,921 gallons

To get some indication of the annual benefit/cost ratio, this data was used in conjunction with the following assumptions:

1.) Each day consisted of one each 2-hour a.m. peak; one each 2-hour p.m. peak; and 12 each 1-hour off-peak periods. Other periods of the day and Sundays were assumed to be the same for all control types.

2.) Each stop resulted in 0.01 gallons of excess gasoline consumed (NCHRP #111).

3.) Stopped delay consumes 0.58 gallons of gasoline an hour (NCHRP #111).

4.) Delay time is valued at 8 cents a minute.

Table 3 shows the value of annual delay and excess fuel consumption. Although these results indicate that actuated control is more efficient from a delay standpoint but consumes more gasoline, the data indicates that this is highly dependent on traffic patterns and that to apply these results and attempt to draw a generalization might well be a mistake. Far more study in this area is required.

5. Software Considerations

The software program incorporates, via a front panel display, features which allow a traffic engineer to look at present timings, detector counts, and coordination parameters. In addition, he can look at current intervals and watch them time down and terminate. The engineer can also alter necessary timings and thresholds through a pushbutton (calculator-type) array. All timings are entered and displayed in decimal so as to preclude the conversion of familiar numbers to octal or hexadecimal numbering systems.

The power failure monitor program continuously monitors the power line, looking for a power outage. Should a power outage occur, the program will bring the controller to an orderly shutdown and prepare for the reapplication of power. When power returns, the program goes through an orderly start-up sequence so as to not display hazardous indications to the motorists.

The continuing need to conserve energy, and increasing public concern with air quality have altered traditional traffic engineering priorities. In the past, minimizing delay was considered to be a prime objective in installing and timing traffic signals. Previous work done by SDC in developing a diamond interchange control strategy was based almost entirely on minimizing delay. More recent work indicates that fuel economy and air quality are adversely affected by minimizing vehicular delay at the expense of the number of stops. The diamond interchange controller with the proper software is capable of duplicating virtually any control strategy. Software being developed by the States of California and New York will permit the controller to function as a two- to eight-phase actuated or fixed-time controller or a master to a system of controllers on an arterial. Software for unusual applications may be developed and maintained by the local engineer based on existing packages or he may purchase it in a fashion similar to purchasing unique hardwired units.

6. <u>Caveat Emptor - Let the Buyer Beware</u>

Whenever a new piece of equipment is purchased, there will be drawbacks. In order to crystallize these in the mind of the user, they are listed below:

1.) Anytime software or programs are utilized, there is a need for software support and/or maintenance. When standard packages are utilized, this will be minimal. However, if a user develops special applications control packages, this could be an important cost element.

2.) There will always be advances in hardware, software, and control strategy techniques. The controller will be readily adaptable to new control strategies. The question of timing of when to buy new controllers or whether to wait for new development is a decision each buyer must decide.

3.) This equipment, like previous controllers, is fairly complicated and should be acceptance tested. This may be done on a small scale sampling of units purchased or by an extensive testing of all units purchased. A program has been developed which will assist with this testing. Further enhancements to this program are being made. Purchase of a programing unit will allow a user with programing expertise to implement his own programs.

4.) At present, a limited number of software packages are available from California and New York States. The status of these packages is described in Appendix B. Should a user have an application not covered by these packages, there are several possibilities: the user can program the special application; the user can purchase the application program with a controller; or the user can have the program developed for him.

5.) Whenever traffic control devices are purchased, there is a question of legal liability. These questions will have different answers from State to State and city to city. Your local legal staff should be consulted, should questions arise.

6.) Cost for these controllers may vary depending on the number of units, training, and software purchased. Your local industry representatives may supply some information. Low bid purchasing should involve careful specification of deliverable items.

C. Summary and Conclusions

A microcomputer controller has been designed, constructed, and installed as part of this contract. The controller was installed in Visalia, California. It was later removed and installed in Jacksonville, Florida.

It will be as easy for the traffic engineer to implement this controller as it is for him to use his electronic calculator. There are three standard control packages available: 1) an actuated diamond interchange program which is currently being enhanced, 2) a ramp meter control program, and 3) an isolated two- to eight-phase control program which is also being enhanced (see Appendix A for detailed status). These packages will handle most applications. When using them, the traffic engineer will only be required to set timings, thresholds, and sequences for the particular intersection, ramp, or diamond interchange he is controlling.

The State of California feels that the recommended controller is flexible enough to be used for many other traffic signal applications and that strong consideration should be given to the use of the Type 170 controller as a standard intersection controller.

The conclusions from the work on this project are as follows:

- The microcomputer controller alternative is the most cost-effective hardware to implement traffic signal control algorithms, while retaining the flexibility that allows standardization.
- The Type 170 hardware is a viable design which has been tested and proven in the field. The unit is multiple sourced. There are six manufacturers who have produced and supplied this unit. The Type 170 is being specified as the standard intersection controller by the States of California and New York on the basis of its low cost, reliability, ease of use, flexibility, and potential for standardization.
- The microcomputer controller is the only controller which can meet the continuing need for advances in control strategy technologies without requiring new hardware.

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APPENDIX A

Status of Software Packages from California and New York

1. Standard Isolated Eight-Phase Controller

   A Type 170 controller unit with this program installed will perform the functions required of a typical NEMA eight-phase volume density controller.

   Four phases have associated concurrent pedestrian movements. The eight phases are arranged into two rings of four phases each. Any phases without a demand can be skipped. Therefore, this program can be used for most two- through four-phase, single ring, and five- through eight-phase, dual ring, applications.

   All phase times are easily displayed and entered. The current phase and interval status of each ring is displayed as are the vehicle and pedestrian calls. Typical phase flags such as recalls, detector memory, double entry, second maximum and red rest are readily displayed and changed.

   The basic program also includes: two railroad preempts, four emergency vehicle preempts, standard and Type 3 calling detectors, right turn detectors and four right turn arrow overlaps.

2. Enhanced Version of the Standard Eight-Phase Controller

   The enhanced version will include detector malfunction monitoring and vehicle count recording features as well as all of the operating features of the basic program.

3. Yellow Yield - Mutual Coordination

   When added to the basic eight-phase program, this subroutine will allow for coordination between a 170 controller and a controller at an adjacent intersection based on a yellow yield circuit.

4. Local 3-Dial 3-Offset Coordination

   This subroutine will be added to the basic program when the controller is to be placed in a 3-dial coordinated system.

   The subroutine will receive dial and offset commands from a master controller via multiplexed or single-function hardwired interconnect.

   The subroutine will exercise the hold and force-off of the basic controller program to provide the required coordinated operation.

5. Master 3-Dial 3-Offset Coordination

This program will operate a 170 controller unit as a master controller for a series of local intersections. The program will be capable of operating on a stand-alone basis or being incorporated into a basic local controller program so as to act both as a master controller and to directly control the local intersection. It will select traffic plans based on both time of day, day of week, and traffic flow information.

6. Enhanced Interconnected System Program

This program will fully implement the Type 170 controller as an on-street distributed processing system supervisor with extensive data collection and timing plan selection capability. The local controllers will gather and accumulate data for transmission to the supervisory controller. This format will minimize communications costs. Extensive equipment malfunction monitoring will be incorporated. Volume, occupancy, and time of day/day of week will be used for timing plan selection.

7. Traffic-Actuated Diamond Interchange Program

This program will operate a diamond interchange in an isolated full-actuated mode. This program operates as a four-ring controller and controls both ramp intersections directly.

8. Enhanced Diamond Interchange Program

This program will allow for operation of a diamond interchange in any one of three modes. The three modes are the four-phase overlap mode, the three-phase lag-lag mode, and the isolated full-actuated mode (see Figures 4A and 4B of text). The mode of operation will be selectable by time of day, day of week, and traffic count information.

The ability to coordinate adjacent intersections as well as be coordinated by a system master will also be incorporated in this program.

The program will contain malfunction monitoring and count recording capability.

9. Acceptance Testing Program

This program, in conjunction with testing procedures, programs the 170 controller unit to test the controller and cabinet. All input and output functions are tested as well as all bits of Ram memory. The logic and timing functions of the microcomputer are also tested.

Status of Software Development

Program Nos. 1 and 7 are completed, debugged, and have been installed in the field. The documentation is in the final stages of completion and should be available early in 1978. From California, Program Nos. 2, 3, 4, 5, 8, and 9 are currently under development and scheduled for completion at various times during calendar year 1978.

Program No. 6 is not presently under development. New York State is presently planning a development along these lines.

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA BULLETIN
Distributed - Movie "Improvements for Diamond Interchange Traffic Conrol"	July 14, 1977

The motion picture film "Improvements for Diamond Interchange Traffic Control" describes a research effort on diamond interchange traffic control that began in 1966. The film describes the development and testing of the real-time control system which evolved through simulation analysis of real-time control using a series of candidate control algorithms, construction of a computerized system in Los Angeles, and field testing of an algorithm which minimized average vehicle delay. Results indicated a 20-30 percent reduction in both delay and stops for motorists using the diamond interchange complex.

It should be pointed out that the hardware and software shown in the movie have become outdated and controllers designed around a microcomputer are now recommended for this application. As a follow-up to the research depicted in the film, the State of California has developed purchase order specifications for a low cost diamond interchange traffic controller. The specifications may be obtained by writing to CalTrans, Division of Highways, 1120 N Street, Sacramento, California 95814.

One copy of the movie is attached for circulation to the States, counties, and cities within your region. Efforts should be made to ensure that each State Traffic Engineer has an opportunity to see the film. Feedback on the use of the film would be appreciated. Further information may be obtained from the Implementation Division, HDV-21, Office of Development.

G. D. Love
Associate Administrator for
Research and Development

Attachment

DISTRIBUTION: H-WDM-1 OPI: HDV-21

APPENDIX C

For Further Information, Contact:

The following manufacturers can provide additional information on the Type 170 controller:

Automation Development Company
A Division of Weaver Associates Inc
521 West Florence Avenue
Inglewood, California 90301

Data Communications Systems
P. O. Box 346
Boulder, Colorado 80302

Eagle Signal
8004 Camero Road
Austin, Texas 78753

Multisonics Inc.
P. O. Box 2295
Dublin, California 94566

Safetran Systems Corp
3281 Scott Blvd.
Santa Clara, California 95050

Traffic Management Center
Honeywell Inc.
600 Second Street, NE
Hopkins, Minnesota 55343

APPENDIX D
California Bid Results (Quantities Purchased in Parenthesis)

California Bids Opened 6/28/78 #4299 VENDOR	Model 400 MODEM (400)	Model 170 Controller Units (120)	Model 200 Switchpacks (1500)	Model 222 Loop Sensors	Model 224 Loop Sensors (500)	Model 210 Monitor Units (100)	Model 242 Isolation Modules (2000)	Model 332 Cabinets (120)	Model 400 Auxiliary Output File (40)
A.D.C. 1% - 30 SmB								$2750.00	
CANOGA CONTROLS 1% - 20 SmB					$142.00				
DETECTOR SYSTEMS 2% - 21 SmB					$124.50				
D.C.S.	$400.00	$1805.00							
EAGLE 1% - 30		$1889.00			$229.00			$3246.00	
GORDOS			$39.65						
HONEYWELL		$1850.00						$3162.00	
LAB. ELECTRONICS SALES CORP. -NY- 1% - 21							$31.00		
MULTISONICS 2% - 30		$1352.00					$37.00		
SAFETRAN		$1392.00				$269.00		$3625.00	$449.00
SIGNAL AND CONTROL SYSTEMS - Wash. 1% - 21	$299.00								
TRACONEX SmB			$44.00			$275.00	$36.00		

California Bids Opened 6/29/78 #4298 VENDOR	Model 400 MODEM	Model 170 Controller Units (120)	Model 200 Switchpacks	Model 222 Loop Sensors	Model 224 Loop Sensors	Model 210 Monitor Units	Model 242 Isolation Modules	Model 332 Cabinets (120)	Model 400 Auxiliary Output File
A.D.C. 1% - 30 SmB		$1350.00						$2797.00	
EAGLE 1% - 30		$1470.00						$3066.00	
HONEYWELL		$1740.00						$3052.00	
MULTISONICS 2% - 30		$1760.00						$3135.00	
SAFETRAN 5% - 30		$1392.00						$3625.00	

California Bids Opened 6/28/78 #4308 VENDOR	Model 400 MODEM	Model 170 Controller Units	Model 200 Switchbacks	Model 222 Loop Sensors	Model 224 Loop Sensors	Model 210 Monitor Units	Model 242 Isolation Modules	Model 332 Cabinets	Model 400 Auxiliary Output File
EAGLE 1% - 30 days				$114.50					
I.C.C. SmB				$ 59.90					
DETECTOR SYSTEMS 2% - 21 SmB				$ 98.50					
SARASOTA				$118.80					
CANOGA CONTROLS 1% - 20 SmB				$117.50 *					
* 25% discount if awarded both 222 and 224 bids									

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-TS-217		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code / 8. Performing Organization Report No.
Diamond Interchange Traffic Signal Controller- The California-New York Specification	5. Report Date: July 1977
	6. Performing Organization Code:
7. Author(s): L.Kubel, G.Bloodgood, F Workmon	8. Performing Organization Report No.:
9. Performing Organization Name and Address: Caltrans, Division of Highways, 1120 N. Street, Sacramento, California 95814	10. Work Unit No. (TRAIS):
	11. Contract or Grant No.: DOT-FH-11- 8250 Task #3
12. Sponsoring Agency Name and Address: U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. 20591	13. Type of Report and Period Covered: Traffic Signal Equipment Specifications
	14. Sponsoring Agency Code:

15. Supplementary Notes

FHWA Contract Manager: David R.P.Gibson (HDV-21)
(202) 426-9205

16. Abstract

The Diamond Interchange Traffic Signal Controller was developed and Implemented by California in both California and Florida under contract to the Federal Highway Administration. The functions of the controller include both traffic surveillance and control in either traffic actuated or fixed time modes. The controller has a wide variety of applications including ramp metering, diamond interchange control and normal intersection control. The specifications have been used for the procurement of over 800 controllers by the States of California and New York.

17. Key Words	18. Distribution Statement
Computers, Detectors, Microprocessors, Controllers, Signals, Traffic Control Systems	No restrictions. Copies of this manual are available from: National Technical Information Service Springfield, Virginia 22151

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