Truck/Mobile Equipment Performance Monitoring Management Information Systems (MIS)

by

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ABSTRACT

Truck/Mobile Equipment Performance Monitoring is a vital part of every mining operation. Performance Monitoring identifies current performance baselines for use in analyzing, refining, and improving equipment performance levels. Further, to be meaningful, equipment monitoring requires real time data collection. Equipment Performance Monitoring is the key to building a Management Information System leading to Computer Integrated Mining.

TRUCK/MOBILE EQUIPMENT PERFORMANCE MONITORING

MANAGEMENT INFORMATION SYSTEMS (MIS)

Typical truck/equipment performance monitoring/management systems take into account many factors.

Appropriately one might ask, why implement a truck/equipment monitoring/management system?

THE NEED:

"You Choose:

GIGO

Babel

Corporate Integration

Can management be of a higher quality than the data upon which it is based? Is there a relationship between the effectiveness of management and the integrity of the information is uses to formulate its decisions?

You bet your bottom dollar there is!

Without doubt, where "management" is maximized, information "integrity" has been maximized. But how is this accomplished? All successful, complex organizations now have a Management Information System (MIS) to gather, compile, and distribute the information that described organizational affairs. Corporate success is then based on MIS success: the complete, accurate, and timely flow of appropriate, definitive information."**

*GIGO — Garbage In Garbage Out

*Babel — The Tower of Babel

Corporate Integration

YOUR CHOICE!

** Harry Burke, "Field of View," Automatic I.D. News, May 1986, pp. 28-31.

Whether equipment owners choose to admit it or not, truck/mobile equipment monitoring does exist in every operation. (Fig 1) It is just that in some operations it is more formalized than others.

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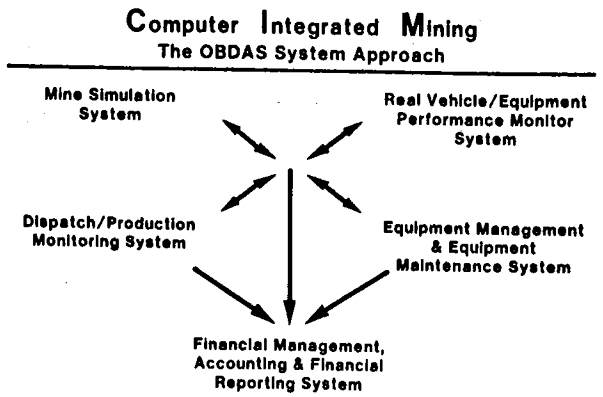


Truck/mobile equipment monitoring is there whether equipment owners choose to legitimize-formalize it or not.

This being the case, accepting and recognizing that truck/mobile equipment monitoring is going to occur one way or another, how does one implement good-valid truck/mobile equipment monitoring?

THE CONCEPT:

The what, when, and where of equipment monitoring. What is being monitored, when are the results available, and where is the information/output obtained.

The what of equipment monitoring:

Equipment monitoring primarily takes two forms: vital signs monitoring and performance monitoring. Consider a runner running a race, his vital signs are his blood pressure, pulse, temperature, rate of respiration, etc., while his performance is his time at the quarter mile, half mile, and finish line.

Vital signs monitoring monitors components, i.e. what is happening to the items being monitored?

Performance monitoring (normally) monitors the whole, i.e. what the item being monitored does?

Typically, truck/mobile equipment items that can be vital signs monitored are:

1. Engine Criticals
   a. Oil Pressure
   b. Water Temperature
   c. Exhaust Temperature
   d. Etc.
2. Hydraulic System Criticals
   a. Hydraulic Pressure
   b. Hydraulic Oil Temperature
   c. Etc.
3. Drive Train Criticals
   a. Wheel/Motor Current Draw
   b. Wheel/Motor Temperature
   c. Etc.

Numerous other items are also capable of being monitored, in fact, for every component on a vehicle there are corresponding vital signs that can be monitored.

Equipment performance monitoring, (nominally) equipment performance as a whole versus individual components; what the equipment does and when the equipment is a truck, some items considered are:

1. Equipment Loading, Amount Being Hauled
2. Equipment Use/Abuse (is the equipment being operated in a proper manner in accordance with mine parameters and manufacturer's guidelines)
3. Equipment Tracking
4. Equipment Cycle Times
5. Equipment Utilization

The Equipment Monitoring Chain. First monitor vital signs/performance signs then process the data obtained so that action initiation can take place reacting to the results of the monitoring process, i.e. monitor, process the results, and initiate action accordingly.

Truck/mobile equipment monitoring system building blocks are hardware and software.

Truck/mobile equipment hardware breaks down into three categories:

Input Devices	Output Devices
- Analog	- Display
- Digital	- Digital (numeric)
	- Alpha/numeric
	- Video
Processor	- Printer
- Analog	- Data storage Devices
- Digital	- Real time data output devices

Truck/mobile equipment monitoring system software interrogates the input devices, directs the processing of the date obtained from the input devices, and consequently formulates and initiates data output.

Vital signs monitoring while normally guarding against premature component failures, fails to address equipment performance.

In today's competitive world, improved equipment performance/utilization is where the returns are at; with improved equipment performance flowing directly to an operation's bottomline profitability.

Equipment Performance is improvable as monitoring identifies current performance baselines for use in analyzing, refining, and improving equipment performance levels. After all if you don't know where you're at, how can you determine if you are maintaining status quo, improving, or worse, falling off, i.e. to go anyplace you have to know where you are at, with Equipment Performance Monitoring establishing both where you are at and where you are going.

THE IMPLEMENTATION:

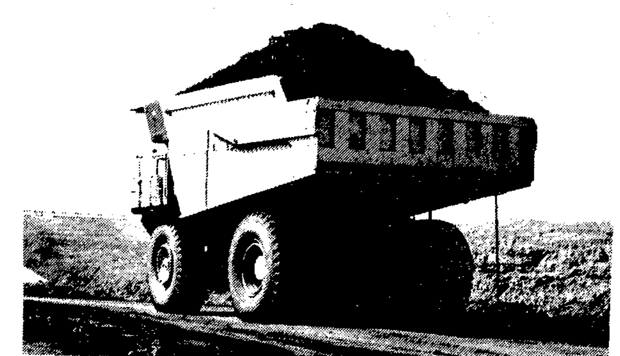
The balance of this paper is directed to equipment performance monitoring and the implementation of truck performance monitoring; specifically in a mining environment and how this performance monitoring can lead to integrated Mine Management Information Systems and Computer Integrated Mining.

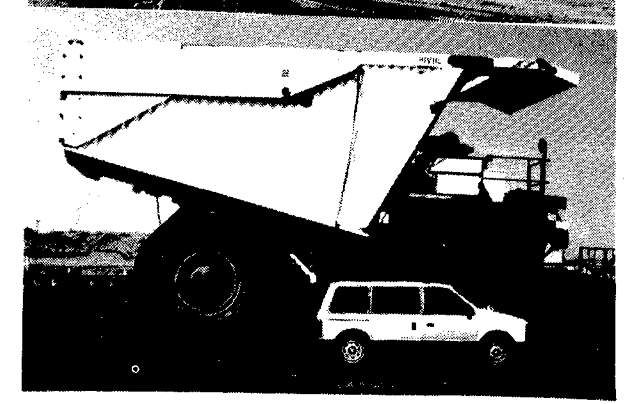
Basic Truck Performance Monitoring Hardware Items

- Load/weighing sensors
- Transmission/vehicle direction monitor F-N-R
- Dump switch
- Vehicle control number status/keypad
- Microprocessor with built in display and battery back-up clock

Load/weighing sensors and why weigh trucks? Trucks are weighed because it is central to truck performance monitoring. Trucking is material haulage. And, optimum truck utilization/performance is basic to efficient/profitable mining operation. The basic definition of work is: to move "X" amount of material from point A to point B over "Y" amount of time. (A basic trucking operation definition.)

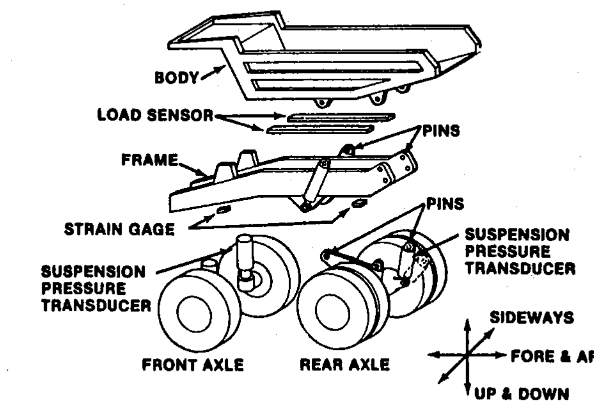
Further, with 170 ton capacity mining trucks costing $750,000 to $850,000, 35 ton trucks at $225,00 to $250,00, and 85 ton trucks at $400,00 to $500,00 it becomes very important, considering the owning operating cost of these trucks, to operate these mining trucks at optimum utilization within performance parameters. (Fig 2 & 3)



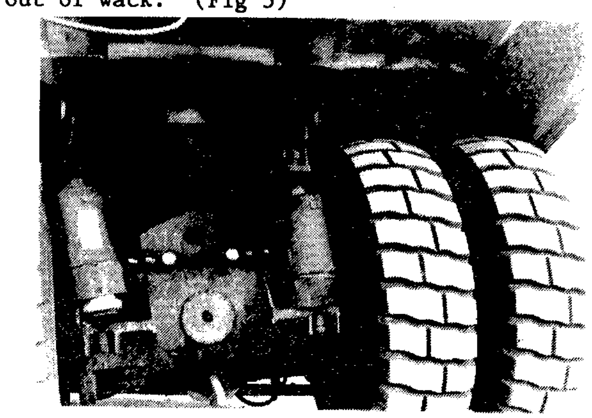


Providing the point is made for the need to weigh trucks, how can an on board truck weighing system be installed? Separating a truck into discrete components: 1) running gear, front axle and rear axle, 2) the truck frame, and 3) the truck body. These are the areas at which a truck can be weighed. (Fig 4)

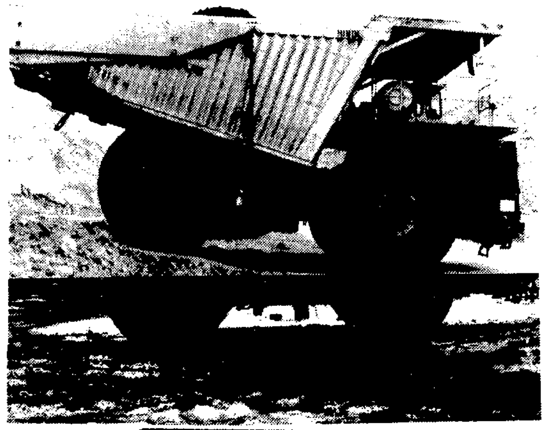
THE VARIOUS POINTS AT WHICH A TRUCK CAN BE WEIGHED

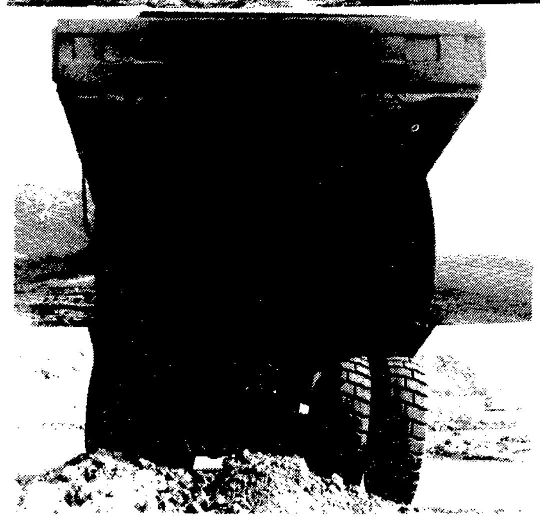


The running gear: it is possible to attach strain gauges to the running gear or in the running gear mounting pins, however, these strain gauges are very susceptible to damage and do require ongoing calibration. Further as the rear axle, in particular, oscillates its relative position to the truck frame changes throwing meaningful load weighing way out of wack. (Fig 5)



The area between the running gear and the frame: various devices can be utilized between the running gear and the truck frame. Nominally, pressure transducers in the running gear suspension cylinders, provided the truck has an air over oil type of suspension. However, with internal friction in the suspension cylinders and because of the fact that the rear axle moves sideways and fore to aft as it oscillates up and down, this method provides only a relative indication of load, i.e. somewhere in the area of +/- 20% of load. (Fig 6 & 7)

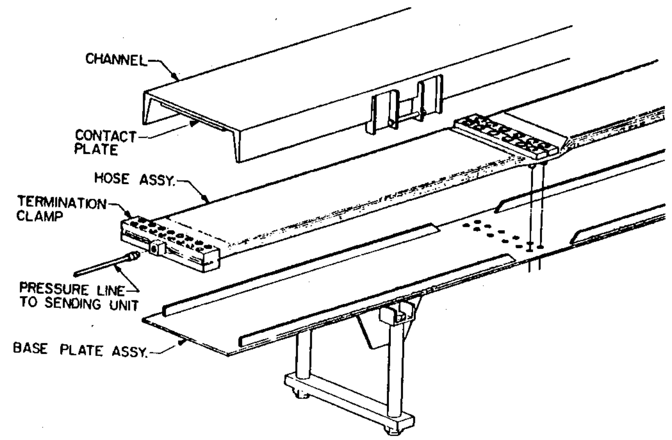




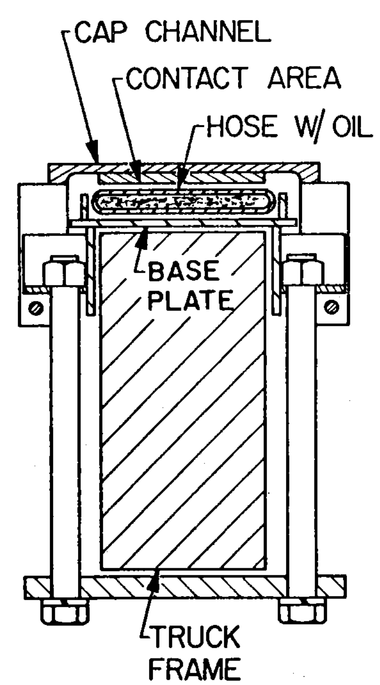
The truck frame: it is possible to attach strain gauges to the truck frame; however, these strain gauges do require on going calibration-recalibration from the nature of the strain gauges themselves and from the standpoint of the truck frame working, i.e. as the frame works (is operated in a dynamic condition) and is racked side to side, front to rear, the truck frame tends to (over time) perceptibly work harden. As such, the same load will not always produce the same relative strain in the truck frame.

The body pivot and hoist cylinders: yes, strain gauges can be put in the body pivot pins and combined with either pressure transducers in the hydraulic hoist cylinder circuit or strain gauges in the hoist cylinder mounting pins. However, this method requires that the body be lifted off the truck frame to take a weight measurement which precludes the possibility of weighing the load dynamically--as the truck is being loaded and/or operated--plus the continuing nemesis of on going strain gauge calibration-recalibration problems.

The area between the frame and the body: yes, it is possible in lieu of frame pads or sill plates to put load sensors in this area. Yes, this is a method that we recommend, with unique load sensors being installed accordingly. An OBDAS Load Sensor the key to a good truck weighing system. Looking at a cut away of this unique load sensor, the load sensor consists of 1) a base plate, 2) hose assembly with fluid in it, and 3) a cap channel with contact plate on the bottom of this cap channel; this contact plate resting on the hose. (Fig 8)



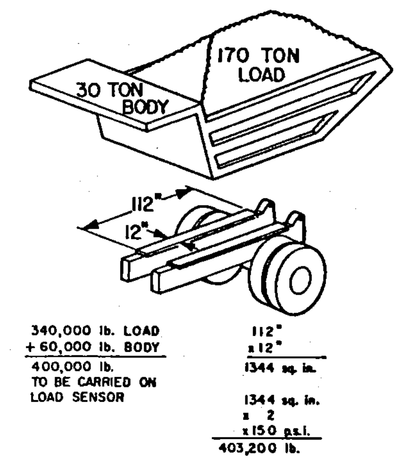
In an end view of this load sensor assembly, note that the hose has a very small amount of fluid in it and that the load sensor height is 3/4" to an 1 1/8" minimum. (Fig 9)



But how does a load sensor, a hose with a little bit of fluid in it at an accuracy of +/- 2% of total load, support a 170 ton load?* Consider a 170 ton load and a 30 ton body (a total load of 400,000 lbs.) on the load sensors.

* LeRoy G. Hagenbuch, "Development of Unique Load Sensors for On-Board Truck Weighing Systems," Sensors Expo '86, North American Technology, Inc.

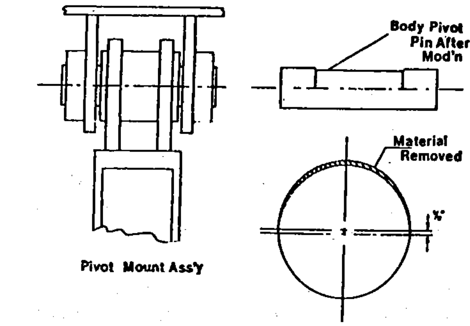
With a load sensor length of 112" and a load sensor width of 12" - 1344 square inches results. Taking this 1344 square inches times two (left and right side of the truck), times a typical 150 lbs. per square inch load sensor hose pressure 403,200 lbs. results. (Fig 10) Thus, with very nominal pressure in the hose it is possible to carry very substantial loads.



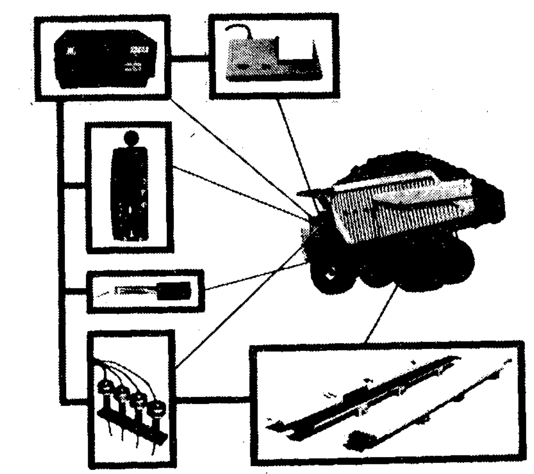
A load sensor assembly on a 140 - 170 ton class vehicle from the side of the truck with the body down. (Fig 11)

Putting load sensors between the frame of the truck and the truck body, in lieu of frame pads, works at its optimum when the body/frame pivot mount utilizes a floating body hinge pin concept. In lieu of the floating body hinge pin concept, strain gauges can be installed in the body hinge pins, however, this procedure defeats the calibration ease of the load sensor weighing system as (nominally) used with a floating hinge pin.

To overcome the problem associated with a fixed body hinge pin, the fixed hinge pin can be modified by removing a crescent shaped piece of material from the top of the hinge pin over the hinge pin length that goes through the frame pivot area. This approach converts fixed hinged pin mounted bodies to floating hinge pin mounted bodies and is done very successfully. (Fig 12)



In a basic truck performance monitoring system, other inputs added to the OBDAS on board weighing sensors are: a gear directional monitor, body dump switch, and keypad with basic system outputs being a digital display and printer. (Fig 13)



Basic Truck Performance Monitoring Input Devices are:

- Load/Weighing Sensors for weighing the load on the truck (analog input)
- A Transmission/Truck Direction Monitor, F-N-R, (digital input)
- Dump Switch for indicating when the truck dumps (digital input)
- A Truck Control Number Status/Keypad for inputting truck status operating/not operating, material being hauled, etc. (digital input)

Taking only these four inputs: load sensor, dump switch, F-N-R monitor, and keypad what output is obtained from a basic truck performance monitoring system?

The processor monitors and initiates output as:

1. Operator number changes
2. Body dumps
3. Gear direction changes
4. Truck starts

1) As the truck is started, data is output as to date and time truck started, truck number, and operator number.

2) As gear directional changes occur, the various haul cycle segments are broken out, including time to load, travel time to dump area, time to dump, and travel time to loading area. For every gear directional change, the tonnage on the truck at time of gear directional change, the direction the truck was going, and how long it was going in that direction is/can be output. (A continuous time and motion, weighing study.)

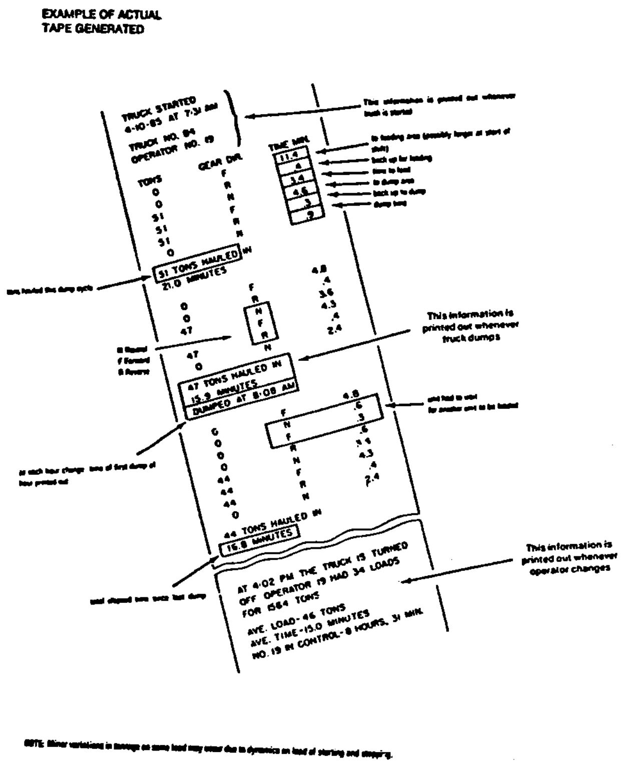
<u>Tons</u> <u>Gear Direction</u> <u>Time</u>

3) When the body is dumped, output generated is how many tons were hauled in the load and the time it has taken from dump to dump to haul this load.

4) An operator number change outputs:

1. Operator number (New and Old)
2. Time of operator number change
3. Number of loads hauled by previous operator
4. Total tonnage hauled by previous operator
5. Average load hauled
6. Average haul cycle time
7. Total time truck was under previous operator's control

Thus, <u>basic</u> output from a truck monitoring system with only <u>four inputs</u>: load/weighing sensors, transmission-directional monitor, dump switch, and operator keypad. (Fig 14)



Additionally, there are several optional enhancements that can occur to this basic truck performance monitoring system. What are these enhancements?

These advanced/enhanced truck performance monitoring systems options are divided into three groups.

1. No additional input/outputs required (manipulates existing data)
2. Additional output devices are required (existing data output in different forms)
3. Additional input devices required (collects further data to be output)

ADVANCED TRUCK PERFORMANCE MONITORING
SYSTEM OPTIONS
GROUP 1

<u>No Additional Inputs or Outputs Required</u>

<u>Group One</u>, Advanced Truck Performance Monitoring System Options include the following:

1. Loading Equipment Analysis, i.e. size of each bucket going into a truck, time from first bucket to second bucket, from first bucket to last bucket, etc.
2. Monitoring of haul back as to any material carried back with an appropriate signal as to when truck bed cleaning might be required.

3. Haul road condition monitoring, where in addition to the total load being carried on the truck, load spikes or load peaks as a truck moves down a haul road (dynamic loading of the load sensors) are recorded.

ADVANCED TRUCK PERFORMANCE MONITORING
SYSTEM OPTIONS
GROUP 2

<u>Require Additional Output Devices</u>

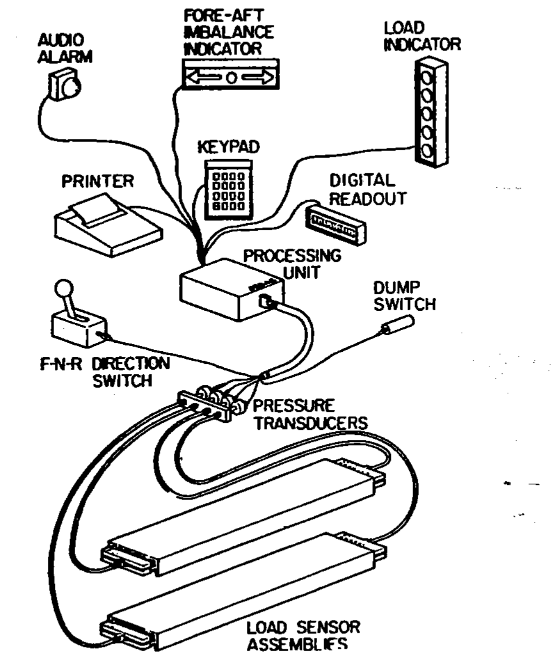
<u>Group Two</u>, Advanced Truck Performance Monitoring System Options are options requiring some additional output devices, still working, however, with the same basic four input devices. (Fig 15) These additional output devices and corresponding outputs are:

1. Load Monitor Lights, a bank of five (5) load indicator lights placed on the outside of the truck to provide feedback to a shovel runner or loader operator as to truck load status. This bank of five lights consists of a green light, three yellow lights, and one red light. As a truck is loaded, average bucket size being loaded is determined by the performance monitoring system. The green light is lit as long as full buckets are required, with the bottom yellow light coming on once only 3/4 of a bucket is required, the middle yellow light if only 1/2 a bucket, or the top yellow light if only 1/4 of any average bucket is required to complete the load. As soon as measured tonnage equals or exceeds the programmed truck load, preprogrammed in the microprocessor, the red light is lit telling the loader operator or shovel runner the truck is loaded.

2. Weight Distribution Monitors

   a. Side to Side Load Imbalance Monitor with an audio alarm for alerting the truck driver of any potentially unsafe off center, side to side loading, again as programmed into the microprocessor.

   b. Fore to Aft Loading Monitor Lights indicting load balance on the truck (front to rear) and giving the loader/shovel operator feedback as to proper load placement for correct front to rear truck loading.



ADVANCED TRUCK PERFORMANCE MONITORING
SYSTEM OPTIONS
GROUP 3

<u>Require Additional Input Devices</u>

<u>Group Three</u>, Advanced Truck Performance Monitoring System Options are options requiring additional input devices to provide some very substantive output. (Fig 16) These input devices and corresponding outputs are:

1. Dump Cylinder Pressure Sensor installed in the dump or hoist cylinder hydraulic circuit to provide a very definitive analysis of front axle/rear axle loading with the microprocessor outputting data as to empirical axle weight loading.

2. Distance Sensor/Odometer outputting both total travel distance and distance traveled in each truck directional segment. This distance sensor also yields two other truck performance outputs:

   a. tire tone mile per hour analysis, i.e. load X distance / time, output for each haul cycle segment, each haul cycle, each hour, each period the truck is under a different operator/control number, etc.
   b. a body up monitor for indicating if a truck has been driven any measurable distance, over a preprogrammed limit, with the body up identifying situations creating unnecessary body pivot mount strain as is often incurred when driving a truck with the body up.

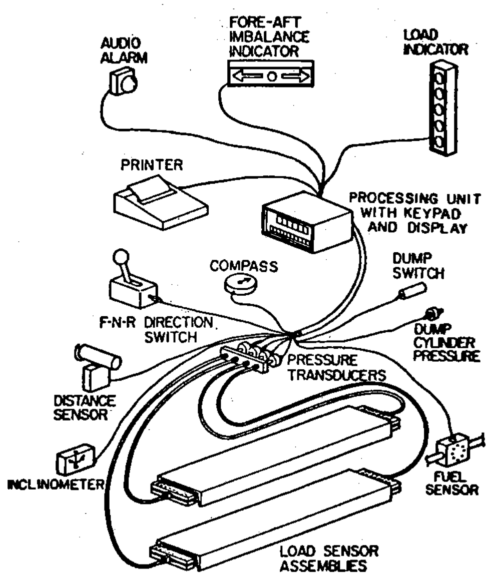
3. Inclinometer (slope transducer)

   a. indicating at what angle the truck is being operated at/driven on

   b. in conjunction with the odometer outputting a haul road plot or profile

4. Compass. A compass in conjunction with the odometer allows remote truck tracking as it leaves known discrete points in the haul cycle, i.e. loading site, dump site, ready line, etc.

5. Fuel Sensor. Providing an indication of fuel consumption through each segment of the haul cycle and/or each period truck is under a different operator/control number (not presently implemented/to be implemented in the future).



TRUCK/MOBILE EQUIPMENT PERFORMANCE MONITORING AS IT LEADS TO A MINE MANAGEMENT INFORMATION SYSTEM

Obviously, the need for data storage in addition to a paper tape exists with a basic truck performance monitoring system. The Advanced Truck Performance Monitoring System further spawns a mine management information system and accentuates the need for data storage -- data processing devices.

The <u>when</u> of equipment monitoring:

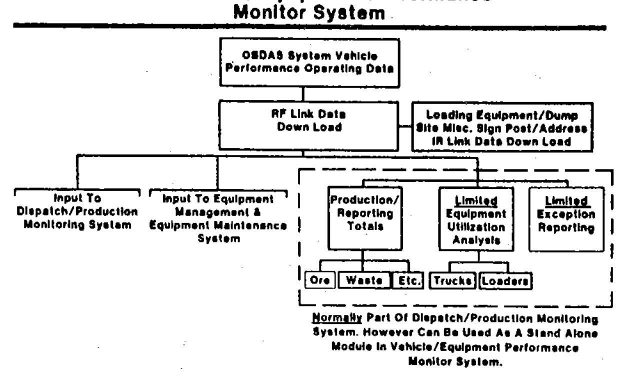
In considering data storage devices, it is important to understand the difference between historical monitoring and real time (near instantaneous) monitoring. Considering the Equipment Monitoring Chain, once we monitor in what time frame do we want to process the results and initiate action, on a historical basis; on a real time basis?

Historical monitoring is a recordation, recording what happens for later review. Real time monitoring means having that same information to review almost as it occurs so real time control is achievable.

In mining, it is nice to know after the Working Faces have been surveyed every month, how much material has been moved; but wouldn't this same information be more meaningful by week, by shift, or by class of vehicle as production occurs?

Real time monitoring implies real time or near instantaneous data down load. (Fig 17) Real time monitoring requires that the on board equipment performance monitoring system be linked through an on-line wireless data link to a central control computer. With this--real time vehicle performance monitoring--potentially inputting to a total equipment management system.

Real Vehicle/Equipment Performance Monitor System



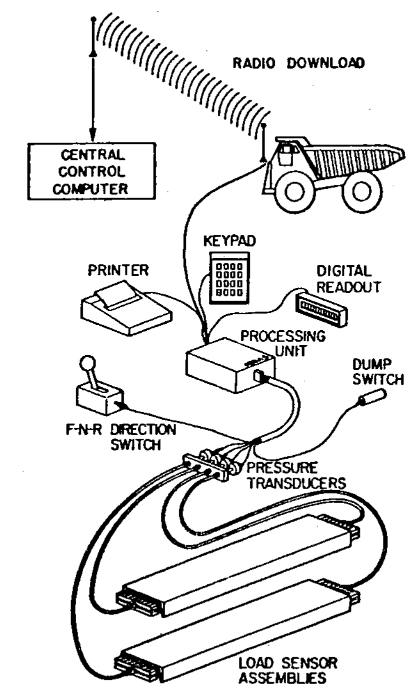
<u>Data Output Forms</u>

1. Historical (On Board) Data Output
   a. Printer
   b. Cassette Tape
   c. Non-Volatile Memory Pack Internal w/Cassette Tape
   d. Non-Volatile Memory Pack (External)

2. Real Time (Base Station) Data Output
   a. Radio Telemetry down loading to a central control computer
   b. Infra Red Telemetry down loading to a central control computer (quasi-real time)

Yes, it is possible to use on board data output devices (printer, cassette tape, or bubble memory) to store data for later processing, however, none of these devices allow for remote <u>real</u> <u>time</u> data collection and review. Meaningful equipment monitoring requires real time remote data monitoring output hardware either in addition to or in lieu of display, printer and on board data storage devices. Thus, on-line wireless data link down load capabilities with radio or infra red real time remote data monitoring telemetry. (Fig 18)

OPTIONAL DATA OUTPUT



Typically, when one is going to spend the money for any on board data storage device, it is wise in lieu of this device to spend a little more money for real time remote monitoring telemetry hardware, allowing for a meaningful Mine Management Information System.

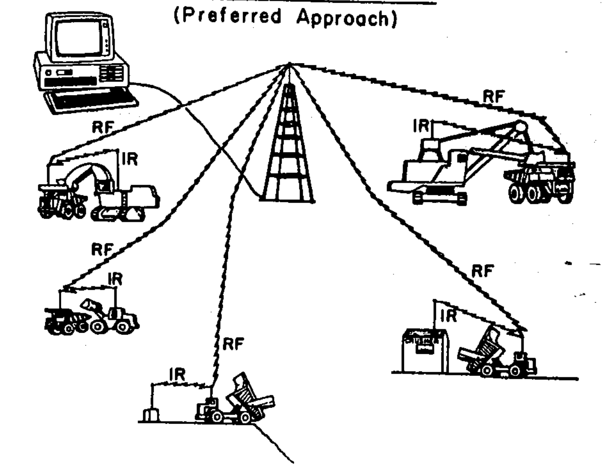
<u>REAL TIME REMOTE DATA MONITORING HARDWARE</u>

* Wireless Data Link - with transceivers on vehicle and at the central control computer
  - Radio Frequency (RF) Data Links
    --polled data collection
    --packet switching data collection
  - Infra Red (IR) Data Links
* Base Station
  - Computer
  - Communications Controller (optional)

OPTIONAL
* Vehicle/Equipment Signpost (Address Code)
  Data Link IR or RF
  - IR Limited Range Data Links Preferred
  - RF Data Link Characteristics Limited Capabilities

This real time monitoring hardware consists of wireless data links with transceivers on each vehicle and a central base station transceiver for receiving data from the equipment and for down loading this data to the central control computer. (Fig 19)

WIRELESS DATA LINKS
(Preferred Approach)



Wireless data links are typically of two different types--Radio Frequency (RF) and Infra Red (IR).

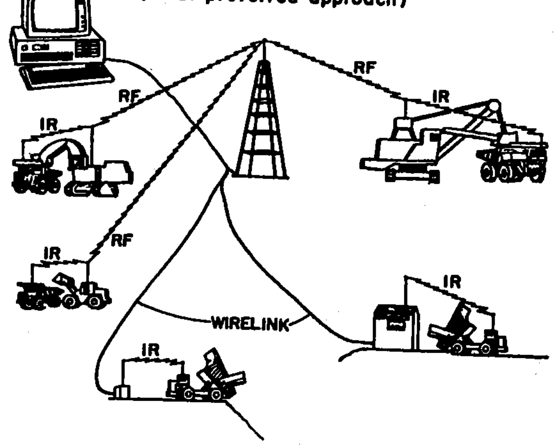
Radio Frequency (RF) wireless data links typically have a range similar to any two way radio. RF data links, however, require data transmission control. There are two basic RF data transmission control methods:

1. Polled data collection system wherein the base station transceiver sequentially calls or polls each of the equipment transceivers 1-2-3-4-5... with a data transfer of any stored data occurring (equipment to base station or vice versa as each polled connection takes place). This polling process takes place quite rapidly and depending on the amount of data to be transferred occurs at the rate of 5 to 10 equipment polls (connections) per second.

2. Packet switching data collection wherein as data is generated by any particular piece of equipment or by the base station, the transmission frequency is checked for clear by the sending transceiver and if so, that particular transceiver sends its data out in a burst or packet to be received by whichever transceiver the data is addressed to. This system works fine as long as data streams are relatively short. (Long data streams from individual pieces of equipment can tend to monopolize the transmitting frequency tying the entire data collection system into somewhat of a knot.)

Infra Red (IR) wireless data links are a quasi real time data link, as IR is of a very limited range, 200 to 600 feet typically and is basically limited to line of sight. When using IR or infra red data links, equipment has to come within range of the receiving transceiver before a data transmission can take place (200 to 600 typically). As such, equipment can be out of contact with the central base station for periods of time before coming within range of an IR transceiver, thus quasi real time. (Fig 20)

WIRELESS DATA LINKS
(least preferred approach)



Infra Red data links do have the advantages of not requiring FCC licenses to operate and with IR's limited range as data transmission occurs the location of the transmitting equipment is known, i.e. it would be within 200 to 600 feet of the IR data collector.

The where of equipment monitoring:

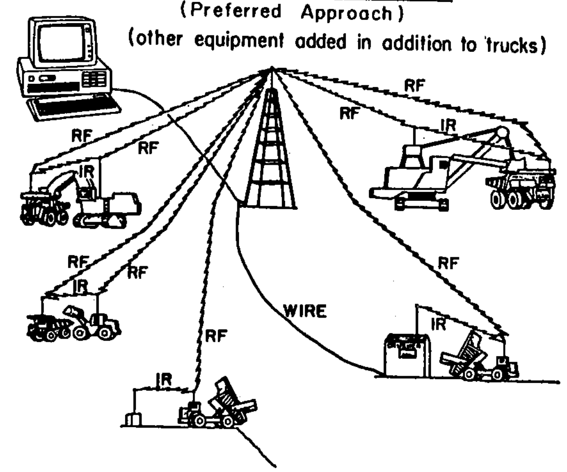
On board or the base station. In reality, to truly, effectively monitor it has to be at the base station. The base station has a RF and/or an IR transceiver for receiving data with a computer for accepting this data for processing, reviewing, and further equipment control. A final piece of base station hardware is, if RF data links are utilized in a polled data collection process, a base station communications controller, controlling communications between the base station and the various pieces of equipment.

Signposts, in addition to standard real time remote monitoring data down load hardware, meaningful real time data monitoring, almost by necessity, requires a method (optional) to establish equipment location or equipment address code; this being done through equipment signposts. These equipment signposts transmit either via an IR or RF data link on a continuous basis so as equipment comes within range of these transmitters (signposts), the signal (identifying that signpost/address) is picked up by the equipment with this signal (data) then included with the equipment's data transmission (down load) to the base station via the wireless data link on the equipment.

Though either RF or IR signpost data signal transmissions can be used, IR is the preferred approach because of its very limited range. IR signals do not skip and jump around and IR signals have an easily adjustable intensity (limited) power. RF on the other hand, even though the transmission power can be severely cut back, may skip and jump around i.e. radio transmission is omni directional and of indeterminate range versus IR transmission which can be very directional and range controlled.

Through proper data links, a total Equipment Monitoring System and Mine Management Information System can result, monitoring all mine equipment: haulage equipment, loading equipment, crushing equipment, etc. (Fig 21)

WIRELESS DATA LINKS
(Preferred Approach)
(other equipment added in addition to trucks)



In addition to the wireless data links from the vehicle to the base station and the base station hardware, there is software at the base station for controlling the data flow and operating this communications data link hardware.

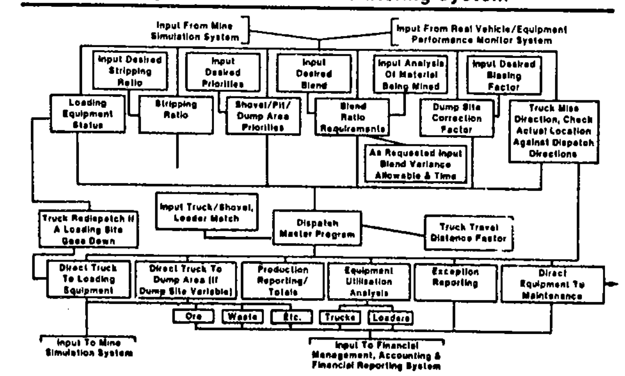
The base station software: 1) accepts equipment data from the data links, 2) processes, manipulates, and stores this data in proper data bases while at the same time, 3) formulating data output. Optionally, the base station software may poll or integrate the equipment microprocessors via the wireless data links to initiate data down load from the equipment, in the polling mode of RF wireless data down load versus packet switching.

With the addition of on-line real time remote data monitoring hardware, a real time Equipment Performance Monitoring System and Mine Management Information System can begun to be built.

THE FUTURE:

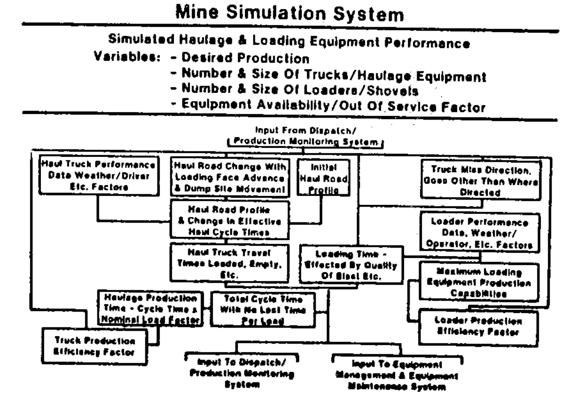
As data accumulates from trucks and other major mobile equipment operating on a mine site, an integrated Management Information System takes one step towards reality and as input occurs to both a production/dispatch monitoring system and a maintenance/maintenance management monitoring system, Computer Integrated Mining has its inception with truck/mobile equipment performance monitoring. (Fig 22)

Dispatch/Production Monitoring System



An integrated truck management information system does include in the mining environment truck/equipment dispatch, truck/equipment management maintenance management, and truck/equipment simulated performance data, and truck/equipment actual performance monitoring, with an integrated computer mining environment evolving. (Fig 23)

Mine Simulation System



In this integrated computer oriented mining environment, how should information be output? Principally through the use of exception reporting with only minimal reports as to normal conditions. Some typical exception reports that would be generated are:

1. Late arrival of a truck/equipment at its projected destination.

2. Delay in loading at loading site.

3. Failure of truck/equipment to be returned to service when projected.

Exception reporting--management is informed of situations requiring timely management input, while giving management only an overview of all normal situations.

A successful mine truck performance monitoring Management Information System does allow mine management to:

1. See what mine production has been and make extremely accurate projections as to future production.

2. To change and assign equipment based on these projections.

3. To use equipment in the most efficient way possible.

As a truck performance monitoring system is implemented, an integrated equipment Management Information System with Computer Integrated Mining results, with this integrated system having as its incipience truck/equipment performance monitoring.

GIGO

Babel

Corporate Integration

The Choice!

Truck/mobile equipment performance monitoring is the leading edge and the way to effective total management and a solid foundation on which to build a Management Information System leading to Computer Integrated Mining.

Computer Integrated Mining. What is happening in factories with stationary equipment today is what will be happening with mobile equipment tomorrow. It is coming!

Truck/mobile equipment performance monitoring systems are the cornerstone of good Mine Information Systems and Computer Integrated Mining.