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. ABSTRACT

It has often been noted that the ixed position of conventional headlamp eams can present drawbacks. When a car ccelerates or decelerates, the angle hat the headlamp beam makes with the oad surface will change due to vehicle itching. This beam angle variation can ause a reduction in visibility istance, or alternatively, glare on ncoming vehicles. Both cases represent ituations in which safety is impaired uring night driving.

The headlamp system to be discussed ere was developed with a view towards olving this problem. It features a ylindrical light shield which, by otating in response to sensors, can ompensate for vehicle pitching and orrect the beam to road angle.

Our test results confirm that by sing this system, the negative effects f changes in vehicle inclination, ncluding glare on oncoming vehicles and educed road illumination distance, can e all but eliminated.

. INTRODUCTION

In recent years, traffic density as greatly increased, and with more and ore vehicles driving closer together, he importance of reducing glare is now ecognized as a major safety onsideration. Strict regulations overning light distribution patterns nd the aiming of headlamps help to minimize glare, and yet these measures are of no avail when vehicle pitching shifts the headlamp beam angle off of its designated axis. To ensure safe night driving, it is necessary for a headlamp system to maintain constant illumination under all conditions.

After being installed and properly aimed, a headlamp system should normally produce a light distribution pattern that will provide optimal illumination of the road ahead and objects in the vicinity, without causing glare. However when vehicle pitching occurs, as when a car encouters a bump in the road or during acceleration and deceleration, the light distribution pattern is shifted either upwards or downwards. This can lead to problems, particularly in the case of the carefully calibrated light distribution pattern of the headlamp's low-beam. A downward shift results in decreased visibility distance, while an upward shift can cause dangerous glare on oncoming vehicles.

As a simple illustration of this phenomenon, consider the case of a European style low-beam headlamp. Figure 1 provides an typical view of what might be seen beyond the front windshield from the driver's seat. The European low-beam's sharp cut-off line will normally be located along the horizon so as to prevent glare from impinging on oncoming vehicles and vehicles ahead. An upward pitch of 2°, such as may occur during acceleration, moves the cut-off line over those

vehicles, exposing them to glare. Alternatively, a downward pitch of 2°, such as may occur during deceleration, will cause the road illumination distance to be reduced from 75m to 20m.

The concept of an auto-levelling headlamp system was introduced as a solution to problems posed by beam angle changes. Such systems are designed to compensate for pitching by automatically correcting the beam angle. Figure 2 shows an example of a French manufacturer's version of this type of system.

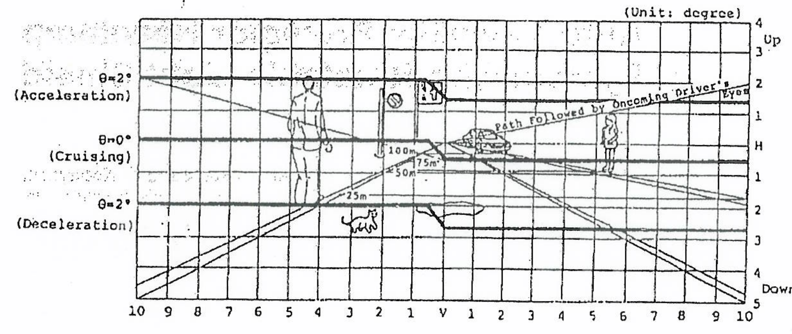

Fig. 1 - Typical Front View from Driver's Seat

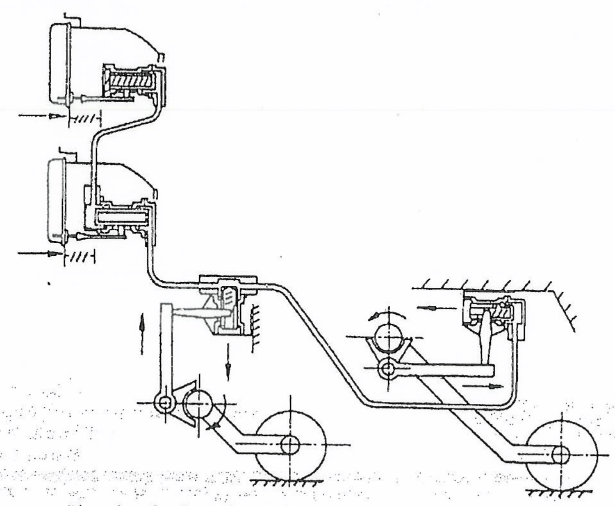

Fig. 2 - An Example of Auto-Levelling Headlamp System

The system was largely mechanical, ving been created at a time when ectronic active response systems were ill relatively unadvanced. Sensors cated at the fore and aft suspension tect vehicle pitching, and an draulic system connects the sensors to e headlamps. When vehicle pitching curs, the entire headlamp units are ved by actuators. Certain problems herent in this system later became parent:

(1) The hydraulics employed by the stem require a complex network of ping, necessitating a difficult and stly installation.

(2) Because compensation for tching is achieved through the vement of the entire headlamp units, rge and powerful actuators must be ployed.

(3) Measures to guard against draulic leakage are necessary.

(4) Hydraulic pressure variation e to temperature change jeopardizes e system's reliability.

The twenty years that have elapsed since the appearance of this system have seen numerous dramatic advances in the field of electronics. Using today's integrated circuit technology, it is relatively easy to convert vehicle pitch measurements into electronic signals, and the tasks of conveying and processing this information can be greatly simplified. The remaining problem was to discover an efficient method of varying the beam angle without requiring the whole headlamp unit to move. This was our goal when setting out to develop the auto-levelling headlamp system discussed here.

3. OUTLINE OF AUTO-LEVELLING HEADLAMP SYSTEM

The auto-levelling headlamp system that we have developed is made up of three units: the lamp unit, the sensor unit, and the controller unit. These can be seen in figure 3-1.

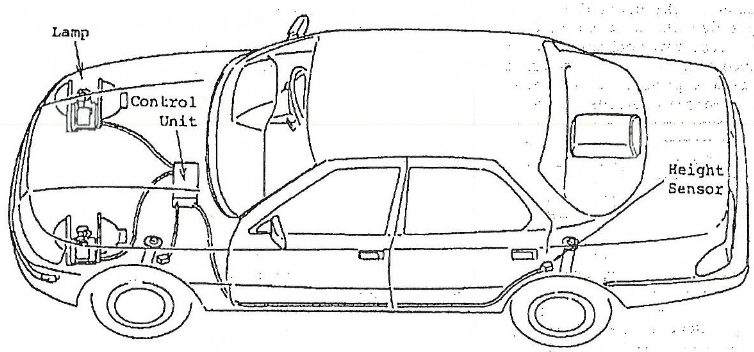

Fig. 3-1 - New Auto-Levelling Headlamp System

3.1. THE LAMP UNIT

The lamp unit (see figure 3-2) uses a projector type optical system composed of an ellipsoidal reflector and a condenser lens. The unit is equipped with a light shield whose specially designed dimensions can be rotated to achieve beam angle shifts. In this way, compensation for vehicle pitch can be made without moving the whole headlamp unit.

The light shield is cylindrical in shape, with an axis of rotation perpendicular to the optical axis ℓ on the horizontal plane (see figure 3-3). The upper edge of the cylinder is located along the optical axis at F, the focal point of the condenser lens. The axis of rotation of the cylindrical shield is located at point C_0, which is slightly off the cylinder's center, C_s. Because of the off-center axis of rotation, the upper edge can be moved either upwards or downwards.

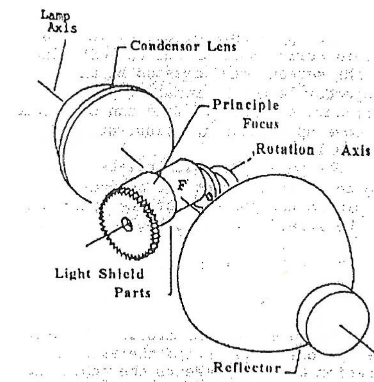

Fig. 3-2 - System Configuration

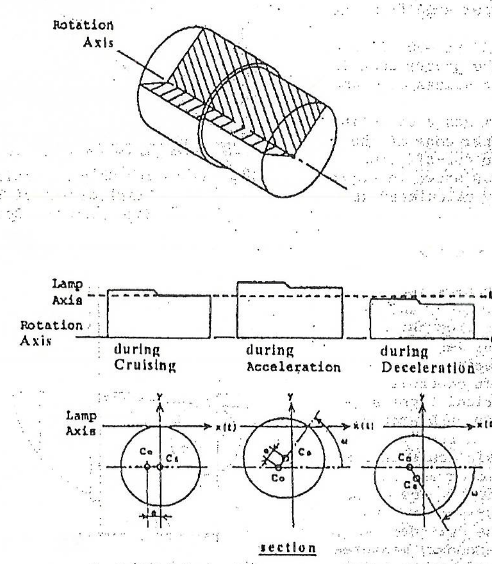

Fig. 3-3 - Shield Configuration

The upper edge of the cylindrical shield corresponds to the cut-off line on the screen image created by the projector lamp. By rotating the cylinder, the cut-off line can be caused to move up or down as illustrated in figure 1.

The equations which relate the degree of rotation of the cylindrical shield to the position of the upper edge of the shield are as follows:

$$x = e\ (\cos(\omega) - 1) \quad (1)$$

$$y = e \sin(\omega) \quad (2)$$

where e represents the distance between the cylinder axis C_s and the axis of rotation C_o, ω represents the angle that the line connecting C_s and C_o makes with respect to the optical axis ℓ, x represents the displacement of the upper edge from point F along the optical axis, and y represents the vertical displacement of the upper edge from the optical axis.

Varying ω from -60° to +60° with e set at e=5mm yields the graphs seen in figures 3-4 and 3-5 for values of x and y.

Using the values x and y to define the position of the upper edge of the cylindrical shield, the cut-off line displacement angle θ, as shown in figure 1, can be approximately calculated as follows:

$$\tan(\theta) \doteq y / (Bf + d + x)$$

where Bf represents the back focal length of the condenser lens, and d represents the distance from the flat surface of the condenser lens to the lens' principal point(see figure 3-6).

The mechanism which controls the movement of the cylindrical light shield consists of a gear train, a DC motor, and a potentiometer (or a rotary encoder). The gear train connects the cylinder shaft to the motor and the potentiometer (or encoder). The motor responds to signals received from the controller and moves the cylinder, while the potentiometer (or encoder) measures the degree of rotation of the cylinder and relays the information back to the controller. To help prevent the

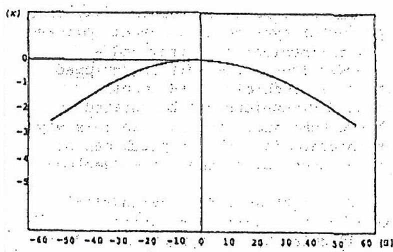

Fig. 3-4 - The Shield Displacement of the Upper Edge from Point F along the Optical Axis

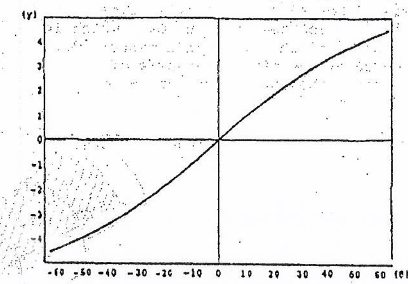

Fig. 3-5 - The Shield Vertical Displacement of The Upper Edge from the Optical Axis

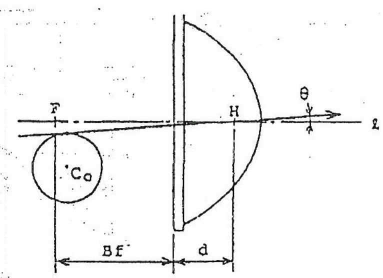

Fig. 3-6 - Relationship among Lens, Light Shield Parts and the Ray

cylindrical light shield from being moved by vibrations produced by a running vehicle, the cylinder is provided with a counterweight that shifts the cylinder's center of gravity to its axis of rotation (see figure 3-2).

3.2 THE SENSOR UNIT

The sensor unit measures deviations in the angle which the vehicle makes with the road surface, and in the overall deviation of this angle from the angle of inclination of the vehicle in an unloaded condition. Three possible sensor systems are as follows:

(1) Height sensors are installed at the fore and aft ends of the vehicle. Deviations from the normal fore and aft elevations of the vehicle's chassis are measured, and the degree of beam angle displacement is calculated within the controller unit.

(2) Ultra-sonic or laser radar sensors are installed at either end of the vehicle. The sensors feed information concerning vehicle inclination to the controller, where beam angle deviation is calculated.

The first two methods described above involve sensor units which detect changes from a predetermined reference position (vehicle inclination at which headlamp aiming was performed). Another method involves the use of

(3) A gyroscopic sensor and load sensors. The load sensors are installed at either end of the vehicle, and they detect the change in vehicle inclination due to load (ω_s) while the vehicle is stationary. The gyroscopic sensor detects the rate of change of inclination while the vehicle is running, and integrating this quantity gives the instantaneous inclination(ω_m). The controller combines these data to determine the overall beam angle divergence ($\omega_s + \omega_m$).

3.3 THE CONTROLLER UNIT

Using data gathered from the sensors on vehicle inclination and data on the current cylindrical light shield position received from the potentiometer (or encoder), the controller calculates any corrections which should be made to restore the beam angle, and relays this information to the actuator motor. The motor moves the cylindrical shield to provide the correct level of cut-off line. Figure 3-7 shows the type of circuit schematic employed in the case when height sensors are installed and a rotary encoder is used to detect shield position.

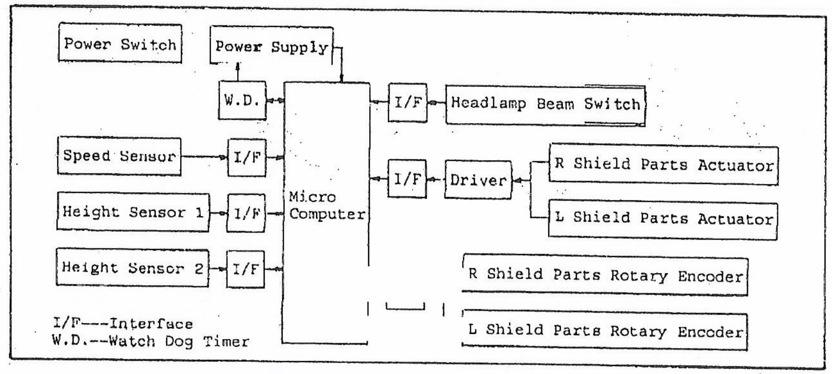

Fig. 3-7 - System Block Diagram

The controller is made up of
terface circuits where data is
ceived, and a microprocessor which
rforms calculations. Data is
ocessed over sixty times per second,
that changes are effectively
stantaneous.

SYSTEM EVALUATION

In order to evaluate this system,
mparisons were made between driving
nditions with our prototype
to-levelling unit installed but off,
d driving conditions with our
ototype auto-levelling unit
nctioning. In both cases, two test
tuations were chosen for close
amination: acceleration from a
ationary position, and deceleration
ile running. The prototype unit used
the tests employed the height sensor
stem as described above.

1 RESULTS WITHOUT BEAM CONTROL

The relationship between
celeration and vehicle inclination
beam angle deviation) is plotted on
e graphs in figure 4-1-1. The
rizontal axes represent time, while
e vertical axes represent the change
velocity and vehicle inclination
spectively. During periods of
celeration, the vehicle tilted as much
+1.0°; during periods of
celeration, the inclination angle
ached -0.7'.

Fig. 4-1-2 shows the light
stribution pattern of our prototype
adlamp system. The 0.5°U-3.0°R point
presents the approximate location at
ich an oncoming vehicle is likely to
pear. Our tests show that during
riods of acceleration, glare at this
int will increase from 500cd to
00cd, causing serious visibility
oblems for the oncoming vehicle's
iver.

Figure 4-1-3 compares the road
rface iso-lux patterns generated when
uising (no vehicle tilting) and during
celeration (vehicle tilt of -1"). The
crease in road illumination is well
lustrated by comparing the relative

positions of the 5 lux line; when cruising, it is located at a distance of 80m, while during deceleration this distance is reduced to 35m.

4.2 RESULT WITH BEAM CONTROL

The graphs in figure 4-2-1 plot the relationship between the change in velocity and beam angle deviation when the auto-levelling headlamp system is activated. The beam angle was observed to diverge no more than +0.3°, providing confirmation that this auto-levelling headlamp system can greatly reduce glare on oncoming vehicles.

However, slightly decreased luminance was also observed during periods of vehicle acceleration. Figure 4-2-2 shows the light distribution pattern when the vehicle was inclined by +1.0°, while figure 4-2-3 shows the road surface iso-lux pattern. The decreased luminance is caused because of the rotation of the cylindrical light shield which occurs during acceleration. The upper edge of the cylinder moves upwards, beyond the reflector's optical axis, blocking a greater degree of the light coming from the reflector of the projector lamp.

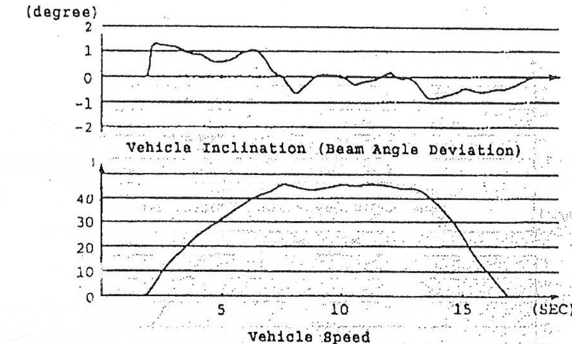

Fig. 4-1-1 - Vehicle Inclination and Vehicle Speed

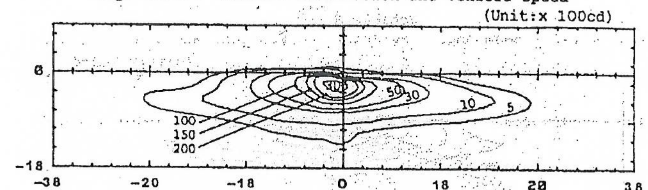

Fig. 4-1-2 - Light Distribution Pattern

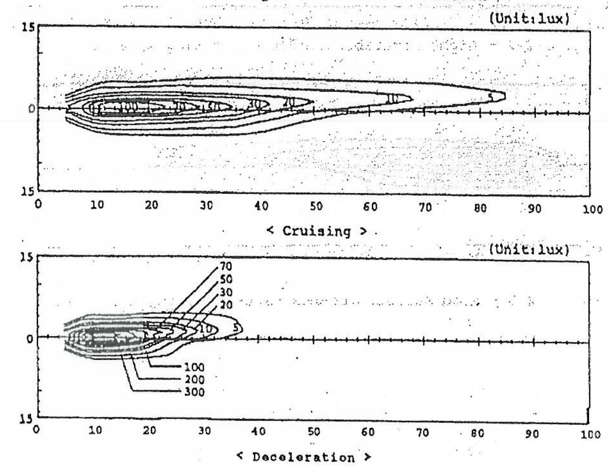

Fig 4-1-3 - Road Surface Iso-Lux Pattern in Cruising and Deceleration

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