A system for vehicle condition evaluation comprises (a) a control unit (1) for regulating operation of one or more of the following facilities and for receiving data from said one or more facilities (2a to 2n) for processing to provide output information indicative of one or more parameters of vehicle condition: (i) tyre tread depth appraisal, (ii) lamp functioning, (iii) side wall condition appraisal, (iv) windscreen condition appraisal, and (v) tyre pressure appraisal, and (b) output means (4) for said information indicative of one or more parameters of vehicle condition. The system suitably also comprises an operator interface (3). The tyre tread depth appraisal facility suitably comprises sources for directing structured linear light at a non-perpendicular angle at the tyre tread surface from different angles, and a camera for monitoring the pattern of illumination of the tyre surface to provide a measure of tread depth by analysis of the pattern of illumination.
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"AUTOMATED SYSTEM FOR VEHICLE CONDITION EVALUATION"

This invention relates to an automated system for vehicle condition evaluation. The invention is especially directed to an automated check system for wheeled vehicles, and in particular, wheeled vehicles having tyres, such as for example private motor cars or automobiles, trucks and aircraft.

A particular object of the invention is to provide an automated vehicle condition evaluation system specifically directed to tyre tread depth measurement. The invention is especially directed to an automated tyre tread measurement apparatus, in particular a fully automated tread depth measurement and analysis system based on laser/camera technology and digital signal processing, suitable for implementation in self-service type installations and computerised test lanes.

Present methods for determining tyre tread depth typically depend on mechanical probe gauges. In addition to its being tedious to perform measurements with gauges of this type, it is generally
impossible to check the entire surface of a tyre on a stationary vehicle, because a significant portion of the periphery of the tyre will be in contact with, or close to being in contact with, the pavement surface on which the vehicle is standing.

There are also known a number of light-based tyre dimensional inspection arrangements, of which US-A-3,918,816 involves mounting a tyre for rotation and impinging on its tread surface, a laser beam. Back scattered radiation is analysed to determine the position in space of the point of impingement. The laser is selectably scanned or positioned to measure various locations on the tyre surface. Apparatus disclosed by US-A-3,918,816 includes a laser device, a mounting unit for the tyre to be inspected, and another mounting unit for a laser gauge. The first or tyre mounting unit permits rotation or annular indexing of the tyre. The second or laser gauge mounting unit permits four separate gauge motions, namely radial or circular scan across the tread surface, lateral scan across the tread surface, rotation of the plane containing the laser beam and the back scattered beam, and spacing normal to the axis of tyre rotation. The first two motions listed above are motor-controlled, while the latter two are manually-controlled. The system disclosed does not therefore provide a fully automated arrangement.

According to EP-A1-0,469,948, an arrangement is provided for measuring in motion the depth of the grooves on the rolling tread surface of a tyre of a vehicle, when the tyre passes over a predetermined path containing troughs formed in the path at the level at which the tyre is expected to pass. The troughs open onto the path by means of windows. Lighting sources provided in the troughs emit a beam towards the window at a non-zero angle with respect to the surface of the path. A photosensitive detector is capable of sensing the rays emitted by the illuminated patch formed by the beam of light on the rolling tread surface of the tyre when it passes over the window. The sensor delivers a signal indicative of the reflections emitted by the illuminated path. Means are provided for processing the signal and
working out the depth of the grooves on the rolling tread surface of
the tyre.

EP-A2-0,572,365 describes a method and apparatus for
circumferentially measuring tread wear on a tyre. A laser probe
sequentially scans each of the ribs of a tyre, to obtain data in
respect of tread depth at various point along the scan. The data is
applied to each rib to determine heel to toe irregular wear of the lugs
of the rib and also to determine a total wear index indicative of the
degree of wear of the lugs. The tyre sidewall may also be laterally
scanned to obtain data for ascertaining any sidewall anomalies.

EP-A2-0,547,364 relates to a further apparatus and technique
for measuring and analysing the tread wear of a pneumatic tyre. The
tyre is indexed about its axis. Between indexing steps, a laser
scanner obtains data from the tread surface. This data is normalised
to eliminate any out-of-roundness of the tyre data. Noise spikes are
removed and replaced with values attributable to valid data. From the
data a reference curve corresponding to a lateral sector of the tyre is
devised. The data from actual lateral sectors is then compared to the
reference curve by a curve fitting process and the deviation between
the actual data and the reference curve establishes the degree of
irregular wear of the tyre at that lateral point.

According to the present invention, there is provided a system
for vehicle condition evaluation comprising
(a) a control unit for regulating operation of one or more of the
following facilities and for receiving data from said one or more
facilities for processing to provide output information indicative of
one or more parameters of vehicle condition:
(i) tyre tread depth appraisal,
(ii) lamp functioning,
(iii) tyre side wall condition appraisal,
(iv) windscreen condition appraisal, and
(v) tyre pressure appraisal, and
(b) output means for said information indicative of one or more parameters of vehicle condition, wherein said tyre tread depth appraisal facility comprises
(1) at least one source for directing structured linear light at the tread surface of a vehicle tyre to be incident on said tread surface at a non-perpendicular angle to said surface, and
(2) imaging means for monitoring the pattern of illumination of said surface by said structured linear light, said control unit being adapted to analyse said pattern of illumination to provide a measure of tread depth for said vehicle tyre.

In a preferred embodiment of the system according to the invention, a plurality of said sources are provided for directing structured linear light at the tread surface of a vehicle tyre, each said source directing said structured linear light at said tread surface from a location different from the location of the other source or sources. The or each said source and said imaging means may be located within a mobile unit displaceable with a tyre during rolling advance of the tyre for an inspection operation, and said mobile unit may comprise a wheeled carriage for travel over a support surface also carrying the tyre. Said wheeled carriage may be displaceable adjacent to a tyre for said travel during advance of the tyre by contact of the tyre peripheral surface with a roller provided on the carriage.

Alternatively, the or each said source and said imaging means may be mounted underneath an inspection window over which a tyre passes during an inspection operation. In particular, the or each said source and said imaging means may be located in a lower region of a well and separated from an upper region of the well by said window, the well being provided with rollers in sidewall regions so that a rolling road structure is defined for support of the tyre during an inspection operation, at least one of said rollers being optionally a powered roller. Said well suitably has a cover plate which is displaceable between an upper disposition in which it is substantially level with a surface region bordering the periphery of the well and a lower disposition in which a tyre carried by the cover in the upper
disposition is supported by the rollers. Said cover plate may also be laterally displaceable between said lower disposition and a withdrawn disposition in which it exposes the periphery of the tyre for an inspection operation effected by the or each said source and said imaging means through said window. The system may then comprise means for introducing water into said well, at least in the region above the level of said cover plate in its lower disposition, and means for draining water from the well.

Said cover plate may incorporate tyre cleaning arrangements such as brushes and/or spray jets and/or compressed air jets, and may also be provided with means for sealing against the walls of the well during said displacement between said upper and lower dispositions to prevent contamination of the region below said cover plate. Said sealing means may be adapted to preclude passage of water from the region above said cover plate to the region below the plate. The cover plate may in addition have wiping means on its lower side to clean the surface of said window during lateral displacement of the cover plate. In all window-incorporating variants of the invention, said control unit may be adapted to carry out an automated self-check in respect of the cleanliness of said window.

In the system according to the invention, said structured linear light from the or each source preferably comprises a linear band of light providing a displaced image line on intersection with a tyre tread groove not parallel to the image line and said control unit is adapted to provide a measure of tyre tread depth from displacement of the image line at its intersection or intersections with a tread groove not parallel to the image line. Said control unit is then suitably adapted to appraise the pattern of illumination of the tread surface of the tyre on a segmented basis over the periphery of the tyre, in particular information relating to the likely cause of abnormal wear patterns indicated by said appraisal of said pattern of illumination of the tread surface.
The or each said source may be mounted for automated adjustable orientation relative to the tread surface of a tyre to be inspected by the system, and said imaging means may comprise a camera.

5 Said tyre sidewall condition appraisal facility may comprise at least one source for directing light at the sidewall surface of a vehicle tyre to provide a line of light incident on said sidewall surface at a non-perpendicular angle to said surface, and imaging means for monitoring the pattern of illumination of said surface by said light, said control unit being adapted to analyse said pattern of illumination to identify deformation of said tyre sidewall. Said at least one source for sidewall appraisal may be adapted to direct structured linear light onto a sidewall surface of the tyre and said imaging means is adapted to monitor the pattern of illumination of said sidewall surface during rotation of the tyre.

10 Said windscreen condition appraisal facility may comprise at least one source for traversing a line of light across the windscreen surface, and imaging means for monitoring the pattern of illumination of said windscreen surface by said light, said control unit being adapted to analyse said pattern of illumination to identify prescribed defects, such as cracks, in said windscreen. In a favoured arrangement, means may be provided for traversing structured linear light across the windscreen. In particular, successive traverses of structured linear light may be effected across the windscreen in two directions substantially at right angles.

20 Said tyre pressure appraisal facility suitably comprises a chamber for connection to the valve of a vehicle tyre, the chamber having an outlet for controlled release of inflation medium from the chamber, so that a flow of inflation medium through the chamber may be established such that conditions within the chamber may be brought to substantially equate to those within the tyre, the chamber also having a pressure transducer for monitoring the pressure of the inflation medium within the chamber and a temperature transducer for monitoring
the temperature of the inflation medium within the chamber, and said control unit being adapted to provide a value for tyre inflation medium pressure at a normalised or standard temperature from data recorded by said pressure transducer and said temperature transducer.

Said chamber may comprise insulating material, at least in the vicinity of said temperature sensor, and the system may also include means for adjusting the rate of said controlled release of inflation medium during a pressure measurement operation.

The system for vehicle condition evaluation according to the invention may further comprise an operator interface.

The invention also encompasses a tyre tread depth appraisal facility comprising a plurality of sources for directing structured linear light at the tread surface of a vehicle tyre, each source directing said structured linear light at said tread surface from a location different from the location of the other source or sources, and each source directing said structured linear light to be incident on said tread surface at a non-perpendicular angle to said surface, imaging means for monitoring the pattern of illumination of said surface by said structured linear light, and a control unit adapted to analyse said pattern of illumination to provide a measure of tread depth for said vehicle tyre.

A tyre sidewall condition appraisal facility according to the invention may comprise at least one source for directing light at the sidewall surface of a vehicle tyre to provide a line of light incident on said sidewall surface at a non-perpendicular angle to said surface, imaging means for monitoring the pattern of illumination of said surface by said light, and a control unit adapted to analyse said pattern of illumination to identify deformation of said tyre sidewall.

A windscreen condition appraisal facility according to the invention may comprise one or more sources for traversing first and
second lines of light across the windscreen surface, said first and
second lines of light being substantially at right angles to each
other, imaging means for monitoring the pattern of illumination of said
windscreen surface by said light, and a control unit adapted to analyse
said pattern of illumination to identify prescribed defects, such as
cracks, in said windscreen.

A tyre pressure appraisal facility according to the invention
may comprise a chamber for connection to the valve of a vehicle tyre,
the chamber having an outlet for controlled release of air from the
chamber, so that a flow of inflation medium through the chamber may be
established such that conditions within the chamber may be brought to
substantially equate to those within the tyre, the chamber also having
a pressure transducer for monitoring the pressure of the inflation
medium within the chamber and a temperature transducer for monitoring
the temperature of the inflation medium within the chamber, and a
control unit adapted to provide a value for tyre inflation medium
pressure at a normalised or standard temperature from data recorded by
said pressure transducer and said temperature transducer.

The invention also extends to a system for vehicle condition
evaluation substantially as described herein with reference to and as
shown in any or more of the accompanying drawings.

In a first aspect, the method of the invention thus uses
structured electromagnetic radiation in the form of for example an
array of focussed strips or bands of light inclined at an angle to the
region of the tyre surface under inspection, such as to provide an
indication of the depth of tyre treads on that surface region. In a
particular implementation of apparatus of the invention in this aspect,
the vehicle is driven forward across a fixed glass plate under which
mobile illumination units and an imaging unit are located, so that the
entire periphery of a tyre is monitored as the tyres are driven forward
over the plate by advancing the mobile illumination and imaging units
with the forwardly rolling tyre. In another implementation, the
vehicle may be driven forward so that the tyre under test is positioned on a rolling road system with the vehicle stationary. In one such arrangement, the illumination units and the imaging head are located directly underneath the tyre so as to monitor the entire periphery of the tyre as the driven rollers of the rolling road rotate the tyre. In a further implementation, the illumination units and the imaging head may be located above the driven rollers so as to monitor the entire periphery of the tyre from in front of or from behind the tyre as it is rotated by the action of the rolling road. In yet another implementation, a module comprising illumination units and an imaging unit moves ahead of, or behind, each of the tyres, as the tyre advances through the inspection system with a rolling movement, the module in this instance travelling on and being supported by the same surface as that on which the tyres roll.

The invention in this first aspect thus enables automatic measurement of the entire tread surface of the tyres of a vehicle, or any other wheeled craft equipped with tyres, as it is progressed through the test system location.

In a particular implementation of the rolling road-based device, a water bath may be incorporated into which the lower portion of the tyre is placed for inspection. The water is suitably recirculated and filtered continuously so as to remove dirt which may be transferred to it from the tyre or from other sources. In operation, when the tyre is first positioned onto the rolling road rollers, a tyre cleaning operation may be automatically carried out. Cleaning may be effected by pressurised water jets and/or rotating brushes or other known cleaning means. The glass plate forming the bottom wall of the water bath and defining a window for the imaging head may suitably be inclined so as to provide gravitationally assisted transfer of dirt and sediment out of the imaging region.

In a further aspect or aspects, the automated vehicle condition evaluation system according to the invention may incorporate
one or more of a multiplicity of further features in addition to, or alternatively instead of, the tyre tread evaluation feature of the first aspect of the invention. Thus the system of the invention may consist of a stand alone arrangement directed to a single one of the tyre tread evaluation function and the further functions now listed below, or it may incorporate any two or more of these various safety-related measurements into a single common package to thereby provide in totality a multifunction test system.

The additional functions which may be present in isolation or may be incorporated with the tyre tread feature or in any sub-combination of the following list include for example:

(a) An operational check for headlights, tail lights, brake lights and indicator lights, to establish bulb functionality.
(b) Tyre sidewall condition.
(c) Windscreen condition.
(d) Tyre pressure measurement.

The system of the invention may be further adapted to provide the capability of receiving vehicle identification input, for example a vehicle registration number or other serial number data. The system may provide for video recordal of this data. The system of the invention may further record on a database or associated with the evaluation arrangement, a record of the test and measurement results associated with any given vehicle, along with the video-recorded vehicle ID information, as well as date, time and any other relevant data of this kind. Current mileage information may also be sought by the system and may be inputted as required. By virtue of these further capabilities, the system is enabled to generate historical records of test results, by way of a paper printer, a magnetic recording card or device, or such other recording means as are commercially available or may become commercially available and suitable for use with the system of the invention, for automatic update on request each time the vehicle is tested by the automated system.
This capability of the system enables vehicle owners or operators to produce documented evidence of the quality of care and maintenance of their vehicles. Such information is of advantage to a fleet owner in fleet planning and fleet economics and in maintaining maximum asset value of a vehicle fleet.

In regard to the image transfer optics design, the transfer optics being the arrangements between the features that are observed and the sensor, the imaging device may acquire images of the tyre periphery by way of a standard lens arrangement or alternatively by way of a fibreoptic based image conduit coupled directly to the imaging element, or by any combination of image conduit, lenses and mirrors or other optical elements which are or may become commercially viable. An image conduit comprises a bundle of optic fibres to transfer image data from the viewing point to a more remote location. Such different arrangements for image transfer to the imaging element enable wide flexibility in imaging head unit design to suit particular space and size constraints which may be imposed by design requirements for such unit implementation. Although such image transfer system design is a well established and known art, its application to overcome possible space and size constraints in the present invention represents a novel and innovative application of the systems in question.

The system may further comprise or be provided with a capability for communicating via telephone modem links, information from the test system controller at each of a multiplicity of test system locations to a computer database or central site remote from the individual test locations. Access to particular information in summary or detailed form may also be provided from the remotely located computer to each test site on request. All such access is suitably security code protected. In this way, information of particular relevance to police authorities, insurance companies, government agencies, and other relevant organisations may be provided on request by the system to the central computer or vice versa.
The system of the invention enables a measurement accuracy up to at least approximately + or - 0.1 millimetres to be achieved, with an inspection speed of typically better than 30 seconds per tyre. The system of the invention enables the depth of major tread grooves to be measured, regardless of pattern and may also provide for the generation of segmented averages of tread depth around the tyre periphery. Printed-out summaries of tyre condition with expert analysis may be provided, while the system may also be integrated with existing automated test systems, optionally with incorporation of data logging and statistical reporting capabilities. The system of the invention is especially suited to operation in harsh environmental conditions.

Embodiments of the invention will now be described having regard to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of a multifeature vehicle condition evaluation system, at the highest level of generality,

Figure 2A and Figure 2B illustrate the use of structured lighting in tyre tread depth measurement,

Figure 3A and 3B illustrate the effect when a groove in a surface is orientated in the direction of the incident line of structured light, so that a blank image results without any depth measurement,

Figures 4A and 4B show an arrangement according to the invention for accommodating all groove orientations, in diagrammatic and conceptual terms,

Figure 5 shows in outline sectional representation, a first embodiment of tyre tread depth inspection head according to the invention,

Figure 6 shows in diagrammatic side view, a mobile tyre tread
inspection head according to the invention for use during rolling
movement of a tyre being evaluated by the system of the invention,

Figure 7 shows in schematic side view, a rolling road
inspection well arrangement applied to the system of the invention,

Figure 8 corresponds to Figure 7 showing a wheel in position
for an inspection operation,

Figure 9 is a schematic pictorial representation of further
features of a preferred rolling road inspection well arrangement for
the system of the invention,

Figure 10 is a schematic side sectional view of the
arrangement of Figure 9,

Figure 11 shows a first stage of operation of the system of
Figures 9 and 10,

Figure 12 shows a second stage of operation of the system of
Figures 9 and 10,

Figure 13 shows a third stage of operation of the system of
Figures 9 and 10,

Figure 14 is a schematic block diagram of one implementation
for tyre tread measurement in a vehicle condition evaluation system
according to the invention,

Figure 15 is a schematic representation of a development of
the periphery of a tyre, showing segmentation and blocking of tyre
periphery portions for analysis purposes,

Figure 16 is a pictorial representation of a manner of tyre
side wall inspection in a system according to the invention,
Figure 17 is a diagrammatic pictorial representation of a manner of assessing windscreen condition in a system according to the invention, and

Figure 18 is a partially schematic sectional representation of a tyre pressure measurement device for use in a system according to the invention.

Figure 1 is a diagrammatic representation of a generalised system according to the invention for evaluating vehicle condition, in which a controller unit 1 is linked for two way flow of instructions and information to and from a multiplicity of function units or features 2a to 2n of the system. The controller unit 1 is also linked in a two way manner with an operator interface 3, and is provided with a further link to an output system 4, which may be a screen, a printer, a datalink to a remote site, or any combination of these. The functions may include such arrangements as tyre tread depth measurement, shock absorber performance, exhaust gas analysis, and so on, and may further include links to data sources, such as vehicle identification readers, a central vehicle information computer, or the like.

Referring now to Figure 2, the system of the invention in a tyre tread depth measurement aspect or function employs a prior known technique used in performing non-contact depth measurement, in which structured linear lighting is used. By structured linear lighting is meant the use of a light source which results in a linear band of light illuminating a surface on which a depth measurement is to be taken, or multiple linear and parallel bands of light, as may be generated by a laser source. Figure 2A is a pictorial representation of a structured linear light beam 11 incident at a non-vertical or perpendicular angle on a surface 12 containing a groove 13, the structured linear light beam 11 being oriented so that the line of light as it appears on the surface 12 is substantially at right-angles to the longitudinal direction of the groove 13.
Structured linear light incident on a grooved surface in this manner enables a depth measurement for the groove to be made by viewing the surface 12 from directly overhead. As shown in Figure 2B, the surface with the groove 13 orientated as shown in Figure 2A, when illuminated at an oblique angle with structured linear light 11, has a line of light 14 extending across it, transverse to the groove 13, on the main surface 12 of the material. A portion 15 of the obliquely directed line of light 11 is however displaced by a dimension "D" from the line portion 14 corresponding to the main surface 12 of the material, and the displacement is proportional to the depth of the groove 13. In other words, because a groove is present, the line of light appears at the bottom of the groove and because the structured linear light is directed at the surface at an angle, a displacement effect exists.

However, in the application of this measurement technique to tyre treads, it must be noted that the orientation of grooves in tyre tread patterns is variable, depending on the manufacturer, the type of tyre, and the application requirements for the tyre. Structured linear lighting directed in a fixed manner at a predetermined angle is suited only to situations where the bottoms of the grooves and the top surfaces of the treads receive adequate illumination from the light source. In the situation shown in Figure 3, a groove 23 in a surface 22 is oriented in or parallel to the direction of the oblique incident line of light 21. In this circumstance, the light does not reach the bottom of the groove 23 and thus no image is produced. As shown in Figure 3B, the result in this situation is a blank image.

In one embodiment, the invention deals with this problem to provide a means for accommodating all groove orientations by employing a multiplicity of structured linear light units arranged at different orientations with respect to each other. Alternatively a rotatable arrangement of one or more light sources may be provided. In the latter rotatable variant, where a plurality of sources is used, each of the plurality of light sources may be individually rotatable to enable
the system to accommodate all tread patterns in substantially optimal manner. An arrangement of the first-mentioned kind, viz., multiple light units, is illustrated in Figure 4, in which a light beam A, reference 31a, is incident at line 34a on a tyre surface 32 of a tyre segment 30 from a source in a direction such that it will cut across certain grooves 33a broadly at right-angles to these grooves, while a light beam B, reference 31b, is incident from a source located in a direction such that the line of light 34b provided on the tyre surface by this beam cuts across others 33b of the grooves again broadly at right angles to those grooves. The line of light 34b, Figure 4B, on the tyre surface 32 generated by beam B suitably intersects the line of light 34a provided by beam A at an angle such that a depth measurement will be provided for all of the tread grooves 33a, 33b on the tyre surface 32 by virtue of displaced portions 35a, 35b, as described in regard to Figure 2B. This angle of light line intersection is typically other than 90°. Each of beams A and B is a linear structured light source, and directs light at a non-vertical angle onto the surface 32 of the tyre segment, i.e. in a manner such that the light beams are non-perpendicular to the instantaneously planar portion of the tyre surface at the location illuminated. As many light sources may be provided as are required to ensure that a depth measurement is established for all grooves.

The result is shown in Figure 4B, for two structured light units arranged in different orientations across the tyre surface region under inspection as per Figure 4A. The image obtained by viewing from vertically above the surface provides various displaced sections 35a, 35b showing where the light reaches to the bases of the grooves 33a, 33b in the tyre, while two blank sections 36a, 36b, one for each beam, indicate where a light beam does not extend to the bottom of a groove 33a, 33b because of the relatively shallow angle of intersection of the light beam line 34a, 34b as incident on the surface 32 relative to the groove 33a or 33b.

With multiple overlapping lines of light, it is complex to
automatically interpret depth by analysing the relative displacement of segments of each line of light. The invention provides a means for simplifying the image analysis task by strobing a number of light sources in a suitable sequence and at a suitable rate. The strobing sequence may additionally be synchronised with the image acquisition timing of imaging units.

In order to accommodate all groove orientations, in one implementation, a multiplicity of structured light units may be used where each is oriented at a different position around the imaging area so as to illuminate the tyre periphery from a multiplicity of different directions. In operation, the particular structured light units most suited for groove penetration for a particular tyre design are automatically selected in an optimisation programme by the imaging system. Alternatively, in another implementation, a lesser number of structured light units are mounted on movable supports which are positioned in the most appropriate manner to illuminate into the grooves of any particular tyre design. The invention may also be applied using a single light source with arrangements for moving the single source into a succession of different orientations relative to the tyre. The positioning of such structured light units is under the control of an image analysis system, to be described, which operates in a control feedback manner known per se for such a set-up.

Figure 5 shows a first implementation of tyre tread inspection head in an inventive system according to the invention. As shown in this drawing, an inspection head 41 is positioned beneath a glass plate 42 over which the tyre 43 under inspection passes. The inspection head has, for example, three strobing structured linear light units 44a, b, c and a camera 45 and is arranged to move along with the tyre 43, in synchronism with the tyre rolling movement, underneath the glass plate 42 in the direction indicated by arrow 46, according as the tyre 43 rolls over the glass plate 42.

In the structure of Figure 6, which represents another embodiment, the inspection head incorporates the same features (light
units 54a, b, c and camera 55) as the head 41 of Figure 5, but is arranged so as to inspect a tyre 53 from immediately in front according as the tyre 53 rolls through the inspection location. The inspection head 51 is mounted on wheels or rollers 56 for support on and movement over a surface 59 on which wheel 53 is also supported and rolls. Head 53 also has a further roller 57 for rolling engagement or contact with the leading surface 58 of the tyre 53, so that the inspection head is driven forward and moved along by the tyre 53 during the advancing movement of the tyre 53 through the inspection station. The light units 54a, b, c and camera 55 are protected behind a transparent window or panel 52.

In the arrangement described in regard to Figures 7 to 13, a rolling road system is applied, as now described in detail:

Referring now to Figure 7, there is shown in schematic side sectional view, a rolling road type arrangement of inspection system according to the invention for the examination of vehicle tyre treads. As shown in the drawing, an inspection well 161 sunk into the floor 162 of typically an inspection bay has two wheel-supporting rollers 163 and 164 located in outwardly sloping upper portions 165 and 166 of the well 161. At least one of rollers 163 and 164 is suitably a powered roller for controlled rotation of a tyre supported on the rollers in conjunction with illumination and monitoring of the tyre tread surface. Light or illuminating units 167 and 168 in accordance with the requirements of the system of the invention are located in the base region of the well, beneath a protecting light-transmitting plate 169. Also located underneath the transparent plate 169 is a camera 171 for picking up light reflected from a wheel during an inspection operation, again in accordance with the principles of the invention as already previously identified.

Referring now to Figure 8, all of the features of Figure 7 are again shown, but now with a wheel 172 in position for an inspection operation, during which the wheel is rotated and supported on the rollers 163 and 164 of the rolling road arrangement, in order to
provide for full 360° inspection of the periphery of the wheel and associated side wall inspection, in accordance with the principles of the invention as already previously identified. This implementation is suited to the situation where the tyre to be inspected is in a clean and dry condition prior to being placed on the rolling road mechanism. In order to facilitate the inspection of tyres which may not be clean and dry, the rolling road implementation as illustrated in Figures 7 and 8 may be modified as illustrated in the sequence of Figures 9 to 13.

In order to support the wheel 172 preparatory to its being lowered into the well 161 for support on the rollers 163, 164, an arrangement such as is shown in side sectional view in Figure 9 may be employed. The arrangement of Figure 9 is further illustrated in end sectional view in the further drawing of Figure 10, which may also be referred to in conjunction with Figure 9. As shown in these drawings, the wheel 172 is initially supported on a cover plate 175 which may be lowered into and raised from the well region 161, so as to displace the wheel between the normal floor level 162 and the inspection position in which it is supported on the rollers 163 and 164. This vertical displacement of cover plate 176 is effected by actuator mechanisms 176 and 177, located one to each side of the well 161, as shown in Figure 9. When the cover plate 175 is in its lowered disposition, so that the wheel 172 is supported on the rollers 163 and 164, it is then withdrawn in a lateral or sideways direction by a horizontal actuator 178, so as to expose the tyre to the light beams directed onto it by the light units 167 and 168 and to allow the reflected signals to be received by the camera 171, located under the light transmitting protective plate 169, which is suitably a transparent glass plate.

The direction of reversible lateral displacement of cover plate 175 is indicated by reference 181.

Plate 175 therefore functions as a protecting cover plate for the inspection panel or well bottom wall 169, until such time as inspection is to commence. Referring now to Figure 11, a wheel or tyre 172 is shown in starting position, supported by cover plate 175 in
a plane substantially level with that of the floor 162. In Figure 12, the plate 175 has been lowered by the actuators 176 and 177, to such an extent that the wheel is supported on the rollers 163 and 164 and the weight of the wheel or tyre is no longer carried by the cover plate 169. Moving on to Figure 13, the cover plate has been removed in the sideways direction by actuator 178, thereby leaving the periphery of the tyre 172 available for illumination by the light units 167 and 168 and inspection by the camera 171.

The arrangement of Figures 9 to 13 may be further adapted to provide for a cleaning operation on the tyre preparatory to inspection. For this purpose, the well 161 is suitably filled with water to substantially floor level, as indicated by line 179 in Figures 9 and 11 to 13 inclusive. When the wheel is lowered into the well, into the disposition shown in Figure 12, it may be initially rotated so as to wet its entire periphery. A certain rinsing effect is achieved in this manner, and a more thorough cleaning of the periphery of the tyre by the removal of extraneous matter from the treads may be effected by providing scrubbing and cleansing arrangements suitably on the upper surface of the transversely displaceable cover plate 175, such as for example brushes, water spray jets, compressed air jets, or any two or more such facilities. These arrangements may also alternatively be provided on the sides of the water-containing well. Thus when the cover plate 175 is displaced sideways to give clear access for the inspection operation, a clean periphery is available for this purpose.

In order to avoid contamination of the upper surface of the transparent plate 169, arrangements may be provided so that the sliding displaceable cover plate 175 seals against the periphery of the inspection well during the initial support and lowering stages for the wheel 172, so that the water underneath the cover plate remains substantially uncontaminated during the cleansing operation. Dirty water above this cover plate may be removed before the cover plate 175 is slid out of the way, following termination of its support phase.
The well may be again flooded with clean water for the inspection operation, which may be conducted under water, or alternatively, the well may be left dry during the inspection function.

In yet another variant, the sealing of the cover plate against the side walls of the well may be such that the region below the plate remains dry during the cleaning operation carried out above the cover plate, and the water used for the cleaning phase is drained off from the upper region before the cover plate is slid sideways to expose the inspection window.

In order to ensure that no dirt or contamination remains on top of the transparent plate 169 during an inspection operation, the underside of the displaceable plate 175 may be provided with a wiper or cleansing arrangement, which traverses the upper surface of the plate 169 during the clearing operation of the cover plate 175. In addition, or alternatively, the transparent plate 169 may be set at an inclination, so as to allow sediment or water to drain off by gravity at the appropriate stage of the inspection operation.

Thus in summary, the inspection operation may be conducted in any of the following environments:

1. All dry, with optional cleaning of tyre in dry condition.
2. All wet.
3. All wet for clean, dry for inspection.
4. Partially wet for clean, dry for inspection.

In a still further implementation, the illumination/imaging head may rotate around a fixed tyre.

Figure 14 is an example of an implementation of inspection system as described above integrated into a vehicle condition evaluation arrangement as described in regard to Figure 1, Figure 14 showing a block diagram of the tread measurement system as linked into
the system controller and operator input and output features. This embodiment of the tyre tread inspection system will now be described in more detail.

5 The supervisory module 61 cooperates with an operator panel 63 and provides output suitably by way of a paper printer 64. The supervisory module additionally facilitates data transfer to and from external computer-based systems via a two-directional communications channel 74. The tyre tread inspection facility is embodied in the features shown in the upper part of the block diagram. Structured linear light units 65a, b, c are driven by a strobe controller 66 which is synchronised with the functioning of the camera 67 by way of a control unit 68. These features are linked with the processor module by way of an analog to digital converter 69, a buffer memory 71 and an image processing and analysis module 72. Further inputs to the processor module 61 may come from further sensors and encoders 73a-n, and further data interchange may also take place between module 61 and features 73a-n, by virtue of which the inspection system of the invention may incorporate a multiplicity of further facilities or may be associated with one or more such further features.

10 The tyre tread measurement feature of the system of the invention has a number of advantages. In particular, the image information generated for a given tyre is the same whether the tyre is wet or dry. The only difference is in the intensity levels of the reflected light segments. These are diminished somewhat by a wet tyre surface, due to increased specular reflectivity of the tyre surface when wet.

15 There is however therefore no special requirement as to surface condition, whether wet or dry, for inspection. This means that the system may incorporate a tyre washing facility immediately prior to inspection. The benefit of such a facility is that tyres which have dirt packed into the tread grooves, which would otherwise prevent accurate measurement, may be cleaned at entry to the inspection
system. This further capability thus enables the system of the invention to be used in environments where cleanliness of tyre surface cannot be reliably guaranteed or provided.

A further advantage of this capability of the system of the invention is that the window may be washed so as to remove any accumulation of dirt or contamination which might otherwise impair the inspection quality.

Whether in the rolling tyre or rolling road implementation, the system may thus have the further capability of performing a cleanliness self-check at regular intervals, which may be on demand or immediately prior to commencement of an inspection operation for a vehicle, as may be appropriate. As previously described, in one implementation of the rolling road based system, a cover plate is suitably arranged so as to be capable of being moved vertically under the control of the supervisory/processor module and for moving out laterally to clear the monitoring region. For cleanliness checking, a cleanliness checking routine requires that the linear illumination units are activated in sequence according to a programme as the cover plate is moved towards or away from being close to contact with the imaging window into an upper limit position, and a test programme for the inspection system is run at the same time. In other words, in any embodiment, a self-cleanliness checking routine, when present, requires the linear illumination units to be activated in sequence according as a protective cover plate is moved away from being in contact with the glass window out to an outer limit position, and a test programme for the imaging of the inspection system is run at the same time.

This test programme analyses the linear illumination lines of reflection generated on the inner surface of the cover plate for continuity and intensity variations which would indicate the presence of dirt contamination over the entire window area being used during inspection. A suitable limit of movement of a protective cover plate in a non-rolling road embodiment may be, for example 14 mm, this
dimension being approximately 100% more than the maximum depth of tread requiring to be measured. Such a cover plate may be spring return loaded and elevated by the action of a small geared electric motor.

In the rolling road embodiments of Figures 7 to 13, for safety and ease of use considerations, the cover plate may additionally serve as a protective cover when the system is not operating and also as a means for lowering the tyre under test into the rolling road operational position. The cover plate may additionally serve to act as the baseplate for the water bath during tyre immersion and preinspection cleaning. Additionally, the cover plate may incorporate the cleaning devices such as water jets and brushes which are activated for tyre cleaning prior to inspection. Alternatively, cleaning such as by brushes and/or air jets may be effected in a completely dry cleaning stage of the inspection process. The cover plate may further have raised outer edges to act as a means for limiting sedimentary dirt on the cover plate from falling onto the glass imaging window. Still further, the cover plate may have a brush or wiper which serves to clean the glass imaging window each time the cover is moved sideways into and out of position. Following tyre cleaning, the cover plate assembly is removed from between the tyre and the imaging window. Movement of the cover for removal may be sideways under suitably activated control.

Dirt contamination in the form of grease or tar, for example, which cannot be removed by a normal wash cleaning operation, may be automatically identified by the system and an operator attention alarm indicator activated.

For any of the design arrangements having a glass window against which, or close to which, the tyre under inspection is located, the window may cause ghost imaging lines to appear on the images. Such ghost lines are caused by partial reflection of the linear lines of light from the two surfaces of the window. These image lines are however of no interest to system analysis and in a particular system design they may be identified and then ignored by the image analysis unit.
In any embodiment of the system of the invention, the linear illumination may be established by use of laser diodes operating at 780 Nm with 50 mW output power and 45° fan angle line generation optical heads.

The wavelength of illumination used is not critical for the system design, although it may be advantageous in some system designs to introduce selective optical filtering on the imaging device input so as to favour the illumination device wavelength. By matching the wavelength sensitivity of the imager to the illumination wavelength so as to permit unattenuated imaging in the illumination wavelength and substantial attenuation of other wavelengths, reliable inspection may be performed in otherwise hostile illumination environments, for example in the presence of car headlight glare or in bright sunlight.

Inspection results may be summarised and presented in any format required by way of a local printer module or video terminal, by means of an intelligent card, a magnetic card or other storage module, a vehicle module or computer, a garage or maintenance shop computer, or at a remote location through a communications cable or radio or other communication link or means. On-board data storage on the vehicle may minimise exposure to tampering with historical records. Expert analysis of the tyre tread depth results may be incorporated, so that abnormal tyre wear conditions associated with for example incorrect tracking adjustment or the like may be identified and reported.

Analysis of tread depth measurements are according to one implementation analysed and interpreted so that average and comparative values for segmented portions of the tyre may be presented. Additionally, expert analysis may be provided citing probable or likely causes of identified abnormal wear patterns. Additionally, an overall results summary may be provided which compares tyre tread condition against prevailing minimum legal requirements.

Analysis of tread depth measurement may according to one
implementation be analysed and interpreted so that average results of tyre tread wear may be generated for consecutive segments of the tyre periphery as shown in Figure 15. The segments in each band represent the rolled out periphery of the tyre. As shown in Figure 15, for analysis purposes, the periphery of the tyre is divided into bands (a) and (b) identified by references 191 and 192 respectively. More than two bands may be provided, if deemed appropriate, for example where a tyre of high aspect ratio with a relatively wide periphery is in question. Each band (a) and (b) is then divided into a series of segments or blocks, $S_1$, $S_2$, to $S_n$ etc. for band (a) and $S_{n+1}$, $S_{n+2}$ to $S_{2n}$, etc. for band (b) and so on for whatever number of bands required and for whatever number of segments or blocks are deemed appropriate to provide adequate segmental analysis of the tyre periphery. The segments are identified by references 193 in the diagram of Figure 15. The results to be presented for each segment may typically include at least the following:

1. Average tread depth.
2. Ratio of average tread depth for the sector to overall average for the tyre.
3. Ratio of average tread depth of segment to overall average for the entire band of which the segment is a part.

Additionally, summary results for each band of segments may typically include:

1. Overall average tread depth.
2. Peak difference of sector averages.

A further overall summary may be presented to include inter alia the following:

1. Conformance with legal requirements, including pass or fail relative to predetermined criteria.
2. Percentage coverage of tyre having a tread depth greater than the legal minimum.
3. The average overall tread depth.
4. The difference in the average for the inside and outside bands.

A results interpretation message may also be presented, including inter alia identification of the following conditions:
1. Possible reasons for the identified wear pattern, for example wheel geometry incorrectly set.
2. A damaged tyre, cut or blister.
3. Tyre pressure too high or too low.
5. Accident damage.

Such information may also be collected for survey or data purposes. Widespread data collection may be relevant to fleet management and also for forensic purposes, in which connection a tread pattern may be reconstructed or recorded and different tyres identified, as may be required.

As noted, the measurement system may be constructed as a fixed installation or alternatively to be portable. The fixed system is especially suited to garage forecourt installation or a like location, whereas the portable system is suited to routine tyre testing checks to be performed by traffic police or aircraft inspectors. The capabilities of both versions of the system are identical, and the differences reside only in the packaging or manner of mounting or installation of the system.

In implementing the various other test options of the system according to the invention, known or novel means may be employed, as now exemplified. A possible method for implementation of each test option is identified below.

For the light tester, two cameras may be positioned so as to view the vehicle from the front and from the rear, and these are
connected to the system controller. A visual display message board is positioned so as to be easily viewable by the vehicle driver. The system controller instructs the driver to carry out light activation actions in a pre-arranged sequence by displaying action messages on the display message board. Images from the cameras are analysed and lamp or bulb operation verified as the sequence progresses. As each test step is completed, the message is updated until all lights are checked. The controller summarises the bulb operation results and presents this summary for incorporation in the final test result display and print-out.

Figure 16 shows a manner of examination of tyre side wall condition which may be incorporated in a system according to the invention, or may alternatively be employed independently. An optical method is again applied in which a line of light 121 is projected from a source 125 at an angle onto the side wall 122 of the tyre 123, suitably in a direction which is upward from a surface 124 on which the tyre 123 rests, and at an acute angle to said surface 123, so as to inspect the top of the side wall 122 of the tyre 123 on a rising undeformed part thereof. In this manner, any suspension elements do not obstruct the beam of light, especially where examination of an inside tyre wall is in question. A substantially uniform line of light 121 should appear on the tyre side wall, and any bulges or blisters in the cover of the tyre are then apparent by variations in the shape of the line 121, which can be detected by the line of light being monitored by a camera and subjected to computer analysis. Cuts in a tyre side wall are not detected by this arrangement, but do not represent a major problem unless they develop into a bulge or blister, which would be detected. In order to carry out a full inspection of the entire side wall surface of the tyre, both inside and outside, the wheel is rotated, either by rolling movement over the surface 124 with accompanying travelling movement of light source 125 and the associated viewing system, or alternatively by the tyre 123 being supported on a rolling structure, so that the wheel remains stationary in location relative to the light source but nonetheless rotates relative to it.
Two light sources and associated viewing equipment may be provided to give internal and external side wall inspection, or alternatively, the rotation operation may be repeated following repositioning of the light source and the associated viewing equipment, namely camera etc.

A windscreen test is illustrated in schematic form in Figure 17. An optical scanning technique is again applied in that a line of light 151 is traversed across the windscreen 152 in a substantially vertical orientation and changes in the image are noted according as the transverse movement proceeds. Changes in image denote the presence of a crack so that a defect map may be built up and the number of defects identified. A second run of the light line at rightangles to the first, reference 153, will enable a full picture to be built up, this second traverse 153 detecting cracks extending parallel to the direction of light travel for the first check. The reason for traversing the windscreen twice with lines of light 151 and 153, is that the vertical line of light 151 will not readily detect completely horizontal cracks, in other words cracks extending parallel to the direction of movement of the light beam and at rightangles to the axial direction of the light beam, i.e. the vertical direction down the windscreen. Similarly, the horizontal light beam 153 will not detect vertical cracks. Cracks which are not at rightangles to the direction of the line of light will however be detected, in other words cracks which are not parallel to the direction of movement of the line of light across the windscreen. Since windscreens are zoned for inspection purposes, so that the zone located in front of the driver should be clear and without serious defects, the defect map built up allows a decision to be made as to whether a windscreen should be accepted or rejected. Defects at locations other than the driver zone may be acceptable.

For tyre pressure measurement, known arrangements may be applied, or alternatively a new concept for pressure measurement system may be used, as shown in Figure 18, this automatically measuring the pressure of the air or other inflation medium in the tyres but with
temperature correction. For accurate measurement of tyre pressure using conventional measurement gauges, the tyres must be cold. Pressure measurement with such gauges is not therefore feasible in situations where the vehicle has recently been driven and particularly so when it has been driven at high speed, such as in motorway driving or in situations involving frequent or severe braking. Aircraft, after landing, have particularly high tyre temperatures, and the tyres typically require several hours to cool to ambient temperature.

The measurement system of the invention as shown by way of example in Figure 18 incorporates a sealing tyre valve adaptor unit 91 which fits onto the valve end at tyre valve stalk 92 by means of sealing ring 93 and depresses the valve core 94 by means of pusher 95 so as to allow air or other inflation medium in the tyre to escape into a chamber 96 of the measurement unit, other arrangements being however possible in other embodiments. This chamber has a fast response temperature sensor 97 located centrally in the chamber at a relatively short spacing from the chamber inlet. A pressure transducer 98 is fitted into the chamber wall, suitably an end wall portion. The chamber is sealed apart from a controlled flow outlet provided by needle valve 99.

In operation, this entire chamber 96 of the pressure unit 91 becomes an integral extension of the internal space within the tyre. Slow controlled leakage from the chamber 96 of the unit 91 through valve 99 causes air from the interior of the tyre to flow gently over the temperature sensor 97. Since there is no measurable pressure differential, there is no adiabatic cooling of the air, so that the temperature measured by the temperature sensor 97 will reflect the actual temperature of the air or other inflation medium inside the tyre, such as nitrogen in the case of an aircraft tyre.

In order to minimise the temperature drop caused by thermal losses to and through the measurement device, it is important that the positioning of the temperature sensor should be as close as possible to
the tyre valve stalk. The introduction of a bulky porous insulation material into the measurement device chamber and in particular in the region of and surrounding the temperature sensor also serves to increase the effective insulation of the device and to shorten the time to reach system measurement stability. In operation, it may be advantageous to have a variable flow rate control on the needle valve. By having an increased flow rate initially, with a progressively reducing rate of flow, the device may achieve measurement stability in a shorter time.

For operation in extremely cold environments, it may additionally be desirable to introduce a heated outer jacket, to cover the entire measurement device and extend so as to cover the tyre valve stalk, the temperature of which is controlled by a feedback reference to the device internal temperature sensor, as shown in Figure 18.

In operation, the controller processor reads the temperature value output from the temperature sensor and acts so as to establish the same temperature at the inside surface of the outer jacket. This measurement and heating operation is continued in an iterative process until approximate temperature equalisation is established between the pressurised air and the inner surface of the heated jacket. When approximate equalisation is achieved, the pressure and temperature readings of the pressurised air are acquired and processed.

The means for securely coupling the device to the tyre valve stalk may be by way of a compressive rubber sealing ring or alternatively by means of a through-threaded adaptor having a sealing ring insert, or any other suitable coupling arrangement. For active locking of the seal, a toggle type clamp may be provided on the exterior.

The system controller 101 is arranged to monitor both the pressure and temperature sensor outputs by way of respective amplifiers 102, 103 and analog to digital converters 104, 105 and to compute a
pressure value corrected to a fixed temperature typically set at 15°C. This corrected value is presented for incorporation in the final test result display and print-out, output 106. Other outputs of the system may also include values of actual temperature and uncorrected pressure.

There is thus provided by the invention an automated vehicle condition analysis or evaluation system providing for appraisal of at least one of tyre tread depth and a multiplicity of other vehicle performance parameters, as enumerated above. The invention further provides for any two or more of these possible parameters to be analysed in combination and combined output data for each of the various conditions monitored to be output from the system, while further providing for additional external inputs, such as vehicle registration number or like identification, to be associated with the test results. The system has the still further capability of linking to an external information source, such as a central computer, for interchange of vehicle data and test results with such central data storage location, so that the vehicle's records may be updated at the central site and the test system may also take advantage of previous vehicle data stored at the central site in undertaking an individual vehicle condition evaluation operation.
1. A system for vehicle condition evaluation comprising  
   (a) a control unit for regulating operation of one or more of the  
   following facilities and for receiving data from said one or more  
   facilities for processing to provide output information indicative of  
   one or more parameters of vehicle condition:  
   (i) tyre tread depth appraisal,  
   (ii) lamp functioning,  
   (iii) tyre side wall condition appraisal,  
   (iv) windscreen condition appraisal, and  
   (v) tyre pressure appraisal, and  
   (b) output means for said information indicative of one or more  
       parameters of vehicle condition, wherein said tyre tread depth  
       appraisal facility comprises  
       (1) at least one source for directing structured linear light at  
           the tread surface of a vehicle tyre to be incident on said tread  
           surface at a non-perpendicular angle to said surface, and  
       (2) imaging means for monitoring the pattern of illumination of  
           said surface by said structured linear light, said control unit  
           being adapted to analyse said pattern of illumination to provide  
           a measure of tread depth for said vehicle tyre.

2. A system according to Claim 1, comprising a plurality of said  
   sources for directing structured linear light at the tread surface of a  
   vehicle tyre, each said source directing said structured linear light  
   at said tread surface from a location different from the location of  
   the other source or sources.

3. A system according to Claim 1 or Claim 2, wherein the or each  
   said source and said imaging means are located within a mobile unit  
   displaceable with a tyre during rolling advance of the tyre for an  
   inspection operation.

4. A system according to Claim 3, wherein said mobile unit
comprises a wheeled carriage for travel over a support surface also carrying the tyre.

5. A system according to Claim 4, wherein said wheeled carriage is displaceable adjacent to a tyre for said travel during advance of the tyre by contact of the tyre peripheral surface with a roller provided on the carriage.

6. A system according to Claim 1 or Claim 1, wherein the or each said source and said imaging means are mounted underneath an inspection window over which a tyre passes during an inspection operation.

7. A system according to Claim 6, wherein the or each said source and said imaging means are located in a lower region of a well and separated from an upper region of the well by said window, and the well is provided with rollers in sidewall regions so that a rolling road structure is defined for support of the tyre during an inspection operation, at least one of said rollers being optionally a powered roller.

8. A system according to Claim 7, wherein said well has a cover plate which is displaceable between an upper disposition in which it is substantially level with a surface region bordering the periphery of the well and a lower disposition in which a tyre carried by the cover in the upper disposition is supported by the rollers.

9. A system according to Claim 8, wherein said cover plate is laterally displaceable between said lower disposition and a withdrawn disposition in which it exposes the periphery of the tyre for an inspection operation effected by the or each said source and said imaging means through said window.

10. A system according to Claim 9, comprising means for introducing water into said well, at least in the region above the level of said cover plate in its lower disposition, and means for draining water from the well.
11. A system according to Claim 10, wherein said cover plate incorporates tyre cleaning arrangements such as brushes and/or spray jets and/or compressed air jets.

12. A system according to Claim 11, wherein said cover plate is provided with means for sealing against the walls of the well during said displacement between said upper and lower dispositions to prevent contamination of the region below said cover plate.

13. A system according to Claim 12, wherein said sealing means is adapted to preclude passage of water from the region above said cover plate to the region below the plate.

14. A system according to Claim 12 or Claim 13, wherein said cover plate has wiping means on its lower side to clean the surface of said window during lateral displacement of the cover plate.

15. A system according to any of Claims 6 to 14, wherein said control unit is adapted to carry out an automated self-check in respect of the cleanliness of said window.

16. A system according to any preceding claim, wherein said structured linear light from the or each source comprises a linear band of light providing a displaced image line on intersection with a tyre tread groove not parallel to the image line and said control unit is adapted to provide a measure of tyre tread depth from displacement of the image line at its intersection or intersections with a tread groove not parallel to the image line.

17. A system according to Claim 16, wherein said control unit is adapted to appraise the pattern of illumination of the tread surface of the tyre on a segmented basis over the periphery of the tyre.

18. A system according to Claim 17, wherein said control unit is adapted to provide information relating to the likely cause of abnormal
wear patterns indicated by said appraisal of said pattern of illumination of the tread surface.

19. A system according to any of Claims 16 to 18, wherein the or each said source is mounted for automated adjustable orientation relative to the tread surface of a tyre to be inspected by the system.

20. A system according to any preceding claim, wherein said imaging means comprises a camera.

21. A system according to any preceding claim for vehicle condition evaluation, wherein said tyre sidewall condition appraisal facility comprises at least one source for directing light at the sidewall surface of a vehicle tyre to provide a line of light incident on said sidewall surface at a non-perpendicular angle to said surface, and imaging means for monitoring the pattern of illumination of said surface by said light, said control unit being adapted to analyse said pattern of illumination to identify deformation of said tyre sidewall.

22. A system according to Claim 21, wherein said at least one source for sidewall appraisal is adapted to direct structured linear light onto a sidewall surface of the tyre and said imaging means is adapted to monitor the pattern of illumination of said sidewall surface during rotation of the tyre.

23. A system according to any preceding claim for vehicle condition evaluation, wherein said windscreen condition appraisal facility comprises at least one source for traversing a line of light across the windscreen surface, and imaging means for monitoring the pattern of illumination of said windscreen surface by said light, said control unit being adapted to analyse said pattern of illumination to identify prescribed defects, such as cracks, in said windscreen.

24. A system according to Claim 23, wherein said windscreen condition appraisal facility comprises means for traversing structured linear light across the windscreen.
25. A system according to Claim 23 or Claim 24, wherein said windscreen condition appraisal facility comprises means for effecting successive traverses of structured linear light across the windscreen in two directions substantially at right angles.

26. A system according to any preceding claim for vehicle condition evaluation, wherein said tyre pressure appraisal facility comprises a chamber for connection to the valve of a vehicle tyre, the chamber having an outlet for controlled release of inflation medium from the chamber, so that a flow of inflation medium through the chamber may be established such that conditions within the chamber may be brought to substantially equate to those within the tyre, the chamber also having a pressure transducer for monitoring the pressure of the inflation medium within the chamber and a temperature transducer for monitoring the temperature of the inflation medium within the chamber, and said control unit being adapted to provide a value for tyre inflation medium pressure at a normalised or standard temperature from data recorded by said pressure transducer and said temperature transducer.

27. A system according to Claim 26, wherein said chamber comprises insulating material, at least in the vicinity of said temperature sensor.

28. A system according to Claim 26 or Claim 27, comprising means for adjusting the rate of said controlled release of inflation medium during a pressure measurement operation.

29. A system for vehicle condition evaluation according to any preceding claim, further comprising an operator interface.

30. A tyre tread depth appraisal facility comprising a plurality of sources for directing structured linear light at the tread surface of a vehicle tyre, each source directing said structured linear light at said tread surface from a location different from the location of
the other source or sources, and each source directing said structured linear light to be incident on said tread surface at a non-perpendicular angle to said surface, imaging means for monitoring the pattern of illumination of said surface by said structured linear light, and a control unit adapted to analyse said pattern of illumination to provide a measure of tread depth for said vehicle tyre.

31. A tyre sidewall condition appraisal facility comprising at least one source for directing light at the sidewall surface of a vehicle tyre to provide a line of light incident on said sidewall surface at a non-perpendicular angle to said surface, imaging means for monitoring the pattern of illumination of said surface by said light, and a control unit adapted to analyse said pattern of illumination to identify deformation of said tyre sidewall.

32. A windscreen condition appraisal facility comprising one or more sources for traversing first and second lines of light across the windscreen surface, said first and second lines of light being substantially at right angles to each other, imaging means for monitoring the pattern of illumination of said windscreen surface by said light, and a control unit adapted to analyse said pattern of illumination to identify prescribed defects, such as cracks, in said windscreen.

33. A tyre pressure appraisal facility comprising a chamber for connection to the valve of a vehicle tyre, the chamber having an outlet for controlled release of air from the chamber, so that a flow of inflation medium through the chamber may be established such that conditions within the chamber may be brought to substantially equate to those within the tyre, the chamber also having a pressure transducer for monitoring the pressure of the inflation medium within the chamber and a temperature transducer for monitoring the temperature of the inflation medium within the chamber, and a control unit adapted to provide a value for tyre inflation medium pressure at a normalised or standard temperature from data recorded by said pressure transducer and said temperature transducer.
FIG. 15