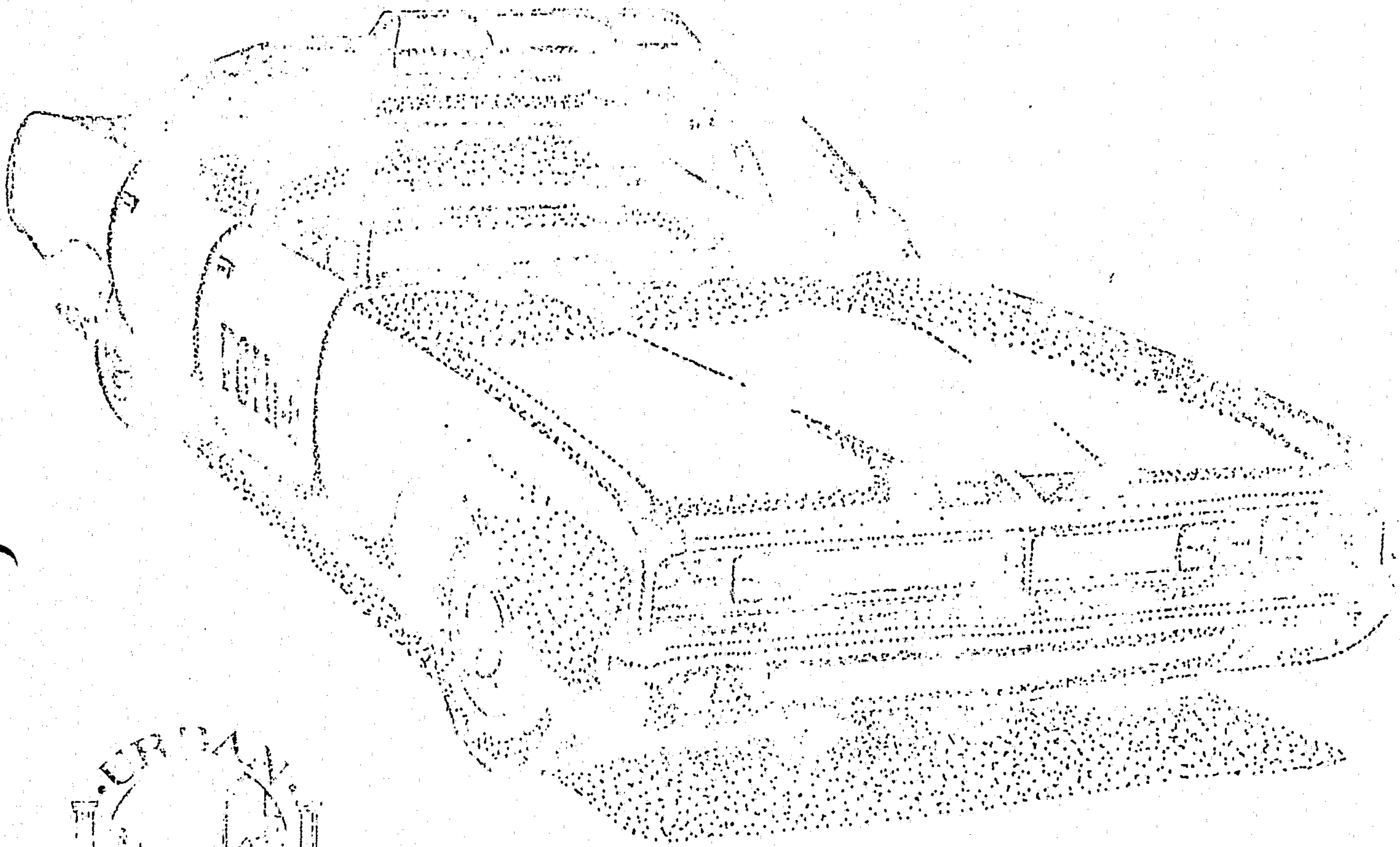
THE IDEAL POLICE CAR



DENVER URBAN OBSERVATORY
CITY AND COUNTY OF DENVER
MARTIN MARIETTA CORPORATION
DENVER RESEARCH INSTITUTE/UNIVERSITY OF DENVER

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THE IDEAL POLICE CAR

Technical Report

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"Improving Local Government Access to Technology"

PREFACE

The Denver Urban Observatory began operation in January 1970 as one of a number of Urban Observatories in a national network. The objectives of the Observatory program are to address the research needs of local government officials and others interested in solving urban problems, to develop a reservoir of comparable, reliable data of general application to the nation's cities, and to build a set of institutional relationships between local public officials and local universities and colleges to help develop and improve public policy and governmental action. The research activities are conducted by university and college faculty and students working together with local governmental personnel and private industry specialists. The establishment and continued operation of this Observatory have been made possible through the support of National League of Cities, Department of Housing and Urban Development, National Science Foundation, City and County of Denver, University of Colorado, Metropolitan State College, Community College of Denver, and University of Denver.

The Denver Technological Innovation Center was established as a part of the Denver Urban Observatory in 1975 with the support of the National Science Foundation, the University of Denver, City and County of Denver and Martin Marietta Corporation to assist Denver government in solving technological problems.

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THE DENVER URBAN OBSERVATORY

City and County of Denver
W.H. McNichols, Jr., Mayor

OBSERVATORY POLICY BOARD

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USE STATEMENT

This report is intended to assist in your selection of new police vehicles. Its rationale is not to focus on a single vehicle, but to concentrate on several selected elements that make up the vehicle.

Our primary purpose is to make you more aware of current technology, of what other cities are doing, and of what research the government is conducting. If this document serves no other purpose than to foster awareness, then we feel it's worthwhile.

How you use this particular document is, of course, optional. We hope you will use it as a part of your decision making process in the selection of a vehicle to best meet your particular needs. In this regard, we ask you to circulate this report to those people in your department who have the responsibility for choice, specifications, and acquisition.

Obviously an undertaking of this kind--attempting to design an ideal police car--cannot possibly incorporate all the excellent ideas which are available throughout the country; therefore, after reviewing this document, should you have suggestions for improvement, we would welcome your forwarding those suggestions to the Denver Urban Observatory. Should we receive a sufficient number of such suggestions, we will publish a second report.

INTRODUCTION

The Police Car of the 1970's is not adequate for the demands placed upon it.

Probably the most important thing expected out of a police car is dependability. It is not sufficient to serve one man for one eight hour shift. The police car is expected for the most part to operate on a twenty-four hour basis, operating under three different sets of personnel. This constant use is expected in all kinds of weather and under a variety of road conditions. For hours the car is expected to move along at speeds not exceeding 30 mph in heavy urban traffic and then instantaneously accelerate to high speeds for an emergency run. At times the police patrol car is expected to serve as a paddy wagon, an ambulance, an interrogation room, a tactical communications center, a vehicle to transport stolen goods, and a bus to transport police officers. In summary, the car is expected to be as maneuverable and quick as a sports car and as durable as a heavy sedan.

As can be seen from the expected uses, the car should be designed to incorporate features of many vehicles on the road today. Some examples are:

(1) Heavy sedan - desirable characteristics include weight, room, durability.
(2) Sports car - desirable characteristics include suspension, power to weight ratio, maneuverability.
(3) Heavy commercial vehicles (trucks, taxicabs) - desirable characteristics include durability, ease in maintenance over long periods of time and mileage.

Although the police car should encompass the characteristics previously described, it must in all cases be safe. It must not only be safe for the passengers within the vehicle itself, but also safe for the people outside and around it. The car operates for long periods of time in areas of very dense population, in situations where mechanical failure, lack of maneuverability, and/or stopping ability carries with it a very high risk in terms of cost to life.

The "Ideal" Police Car will never be manufactured.

Ideally, a police car should be designed for its job, much the same as any other service vehicle. This design -- from the ground up -- would place an unrealistic financial burden on any municipality; thus, it seems highly impractical that the "super car" will ever be a reality. It is also highly unlikely that an "ideal" vehicle will serve the needs (likes/dislikes) of the numerous police departments throughout the nation.

The available alternative is to adapt existing technology to the stock vehicle in an attempt to approach ideality.

Nationally, does there seem to be an "ideal" vehicle?

Five years ago, Prince George's County in New Jersey conducted a survey of 43 police departments across the United States. Some of their key findings were:

- All departments purchased a standard size vehicle.
- 93% purchased 4-door vehicles.
- 50% purchased air conditioned vehicles.
- 72% specified disc brakes
- 72% specified power steering.

The engine sizes ranged from 250 C.I.D. (4100cc) to 430 C.I.D. (7000 cc); carburation either 2- or 4-barrel. Almost all departments specified heavy duty suspension. All departments specified automatic heavy duty transmissions. Uses covered highway patrol, general patrol, and city use.

What is the current State-of-the-Art?

The National Institute of Law Enforcement and Criminal Justice (NILECJ) has established a Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards in Gaithersburg, Maryland. Under this program, evaluation and testing of police equipment has resulted to date in several documents:

- LESP-RPT-0003.00, June 1974. LEAA Police Equipment Survey of 1972, Volume III: Sirens and Emergency Warning Lights.

- LESP-RPT-0007.00, April 1974. LEAA Police Equipment Survey of 1972, Volume VII: Patrol Cars.

- LESP-RPT-0401.00, May 1974. Terms and Definitions for Police Patrol Cars (Stock No. 2700-00252).

- LESP-RPT-0403,00, July 1975. The Police Patrol Car: State of the Art (Stock No. 027-000-00345-1)

There are several other documents pertaining to radial tires, life cycle costing, sirens, and warning devices.

We feel all law enforcement agencies should be aware of these documents and of LESL's role in their generation.

COMPONENTS

The Engine - Police are at a disadvantage.

The kind, type, and size of engine has, and will continue to be one of the major problems in police vehicle design. Above and beyond the concept of the pursuit of another vehicle, is the consideration of emergency runs where police vehicles must get from one area to another as quickly as possible. Asked to sprint at times, the car is also asked to run continuously. To characterize the power requirements for such a vehicle is virtually impossible. What is gained in durability and ease of maintenance is lost in power available for peak demands.

Considering the police cruiser as a pursuit vehicle, one must look at the huge power requirements. The cruiser is now competing with some of the best technology in the field of powering automobiles. It is competing with cars that have the best maintenance and are only operated at a very small fraction of the time that police cars are.

Many of the cars that will be competed with are much lighter. This is the most important consideration in powering a vehicle; that is, the power to weight ratio. A three-hundred and fifty horsepower engine is considerably more effective in a three thousand pound car than in a five thousand pound car. By the very nature of police work, a heavy car is desirable, putting the police at a disadvantage, no matter how big the engine.

One other situation that requires the use of a large engine is emergency runs. Emergency runs, unlike high speed pursuits, cannot be eliminated by a change of "hot pursuit" policy.

An emergency run requires the car to get between two points as quickly as possible. In city driving this does not so much require such high rates of speed as it does high acceleration. The car would have to be able to maneuver through heavy traffic, then speed up, slow down for the interesection, speed up again, slow for curves, and speed up continuously. The constant change in speed requires power. Here again comes the need for a very large engine for a large car. This engine need not be as large as that which would be required for an effective pursuit car.

Both of the above mentioned uses of the police vehicle are directly opposed to its use as a patrol vehicle which runs at low speeds. Better than thirty-percent of the vehicles operating time is spent as a patrol vehicle. The time spent as a patrol car is the hardest time on the engine. The car is operating hour after hour in city traffic at ten to thirty miles per hour. Operating at low speeds causes carbon deposits to build up within the engine. These carbon deposits foul the spark plugs and reduce the size of the combustion chamber, greatly reducing the efficiency and productivity of the engine. Where as a clean internal combustion engine operated at an efficiency between 20% and possibly 40% (a highly tuned, specially built engine), a carboned-up engine will operate as low as 5% before refusing to run. The carboning problem is one of the major contributions to the 20% downtime which many patrol cars suffer beyond their regular scheduled downtime for maintenance.

The problem is a very difficult one to alleviate. Some partial solutions would be: lowering the gear ratio, raising the operating temperature, changing the carburetion, redesigning the engine, using a smaller engine, or using a different type of engine.

By lowering the gear ratios, the engine would be turning over faster, much as it would in highway driving, thus blowing the carbon out. The major drawback is that it reduces the top speed of the car considerably. Some type of compromise could be worked out by redesigning the transmission and adding more gears to develop a greater range of gear ratios. Considerably more research would have to be done, but this approach appears to be the most practical one to be realized in the near future.

Another possible solution that could be combined with the first would be raising the operating temperature of the engine. This could be done in various ways. The most obvious would be a slight change in the cooling system. By operating at a higher temperature, the engine would become more efficient, burning more of the carbons in the fuel. Engineers for years have been trying to raise the temperature, but the limitation of materials continues to hold them back. The outlook might possibly be changing with the development of high temperature materials for aerospace applications. However, it must be possible for these materials to be mass produced economically before their application can be widespread in the automobile industry.

Changing the carburetion so that the engine runs leaner can also reduce the build-up of carbon deposits. The major disadvantage is that the large, powerful engines used today are designed to run rich to gain their power. When they are set to run lean they do not generate maximum power, and they do not run smoothly or start as easily.

Redesigning the internal combustion engine has distinct possibilities, although the feasibility is questionable. Much work has been done already to eliminate the problem of carbon deposits. Any new, radical design that could feasibly accomplish this would need to be a major breakthrough in the field and would most likely require a change in fuels as well.

Using a smaller engine appears to be the ideal, immediate solution to the carbon deposit problem. It would be operating near optimum load at slower speeds, burning its fuel more efficiently and operating at higher temperatures. The problem with using a smaller engine is that the police departments don't want them for the reasons already mentioned.

At the present time, considering the size of vehicles and the general demands placed on the patrol car, it is felt that the engine should generate at least 350 hp and be in the 400 cubic inch class (6500 cc) with 4-barrel carburetors.

The Brakes - Disc vs Drum

Probably the most important aspect of any vehicle is its braking system. Presently, many police cruisers use disc brakes for the front tires and the brake shoe type for the rear tires. The disc brakes have proven to be far superior to the brake shoe type in the past.

With the conventional type of police vehicle, the engine is located in the front end. Therefore, the center of gravity is located approximately four feet from the front wheels and twenty-eight inches from the ground. Using a deceleration of 25 ft./sec.^{2} (7.6 m/sec^2), the front engined vehicle will have reactions of .781 of the car's weight (.781W) on the front wheels and .219 of the car's weight (.219W) on the rear wheels. In all front engined vehicles, the braking force on the front wheels vary from about 75% to 83%. Thus, the front wheels have to steer the vehicle and also do the majority of the deceleration. In the past, when a vehicle has decelerated fast, the front wheels have skidded after the back wheels have started skidding. Once the front wheels have commenced slipping, their braking ability is decreased, and the control is lost due to the tires losing traction. The frictional force applied to the front wheels is greater than that applied to the rear wheels. Thus, if the cruiser starts swaying while decelerating, the cruiser may very easily start fish-tailing and spin-out. The reason for this is that the front tires have greater force holding the vehicle back while there is less force on the rear tires. In addition, the rear end tends to act as a lever arm once the vehicle starts fish-tailing. As the force is less on the rear tires, the rear end tends to throw the vehicle into a spin.

It has been suggested that the vehicle will have more control while decelerating if the engine is moved to the rear. The center of gravity would change to approximately 3.5 feet from the rear tires when the engine is relocated to the rear. With this modification, the weight distribution would be more uniform with .531 of the weight on the front wheels and .469 of the weight on the rear wheels. This would give the vehicle more stability and help prevent spinning-out while decelerating.

Ideally, there should be a greater braking force exerted on the rear tires. This would practically eliminate the possibility of the vehicle spinning-out.

By moving the engine to the rear, a greater frictional force may be obtained on the rear tires to permit greater acceleration. Presently, when a police cruiser accelerates at 12.5 ft./sec.^{2} (3.8 m/sec^2), there is a force of .5096 of the vehicle's weight on the front tires and .4904 of the weight on the rear tires. With the engine in the rear, the force on the front tires is .169 of the weight, and the force on the rear tires is .831 of the vehicle's weight. Thus, the rear engine vehicle would be capable of higher acceleration than that of the front engine vehicle.

Presently, the brakes on the police vehicle have faded after continually hard use. It is felt that this has been attributed to the rear brakes heating, and not to the front disc brakes.

Other problems with the braking system include the fact that the fluid may become excessively hot. When this happens, the fluid may vaporize, thus causing the brakes to fail or become spongy. Also, the brake fluid may blow-by the master cylinder, rendering the brakes useless. The best solution to the braking problem would be the installation of disc brakes on all four wheels.

In conjunction with the disc brakes, a triple valve should be employed at each wheel. When the wheel starts to skid, the triple valve would release enough pressure to prevent skidding. Thus, the triple valve would permit the maximum braking force to be applied to the surface in contact without skidding.

To prevent the brake fluid from vaporizing, a larger master cylinder could be employed. Two master cylinders could be used. One could be used for the front and the second for the rear brakes. Thus, through the use of two master cylinders, the possibility of losing the brakes though failure of the master cylinder would be decreased. With two master cylinders, the amount of fluid in the braking system would be increased.

If engine placement remains located at the front of the car, it would seem to offer little improvement to have disc brakes on all four wheels.

The Frame - how strong?

Within the past few years there has been much controversy about the strength of the frames. The automakers have been going to lighter metal with different configurations. There is a question as to the strength of these frames for the purposes of pushing other vehicles and the mounting of energy absorption devices. There is also a question as to whether or not the frames can withstand the punishing driving of the police departments.

The hard driving of the police departments really does not affect the horizontal configuration of the frame, but rather the frame members designed to keep the frame in a single plane (i.e., cross members). This problem has grown to some extent in later years due to the use of unitized, all welded frames. The frames get their strength from the box construction. These solid frames do not have any play in them. The combination of vibrations and sharp jolts, such as driving over curbs and chuckholes, cause the joints, and sometimes the frames, to crack. The problem of cracked frames has, and will contine to decrease, as welding and forming techniques improve.

The strength of the frame along the car's axis of motion is not known. The strength has been decreased with the advent of the safety or collapsible frame. The safety frame has dog-legs in front, and when in a head-on collision these dog-legs bend even more, collapsing the front part of the frame, absorbing energy without doing damage to the passenger compartment.

Since the safety frame will collapse, the question has been brought up as to whether or not the frame is strong enough to push stalled vehicles off the busy streets and freeways before a traffic jam can occur. Some departments do have a framework that they attach to the front of the car for this purpose.

The Suspension - a "soft" ride or maneuverability?

Since the police cruiser must be capable of high speeds, the suspension must be strong and agile. To accomplish this, the vehicle should have leaf springs in the rear and torsion bar suspension in the front. With leaf spring suspension in the rear, the police vehicle would be more stable at high speeds as compared with one using coil springs. Also, the leaf springs may be reinforced and removed easier than coil springs. The present racing vehicles at Indianapolis use torsion bar suspension completely. Leaf springs are used by the majority of the stock cars because coil springs in the rear have proven to be unsuccessful where high speeds and cornering are required.

The police vehicle should have posi-traction. In the past, police cruisers have faced different types of terrain and a variety of driving conditions. Especially where snow, ice, and sleet are encountered, posi-traction is almost an essential. The present police force in Denver supposedly was 70% immobile when a snowstorm struck the city in January, 1971.

Presently, the police vehicles use an anti-skid auto stabilizer. This device has been very successful, and it is highly recommended for use in the ideal police vehicle.

Most police departments have ordered the heavy duty suspension package during the past. This package has included heavy duty stabilizer bars for the front and rear. Also included have been heavy duty shocks. The shocks should be equipped with overload helper springs to facilitate the moving of heavy articles that may be confiscated, or the carrying of prisoners or officers.

The Interior - the policeman's home

The interior of the police car needs to receive some very special attention. It is used continuously, day in and day out. It serves to shelter the officers at all times. It acts as an investigation room. It is used to transport prisoners. It also acts as a communications terminal. In general, the police car is the office for the patrolmen.

The greatest thing the present car interiors lack is durability. Upholstery and floor mats wear out at a rapid rate, and the seats often break down after about three months.

The seats take a harder beating than those in regular cars. Although still mechanically sound, the seats usually have to be rebuilt sometime around three months. Once the seats breakdown, they tend to tire the officer out by making him uncomfortable, and thus, less efficient. Besides having to take the cars off the line, rebuilding the seats is a very expensive problem (approximately $40.00/seat). One of the most durable seats found is one which has both coil springs and mesh springs combined.

The interior of the car should be designed to give the officers enough room to be comfortable. There is a lack of room in two areas at the present time. The first is in getting in and out of the car. The second area where the lack of space is felt is in the amount of head room. It is very important for the officers to be able to exit the car quickly in an emergency situation. Improvements would include the elimination of the raised door threshold, and the installation of a higher door.

Many departments have dividers between the front and rear seats to enable them to transport prisoners. This may not be important in a major city where help and/or the paddy wagon are only minutes away. Another reason that this barrier may not be necessary is that the rear seat is often used to question accident victims, and trying to communicate with them through the plexiglass wall or screen makes the situation less personal.

Another minor recommendation that is already being incorporated in many departments is the use of power windows. Quick release shoulder harnesses of the design that race car drivers have should be installed for the officers. At the present time, due to the location of the equipment controls and the restrictions caused by getting in and out of them, many officers do not use either the shoulder harness or the seatbelt.

The Warning System - "Here I come, ready or not."

An important function of the equipment on a police car is to make people aware that a police vehicle (or any emergency vehicle) is approaching. There are two ways of making the person aware -- by sight and by sound.

A siren is designed at almost optimum. Most of the sirens emit sound at 1000 cycles per second (Hz) and approximately 120 decibels (db) near the car. One-thousand Hz is a noticeable frequency to the human ear. The 120 db (approximately 30-40 db above street noise) is right at the threshold of pain for the human ear. Major improvements could be accomplished by changing the location of the siren. At the present time, many sirens are located down between the grill and the radiator, completely surrounded by metal. This muffles the sound immediately. Another disadvantage of the location is that due to lack of space, the siren is placed so that its axis of projection is perpendicular to the axis of travel of the vehicles. This reduces the effectiveness considerably since the sound is traveling off to the side of the car. It has been recommended putting the siren on the roof (i.e., light bar) facing forward.

The area which gives the greatest opportunity to improve the noticeability of the police car is that of visibility. More lights can be added, the color can be changed, the lights can be made brighter, and the frequency can be increased.

It has been proposed that there should be at least two lights on top of the car. An alternative would be the single one mounted on top of the siren. The advantages of the two lights are that it takes up a larger area of the visual field and that it improves the chances that at least one light will not be engulfed by the lights in the background.

It has been shown to be advantageous in highway cars to raise the warning lights above the cars. Many chain reaction collisions happen because the car behind cannot see the warning, which often prevents that car from stopping in time. Debate is going on throughout many departments as to whether or not the color of the police lights should be changed from red to blue. All colored filters presently used give very poor quality color, emitting a large percentage of white light, but also the visibility of an object is determined by the contrast factor. The contrast factor is given by:

$$C_0 = (C_b^2 + C_c^2)^{\frac{1}{2}}$$

C_0 = total contrast factor
C_b = brightness contrast factor
C_c = chromatic or color contrast factor

The chromatic contrast factor does not vary over 25% from one color to another.

The most visible color is close to sodium yellow in the daytime. At night there is a slight shift toward the green region. The disadvantage of the blue light comes from its short wave length. The short wavelength is reflected easily. As a result, by driving in any conditions that would have particles in the air, the short waves would be greatly attenuated.

These conditions could be smoke, dust, fog, rain, snow, or pollution. The longer the wavelength the better the penetration through these conditions, hence the more visible. For both day and night visibility, the yellow light appears to be the best. However, since the yellow light has been designated in many cities as the color for caution on all vehicles, an orange or the standard red should be the color for the police vehicle.

The area where the contrast factor can be greatly increased is in the brightness. The brightness contrast factor is given by

$$C = \frac{B-B'}{B'}, \text{ where:}$$

C = brightness contrast factor
B = brightness of the object
B' = brightness of the background

Present lights are about 50 candlepower. Staying within the same price range, this can be increased up to one million beam candlepower by using a strobe light, a xenon, much like those used as anti-collision lights on airplanes. A typical light is much smaller than the unit used by the police now, and it flashes at approximately the same rate, 50 ± 10 a minute. The rate of flash could be changed by changing the size of the capacitor in the strobe.

CONCLUSION

It would seem apparent that the present day police vehicle is not adequate for the wide range of demands that are placed upon it; yet, it is unlikely that the "ideal" vehicle will soon be built. This report, therefore, does not attempt to build a car from the ground up, but rather to emphasize existing technology as an option for law enforcement agencies.

In conclusion, the following key elements to the "ideal" vehicle are noted:

- 4-door vehicle
- Air conditioned
- Power steering
- Heavy duty suspension with overload helpers
- Automatic heavy duty transmission
- 400 C.I.D. (6500 cc), 350 hp, 4 bbl carburator
- Front disc brakes
- Triple valves
- Dual master cylinders
- Push bars attached to frame
- Rear leaf spring, front torsion bars
- Posi-traction
- Anti-skid stabilizers
- Coil and mesh seats
- Adequate headroom
- Low threshold
- Quick release seat belt/harness
- Forward directed siren
- Red warning lights
- Increase light output (strobe)
- Multiple lights to increase field

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