



GEM™ 2000

GAS ANALYZER & EXTRACTION MONITOR

OPERATION MANUAL

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1 Introduction

CES-LANDTEC is the premier manufacturer of products, instruments and software for landfill gas extraction and for regulatory monitoring compliance. CES-LANDTEC has provided the landfill industry with a technologically innovative family of products for more than a decade. These products are the result of field-proven experience in design, operation and maintenance of landfills for environmental compliance.

The GEM™2000, designed by CES-LANDTEC, is specifically for use on landfills to monitor landfill gas (LFG) extraction systems, flares and migration control systems. The GEM™2000 samples and analyses the Methane, Carbon Dioxide and Oxygen content of LFG. The readings are displayed and can be stored in the instrument or downloaded to a personal computer for reporting, analysing and archiving.

The GEM™2000 instrument is frequently shipped in an optional protective hard case with a foam interior offers additional protection, transportation convenience and component hardware storage. When properly sealed, the hard case is watertight. The hard case is equipped with a pressure relief valve (located under the handle on the case) that is normally kept closed. If there is a change in elevation, the hard case may not open until turning the pressure relief valve equalizes internal pressure. When shipping a GEM™2000 back to CES-LANDTEC for calibration or service, always ship it in the original packaging to protect unit from damage.

Carefully unpack the contents of the GEM™2000, inspect and inventory them. The following items should be contained in your package:

- The GEM™2000 instrument
- GEM™2000 Operation Manual
- Registration/Warranty Card
- Soft carrying case with replaceable protective window and carrying strap
- Clear ¼" vinyl sampling hose assembly (5 ft.) with external water trap filter assembly
- Blue ¼" vinyl pressure sampling hose (5 ft.)
- Spare internal particulate filter element
- Polypropylene male connector (hose barb) connects to blue vinyl tubing
- Spare external water trap filter element
- 100-240 volt battery charger
- DataField 3.0CS software on CD-ROM
- RS-232 serial cable for computer/printer data downloading
- Temperature probe (optional)
- Hard carrying case (optional)

Complete the Registration/Warranty Card and return it to CES-LANDTEC. The model and serial numbers are located on the back of the GEM™2000 instrument.

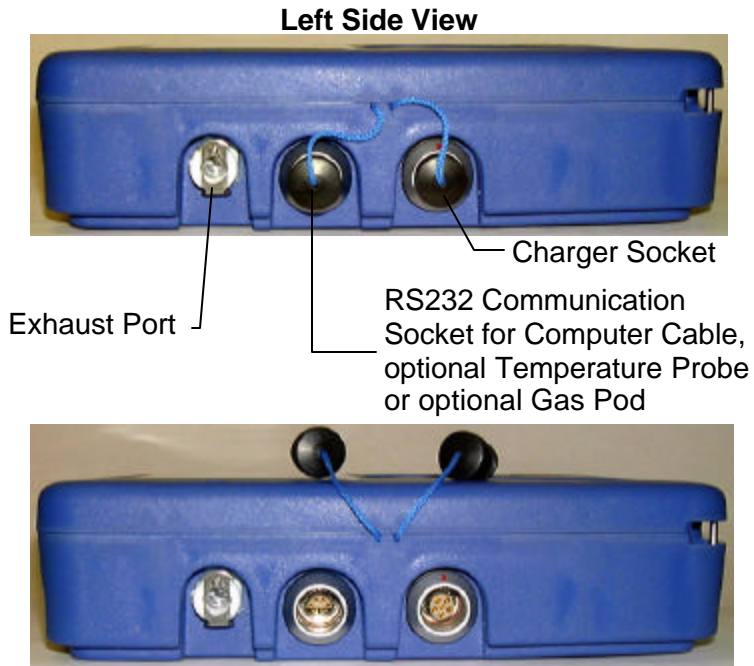
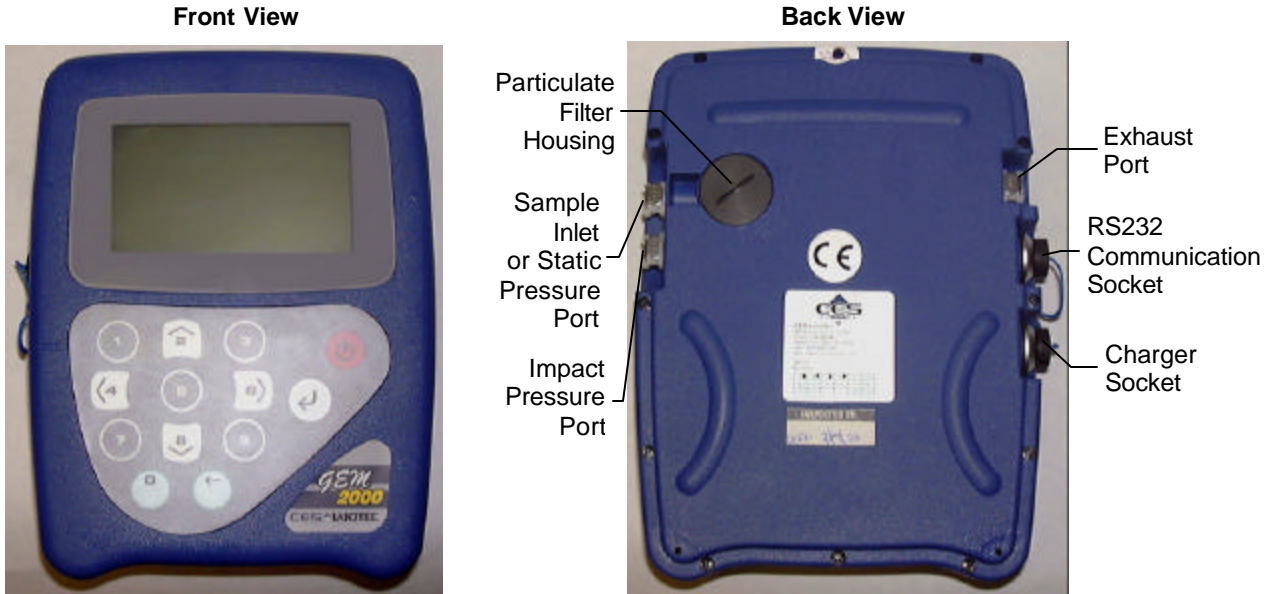
Immediately notify shipper if the GEM™2000 unit or accessories are damaged due to shipping. Contact CES-LANDTEC immediately if any items are missing.

For questions regarding instrument operation and procedures, please contact CES-LANDTEC at:

Customer Service or Technical Support	
Factory Service	(800) 821-0496
Spare Parts and Calibration Gas	
DataField Software Support	(888) 400-2272

2 General Operational Features

2.1 Physical Characteristics of the GEM™2000

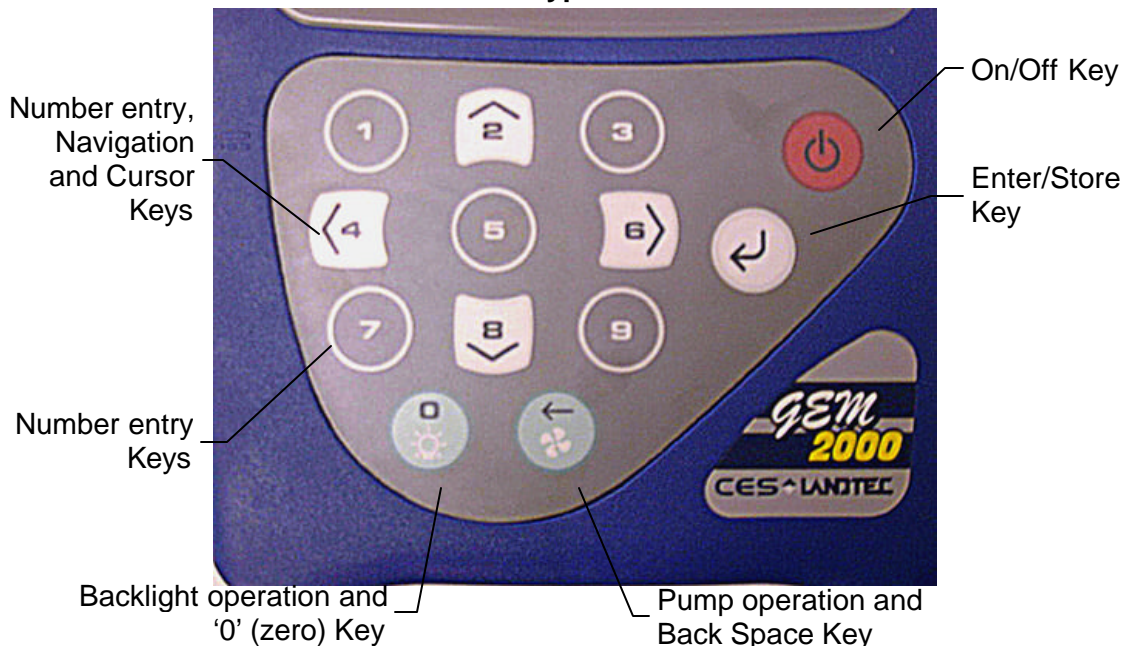


Right Side View



Impact Pressure Port Sample Inlet or Static Pressure Port

Keypad



Whenever a key is pressed the unit will emit a short 'beep' as an acknowledgement. This function cannot be turned off.

2.2 Turning the Instrument On/Off

When switching the instrument on, a long beep will sound, followed by the CES-LANTEC logo being displayed and the self-test will commence.

When switching the instrument off, the On/Off button must be held down for approximately 15 seconds, at which point a clean air purge will be carried out. If for any reason the instrument 'locks-up' and will not switch off, press and hold the On/Off button for 15 seconds. This will force the instrument to switch off.

2.3 Warm-up Self Test

When switched on, the instrument will perform a predetermined self-test sequence taking approximately 20 seconds, during this time many of the instrument's functions are tested, including:

- General operation
- Pump function
- Gas flow measurement
- Calibration
- Backlight function
- Solenoid function

During the self-test, the following information is also displayed:

- Calibration due date.
- Software version.
- Lifetime guarantee covered (or not).
- Date format.
- Serial Number.
- Operating language.

Upon self-test completion, the GEM™2000 should automatically enter read gas levels screen.

2.4 Warning and Error Display

During the self-test, if any operational parameters are out of specification or the pre-programmed recommended calibration/service date has passed errors or warnings may be displayed. Only three errors/warnings can be displayed at any time. To ascertain if more errors occurred, use the 'Ú' and 'Û' key to scroll up/down the list.

2.4.1 WARNING Displayed

All warnings displayed will be prefixed by the word '**WARNING**' followed by a relevant description. Two types of warnings may be displayed.

1. General warnings that may not have an effect on the instrument's function and those where the self-test has detected a function that is outside the usual programmed operating criteria (e.g. Battery charge low, memory nearly full, etc.).
2. Specific warnings of operational parameters that can affect the performance of the instrument (e.g. O₂ Cell out of calibration, CH₄ out of calibration, CO₂ out of calibration, etc.).

The most likely reason for the errors is either an incorrect user calibration, or sensor failure. If an incorrect user calibration has caused the warning, it should be correctable by way of returning the instrument to factory settings, zeroing or carrying out a user calibration as necessary for the relevant function.

2.4.2 ERROR Displayed

All errors displayed will be prefixed by the word '**ERROR**' followed by a number and description. The errors detected by the self-test are usually caused by a user calibration being out of specification or possibly memory corruption. This will have an effect on the functionality of the instrument and should be corrected before use (e.g. 01 - User cal data, CH₄ reading or channel out of specification, 02 - User cal data, CO₂ reading out of specification).

If any other Warnings or Errors are displayed, contact CES-LANDTEC for further information.

CES-LANDTEC is the ONLY authorized service center for the GEM-2000 instruments for the Americas

2.5 Storage

Do not keep the instrument in the trunk of a car or shed because it may be exposed to temperature extremes.

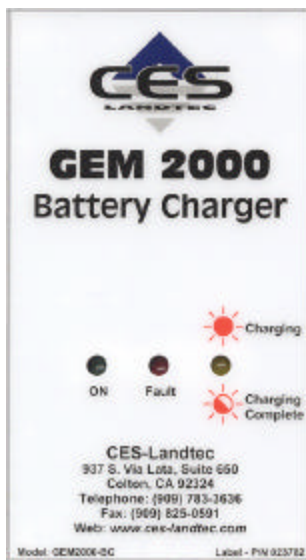
When not in use, instruments should be kept in a clean, dry and warm environment such as an office.

The instrument batteries should be discharged and fully charged at least once every four weeks regardless of indicated charge state. The discharge function may be carried out with the use of the Data Logging Function in GA mode of operation.

2.6 Battery/Charging

The Battery Charger IS NOT covered by the unit UL certification. Therefore, when connected to the Battery Charger, the instrument IS NOT intrinsically safe and should not be used in confined spaces.

The battery used in the GEM™2000 is a Nickel Metal Hydride manufactured as an encapsulated pack from six individual cells. This type of battery is not so susceptible to “memory effects” as Nickel Cadmium batteries, although it is not recommended that the unit be given short-term charges. When the flashing LED indicates “Charging Complete”, disconnect the charger.



The battery charger indicates when the unit is charging, charged or if there is a fault. A full charge should take approximately 2 hours. Charge the batteries until the ‘Charging Complete’ indicator is flashing.

2.7 Read Gas Levels Screen (GA mode of operation)

The read gas levels screen is also considered the normal operation screen and all operations are carried out from this starting point. The following information is displayed in various boxed sections at this time:

- Current programmed time and date.
- Current selected ID code.
- Pump status.
- Pump run time.
- Three main constituent gases – CH₄, CO₂, O₂ (in %).
- Balance gas.
- Last read time/date (if previous data is in memory), the benefits of this are, 1 – it is easily noted if a reading has been taken/stored, 2 – the current and previous readings can be easily compared.
- External Gas Pod “Not Fitted” (displays pod type when attached).
- Peak CH₄ reading (in %) (GA mode only).
- LEL CH₄ (GA mode only).
- Current barometric pressure reading.
- Current relative pressure reading (GA mode only).
- Gas Pod or Temperature Probe reading (if connected).
- Battery Charge graph (5 segment, flashes at 20% remaining).

- Memory Usage graph (5 segment, flashes at 5% remaining).

Other options:

- ① Menu Allows access to all instrument user functions.
- ③ Next ID Allows the next ID to be selected (if data available).
- ⑦ Previous Reading Allows the previous reading of the selected ID to be viewed (if data available).
- ⌵ Store Reading Stores the current displayed reading. (GA mode only)

2.8 Optional Gas Pods

Optional gas pods are available for use with the GEM™2000. These pods are available in seven different gases with nine different PPM ranges. Connection to the instrument is made via the data port and exhaust port. The detected PPM level is displayed in the upper right area of the gas read screen and is saved in the same manner as the other gas readings.

Gas Type	Range (PPM)	Resolution (PPM)
H ₂ S	0-50	0.1
	0-200	1.0
CO	0-1000	1.0
	0-20	0.1
SO ₂	0-100	1.0
	0-20	0.1
NO ₂	0-20	0.1
CL ₂	0-20	0.1
H ₂	0-1000	1.0
HCN	0-100	1.0

Gas pods are intended for use as an inexpensive detection means and not for regulatory reporting purposes. Should their use indicate the presence of the selected gas, further testing should be performed with regulatory approved instrumentation. CES-LANDTEC recommends that field calibration be performed using the relevant gas and concentration, prior to sampling with a gas pod.

2.9 Cold Start

THIS FUNCTION SHOULD BE USED ONLY AS A LAST RESORT.

(For Gas Calibration Error Messages, confirm that Factory Setting and User Calibration is done).

A Cold Start should only be carried out to correct an instrument if no other course of action has proved successful. This function **WILL ERASE** the instrument memory entirely. After a cold start is performed the user will need to reset the instrument to factory settings, perform a field calibration and reset the internal time/date to the default settings. Please note, the time/date may only be updated through DataField 3.0 software. It cannot be updated manually.

To carry out a cold start, turn the instrument on, during the self-test press and continue to hold the '⌵' key until the self-test has been completed. Upon completion of the self-test, a pass code entry screen will be displayed. At this point the '⌵' key may be released. Enter the code **12345** and press '⌵' to confirm.

After the pass-code entry has been accepted, the instrument serial number will be displayed along with the hours of operation and two options:

- 1 - Cold Start
- 0 - Continue

ONLY select option '1' if a Cold Start is to be carried out. Press key '1' to confirm this operation. The cold start menu will be displayed again, press key '0' to continue with normal operation.

3 General Operations Menu

The following features and functions are selectable from the main menu via key 'Ⓜ **Menu**' from the read gas levels screen. Various options are available to the user including:

3.1 Zero Transducers

Allows the user to zero the pressure transducer(s). Upon selection, the current pressure reading is displayed. The operation will be carried out when the '↵' is pressed.

3.2 Update Site Data

Allows the user to answer questions (pre-defined in DataField3.0 software) relating to the site (e.g. name of operator, weather conditions, etc.). Site Questions are different from Site Comments.

This is covered in more detail in Section 6 of this manual.

3.3 Data Logging (GA mode only)

Enables the user to leave the Instrument unattended to take samples at a pre-determined time. The reading interval and pump run time may be edited prior to commencing the logging cycle. The ID code may ONLY be set in DataField3.0 communication software.

Once the logging function is activated, the instrument will carry out a 30 second 'Warm-up' countdown (displayed bottom right) and begin the first sample. After each sample, the unit will shut down (sleep) to conserve power if the time between the pump ending and the next sample is greater than 30 seconds.

The instrument is reactivated (awakened) during a logging cycle, the company logo will be displayed for a few seconds and the read gas levels screen will be displayed. This will initiate a 30 second countdown to the next sample being taken unless the operator stops the logging function.

If for any reason during a logging cycle the inlet port were to become blocked the Instrument will sense this as a flow fail during the 'pump on' time and will automatically retry until a reading can be obtained. Therefore, position the sample tubing carefully to ensure no blockage due to water/moisture can occur.

3.4 Print Data

Allows ALL the data currently stored to be printed. This may ONLY be carried out with an appropriate RS232 cable (included with new instruments & available from CES-LANDTEC) and a printer with a serial port connection.

3.5 Adjust Contrast

The GEM™2000 automatically adjusts the screen contrast according to the ambient temperature to maintain normal viewing.

The contrast can be manually adjusted by using the '<' and '>' cursor keys. The manual contrast setting is stored when the instrument is switched off.

3.6 Field Calibration

Whenever carrying out a user calibration function it is important to ensure the correct value is entered. Additionally, in the case of a zeroing function, ensure only ambient air is used and no connection is made to a probe or wellhead fitting. The calibration cylinders sold by CES-LANDTEC have a volume of 17 liters. The regulator, sold by same, is set to 0.5 liters per minute. A normal field calibration usually requires the

gas to be running for about two minutes. Therefore you can expect to get between 14 and 18 calibrations per cylinder of calibration gas.

Upon selecting this option, the Field Calibration screen is displayed. A brief description of the user span calibration procedure and the current reading (row 'R') and user span calibration gas values (row 'S') are displayed.

The span gas values may be changed via the '③ **Edit Target Concentrations**' option. Once this option has been selected, **all** the gas values will require entry. Each entry is to be confirmed by pressing the '↵' key.

3.6.1 Zero Channels

Selected from the **Field Calibration** - '**↵-Calibration Menu**' allows the relevant reading to be zeroed. When selected, a list of the available options will be displayed, this usually includes CH₄, and O₂, also the Gas Pod (if fitted).

Supply a zero gas mixture to the instrument for the gas to be zeroed. Insure the reading for the selected gas has settled to its lowest value before selecting the zero function. When the required option is selected, the user zero function will be carried out automatically. The operation will be carried out when the '↵' key is pressed.

3.6.2 Span Channels

Spanning Channels should be carried out prior to use or when the ambient operating temperature changes greater than +/- 20 degrees. Selected from the **Field Calibration** - '**↵-Calibration Menu**', allows the relevant reading to be span calibrated (in accordance with the calibration value entered). When selected, a list of the available options will be displayed, which includes CH₄, CO₂, O₂, and Gas Pod (if fitted).

When the required option is selected from the list, the span calibration function will be carried out automatically. When carrying out this procedure, ensure the span calibration procedure (as outlined below) is followed:

1. Apply the relevant known certified gas concentration through the inlet port of the Instrument.
2. Wait until the current gas reading has stabilized.
3. Select the required calibration option via the '**↵-Calibration Menu**'.

3.6.3 Factory Settings

This will clear any user zero and span calibration data. It will also restore the pre-programmed factory settings for **ALL** channels – CH₄, CO₂, O₂ or Gas Pod (if fitted) and pressure transducers.

3.6.4 Last Field Cal

Displays the date the last field calibration was carried out (zero or span).

3.7 Mode of Operation

Allows changing instrument between GA mode and GEM mode of operation.

4 Taking Probe Readings (GA Mode)

CES-LANDTEC classifies non-extraction wells as Probes when **NOT** connected to an active vacuum extraction system. Probes, (commonly known as migration probes), may be placed on the perimeter of the landfill to test for gas migration or may be placed next to a building or road to test for the presence of Methane. The GEM™2000 instrument may be configured as a Gas Analyzer (GA mode) for sampling probes. To access this function from the gas read screen press '⓪' for menu and scroll down to **Mode of Operation**, press the '⌵' key and highlight **Landfill Gas Analyzer**, pressing the '⌵' key again will select GA mode of operation.

4.1 Preliminary Checks

Prior to going to the test site, it is good practice to ensure:

- All necessary ID codes and readings have been uploaded via DataField3.0 software.
- The time and date are correct.
- The water trap has a clean and dry filter fitted.
- The inlet-port particulate filter is clean and dry.
- A supply of spare filters is available in case of accidental water blockage or contamination.
- The battery has a good charge (minimum 25% charge, even if only a few readings are required).
- The memory has sufficient space available.
- The CH₄, CO₂, and O₂ readings have been auto-zeroed, without gas concentration present.
- Check the span calibration with a known concentration calibration gas.

Travel to site with the analyzer in the vehicle's interior - not in the trunk or truck bed, where it may be subjected to extremes of temperature and possible shock damage. Do not place the analyzer against anything hot (e.g. gas extraction pipe, car body or in an unattended car during the summer). This may cause erroneous readings.

When moving around a site, protect the instrument from strong direct sunlight, heavy rain or wind-chill. Strong direct sunlight can raise the temperature of the instrument beyond its operating range. If this occurs, the LCD display will appear almost black and the contrast setting cannot alter the contrast.

Always use the water trap! If the water trap becomes flooded, change the filter immediately and ensure all tubes are clear before re-use.

4.2 Update Site Data

Prior to taking the readings at a particular site, the Site Data should be updated (if programmed). This is accessed via the General Menu ⓪ **Update Site Data**'. This function removes the need for the site conditions to be recorded manually.

A series of up to five questions can be pre-programmed with the use of DataField 3.0 and answered at this time. The answers to these questions are stored and appended to each reading stored thereafter, until the site data is updated for another site.

4.3 Taking Readings – With ID

For this function to be used it is essential that the relevant ID and if required, previous readings are uploaded to the Instrument. An ID **cannot** be entered from the Instrument.

1. When the read gas levels screen is displayed, option '⓸ **Next ID**' should be selected. A list of stored ID's is displayed for selection via the '⬆' and '⬆' cursor keys, the 'next' ID on the list is automatically

- highlighted. To confirm selection, press the '↵' key. The display may be toggled to display any relevant ID information such as a description of the probe location, work to be carried out, etc.
2. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the previous sample from the instrument. Purge time may be set via DataField 3.0 (default is 30 seconds). Once the '↵' key is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the 'ⓂEXIT' key.
 3. The ID number selected and the pump runtime is displayed in the upper left corner of the read gas levels display.
 4. At this point, connect the sample tube (with water trap) from the sample point to the inlet port of the instrument, ensuring the connector 'clicks' into place. Then connect the sample tube to the probe sample port. **Do not connect the sample tube to the probe port before connecting to the instrument as this will cause any pressure in the probe to dissipate and a proper pressure reading will not be taken.**
 5. As soon as the connection is made, the relative/static pressure reading will be displayed. No sample is taken from the probe at this time. Once the reading stabilizes and the pump starts, the relative/static pressure reading is stored. The relative/static reading will remain displayed as the pressure last taken.
 6. The pump will run for the pre-programmed time and a countdown timer will be displayed. The pump may be stopped or started at anytime by way of the 'Ⓜ' (pump) key. The reading may be stored at anytime with the use of the '↵' key. When the pump automatically stops this should be used as a prompt to store the reading.
 7. Upon storing the reading, any pre-programmed questions will be displayed for response. This may require a numeric, alphanumeric selectable comment, or exclusive comment answer. A maximum of eight selectable and exclusive comments may be entered.
 8. Disconnect the sample tubing from the probe and proceed to Step 1 for the next probe.

For each reading, the following information will be stored:

- ID code.
- Current time/date.
- Site data (if entered).
- All gas readings and balance (CH₄, CO₂, O₂).
- LEL CH₄.
- Barometric Pressure.
- Relative Pressure.
- Questions/comments.
- Temperature (if temperature probe is connected).
- Gas Pod (if connected).

When the instrument is switched off, a clean air purge is automatically started for a pre-determined period. This may be aborted with the use of the '↵' key, although it is not recommended.

A tone will sound and a flashing bell will be displayed next to the appropriate gas reading value if a preset alarm condition has been exceeded.

4.4 Taking Readings – Without ID

1. From the ID list press 'Ⓜ Select No ID' or, if ID information has not been uploaded to the instrument, an ID list will not be available. In either case, the ID will be displayed and stored as '-----'.
9. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the previous sample from the instrument. Purge time may be set via DataField 3.0 (default is 30 seconds). Once '↵' is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the 'ⓂEXIT' key.

2. At this point, connect the sample tube (with water trap) from the sample point to the inlet port of the instrument, ensuring the connector 'clicks' in to place.
3. Now connect the sample tube to the probe sample port. **Do not connect the sample tube to the probe port before connecting to the instrument as this will cause any pressure in the probe to dissipate and a proper pressure reading will not be taken.**
4. The pump may be started or stopped at anytime by way of the '☺' (pump) key and a 'time-on' timer will be displayed. The pump should always be stopped using the '⌂' key, before storing a reading.
5. Upon storing the reading, a virtual keyboard will be displayed for any alphanumeric comments to be entered.
6. Disconnect the sample tubing from the probe and proceed from step 1 for the next probe.

Except for the ID code information, which will be stored as '-----', and probe questions, for each reading the information stored will be the same as that for a reading with an ID.

A tone will sound and a flashing bell will be displayed next to the appropriate gas reading value if a preset alarm condition has been exceeded.

4.5 Temperature Probe Reading

The GEM™2000 has the facility to automatically display and record the probe temperature via an optional temperature probe (TP-100). When a temperature probe is fitted to the RS232 Communication Socket, the temperature will be displayed in the read gas levels screen and recorded with all other data. The temperature probe is part of the GEM™2000 UL certification and is therefore certified for use under the same conditions as the instrument.

4.6 Cross-Gas Effects

4.6.1 Methane, Carbon Dioxide and Oxygen

The Methane reading is filtered to an infrared absorption frequency of 3.41µm (nominal), the frequency specific to hydrocarbon bonds. Instruments are calibrated using certified Methane mixtures and will give correct readings provided there are no other hydrocarbon gasses present within the sample (e.g. ethane, propane, butane, etc.). If there are other hydrocarbons present, the Methane reading will be higher (never lower) than the actual Methane concentration being monitored.

The extent to which the Methane reading is affected depends upon the concentration of the Methane in the sample and the concentration of the other hydrocarbons. The effect is non-linear and difficult to predict.

The Carbon Dioxide reading is filtered to an infrared absorption frequency of 4.29µm (nominal), the frequency specific to Carbon Dioxide. Therefore, any other gases usually found on landfill sites will not affect the Carbon Dioxide reading.

The Oxygen sensor is a newly developed galvanic cell type and suffers virtually no influence from CO₂, CO, H₂S, NO₂, SO₂ or H₂, unlike many other types of Oxygen cell.

The infrared sensors will not be "poisoned" by other hydrocarbons. Normal operation will resume as soon as the gas sample has been purged.

Note - there has been one reported incident of a high reading due to the presence of Carbon Disulphide, which has a similar absorption frequency to Carbon Dioxide.

4.6.2 H₂S, CO and other Optional Gas Pods

The Gas Pods used to measure H₂S and CO do suffer from cross-gas effects. Such effects are not accurately specified. However, the following table may be useful as a guide. This table represents how many ppm would be read by a Gas Pod if 100ppm of the interfering gas was applied, (with no other cross-contaminates being present in the sample).

Cell	CO	H ₂ S	SO ₂	NO ₂	CL ₂	H ₂	CH ₄	CO ₂
CO	100	<3	0	<-20	0	<40	0	0
H ₂ S	<0.5	100	~20	~-20		~0.1	0	0

NOTE: All readings are given in parts per million (ppm). The life of an electrochemical cell is determined by exposure to gasses, typical life being one to two years. It is recommended that Gas Pods be field calibrated at regular intervals.

4.7 Memory

The instrument's memory is volatile. It is maintained by a battery back-up system, which will maintain the memory while the battery is being changed.

The memory is not to be used as a permanent storage medium and any data should be transferred to a more permanent storage medium as soon as possible. An Instrument should never be stored for prolonged periods with valuable data in its memory.

Although unlikely, sudden shocks, high levels of electromagnetic interference or static discharge may cause memory corruption or loss. If this occurs, the instrument should be Cold Started and the calibration reset to factory settings before further use. **Cold starting will erase all data in the instrument including resetting the time and date to the default value.**

5 Taking Extraction Well Readings (GEM Mode)

CES-LANDTEC classifies gas-producing penetrations on landfills as wells when used with vacuum extraction systems and flow determining devices such as the Accu-Flo wellheads, orifice plates or pitot tubes. The GEM™2000 may be configured as a Gas Extraction Monitor (GEM mode) for the purpose of sampling wells and obtaining flow measurements. To access this function from the gas read screen press 'Ⓚ' and scroll down to **Mode of Operation**, press the '↵' key and highlight **Gas Extraction Monitor**, pressing the '↵' key again will select GEM mode of operation.

5.1 Preliminary Checks

Prior to going to site, it is good practice to ensure:

- All necessary ID codes and readings have been uploaded via DataField 3.0 software.
- The time and date are correct.
- The water trap has a clean and dry filter fitted.
- The inlet-port particulate filter is clean and dry.
- A supply of spare filters is available in case of accidental water blockage or contamination.
- The battery has a good charge (minimum 25% charge, even if only a few readings are required).
- The memory has sufficient space available.
- The CH₄, CO₂ and O₂ readings have been auto-zeroed without gas concentration present.
- Check the span calibration with a known concentration calibration gas.

Travel to the site with the analyzer in the vehicle's interior - not in the trunk or truck bed, where it may be subjected to extremes of temperature and possible shock damage. Do not place the analyzer against anything hot (e.g. gas extraction pipe, car body or in an unattended car during the summer). This may cause erroneous readings.

When moving around a site, protect the instrument from strong direct sunlight, heavy rain or wind-chill. Strong direct sunlight can raise the temperature of the instrument beyond its operating range. If this occurs, the LCD display will appear almost black and the contrast setting cannot alter the contrast.

Always use the water trap! If the water trap becomes flooded, change the filter immediately and ensure all tubes are clear before re-use.

5.2 Update Site Data

Prior to taking the readings at a particular site, the Site Data should be updated (if programmed). This is accessed via the General Menu 'Ⓚ'. This function removes the need for the site conditions to be recorded manually. A series of up to five questions can be pre-programmed with the use of DataField 3.0 and answered at this time. The answers to these questions are stored and appended to each reading stored thereafter, until the site data is updated for another site.

5.3 Taking Gas and Flow Readings (GEM Mode)

The GEM mode of operation is designed to allow for gas flow (SCFM) and energy measurements (BTU) to be calculated at the wellhead. This function requires the use of an ID that has been uploaded from DataField 3.0 software with the type of flow device defined. **Gas flow and BTU will not be calculated if this action has not been performed.**

1. When the gas read screen is displayed select 'Ⓜ **Next ID**'. A list of stored ID's will be displayed for selection via the '↑' and '↓' cursor keys, the 'next' ID is automatically highlighted, to confirm the selection press the '↵' key. The screen may be toggled to display any relevant ID information such as a description of the well location, work to be carried out, etc.

2. A reminder is displayed to disconnect sample tubes, as a clean air purge will automatically remove the previous sample from the instrument. Purge time may be set via DataField 3.0 (default is 30 seconds). Once the '⌵' key is pressed, purge will begin and the Read Gas Levels screen will be displayed upon completion. The purge may be aborted by pressing the '① **EXIT**' key.
3. Connect the sample tubes (with water trap filter) to the wellhead ensuring the gas sample tube and impact pressure tubes are properly oriented. Insert the temperature probe if used.
4. Press the '⌵' key to start the sample pump; a countdown timer will be displayed in the upper left area of the display. The pump may be stopped and restarted any time by pressing the '⌵' key. The pump run time is set in DataField 3.0 software. Allow the gas readings to stabilize and press '⌵ **Measure Flow**' key, this will store the gas level readings and display the '**PRESSURE READINGS**' screen. Note; a flashing bell will be displayed next to the appropriate gas and a beeping tone will be heard, if a preset alarm condition has been exceeded.
5. The '**PRESSURE READINGS**' screen will prompt the user to disconnect the sample tubes and allow the pressure to stabilize. Once the pressure has stabilized press '⌵ **Zero Transducers**'. Press '①' to continue. **Note**; if Accu-Flo wellheads are used this zero function may be performed prior to connecting the sample tubes to the well head by selecting '① **MENU**' and highlighting '**ZERO TRANSDUCERS**'. This eliminates the need to disconnect and re-connect the sample tubes on the same wellhead.
6. If a temperature probe is not connected, the user is prompted to manually input the gas temperature, press the '⌵' key when entry is finished.
7. The gas flow and energy screen is now displayed showing all the gas level readings taken in the gas read screen as well as the level of gas flow (SCFM) and power (BTU). In addition, Adjusted, Current and Previous (if downloaded) readings are displayed so modifications may be made to the well if required.
8. Pressing '⌵ **STORE**' will save the readings to memory. Then, the comments screen (if comments were loaded) will display and allow you to answer questions or select comments about the condition of the well. A total of seven comments and one exclusive comment may be stored with each ID.
9. Press '③ **NEXT ID**' and proceed to the next wellhead. An automatic purge will be performed at this time to ensure the sample has been exhausted from the instrument.

For each reading, the following information will be stored:

- ID code.
- Current time/date.
- Site data (if entered).
- All gas readings and balance gas (CH₄, CO₂, O₂).
- Barometric Pressure.
- Temperature.
- Gas Pod (if connected).
- Gas flow (SCFM) and Power (BTU).
- Comments and exclusive comment.

When the Instrument is switched off, a clean air purge is automatically started for a pre-determined global period. This may be aborted by pressing the '⌵' key, although we do not recommend this action.

6 DataField 3.0CS Software

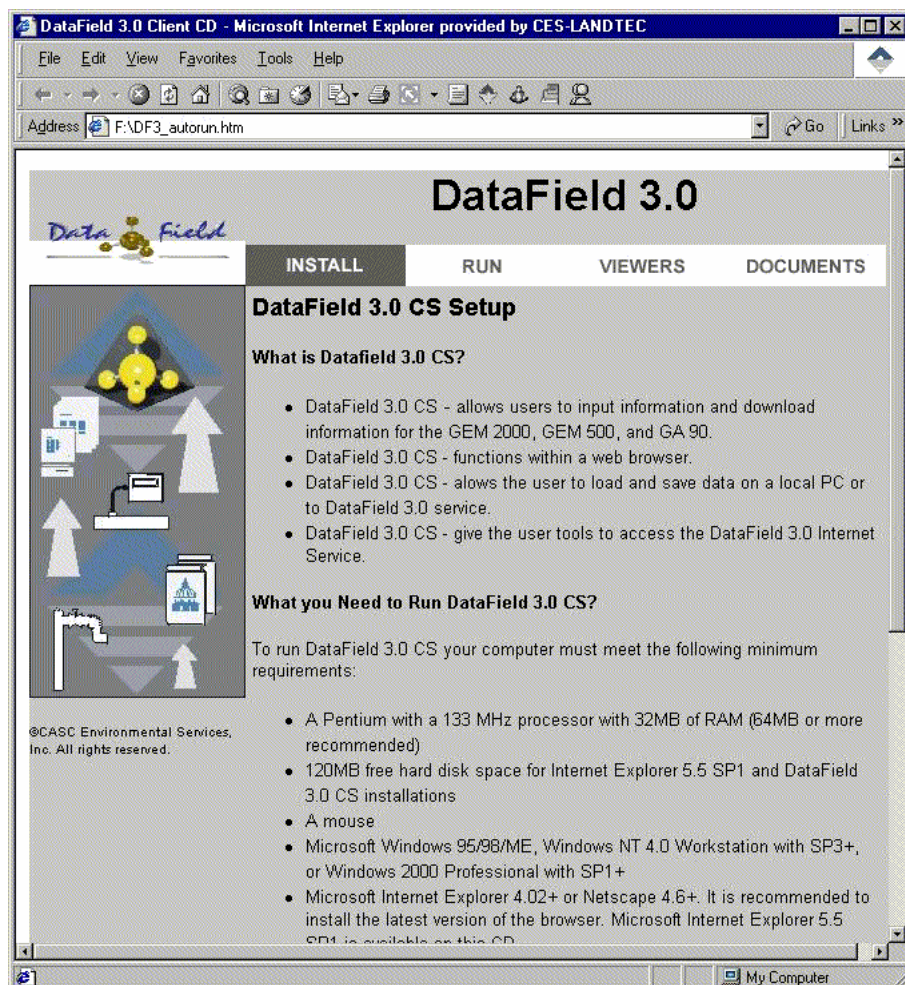
DataField 3.0CS is an integrated software program designed to communicate with the GEM™2000, 500 and GA90 instruments. The software will create files used for storing gas read data, ID data, comments and instrument configuration data. The files created are significantly different from the files created with GEM_COMM or GA_COMM software and are not compatible with these versions of software.

DataField 3.0CS is browser based (Java enabled) and will operate on Windows95b and higher Windows operating systems. Minimum hardware requirements are:

- Pentium 133 level microprocessor or equal.
- 32MB RAM.
- 120MB hard disk space.
- CDROM drive.
- Mouse or pointer system.
- Standard keyboard.
- Installed printer.

6.1 Installing DataField 3.0CS

Be sure your computer is turned on and all software programs have been properly closed. Place the program disk in the CD ROM drive and close the tray. DataField 3.0CS will self start and display the DataField C.S. set-up screen.



Install – Scroll to the bottom of the set-up screen and follow steps 1 thru 3.

Note: Make sure to reboot the computer after step 1, re-insert CD Rom to start autorun to go to step2.

Run – Allows the user to run the application from the CD Rom Drive.

Note: This option could make the application run slower due to the speed of the CD Rom.

Viewers – Allows the viewing of electronic information as supplied by CES-LANDTEC (after installing the appropriate viewer.)

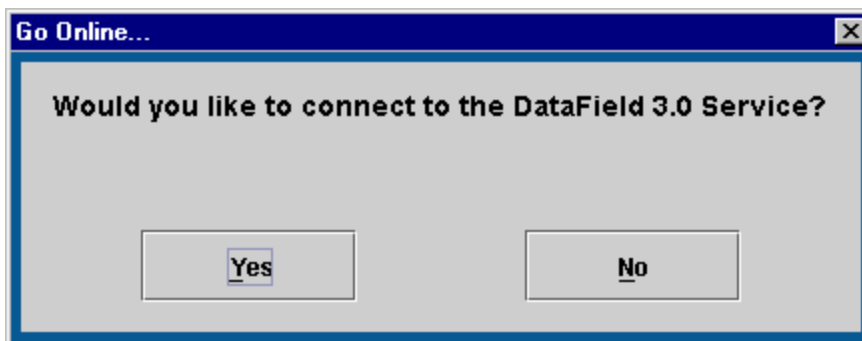
Documents – Electronic Manuals and Data sheets.

6.2 Establishing Communications

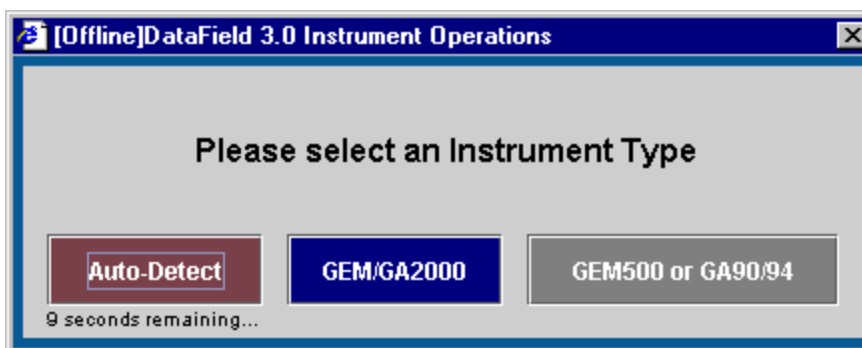
Connect the RS-232 download cable to an open COM port on your computer. Connect the other end of the RS-232 download cable to the GEM™2000 data port. DataField 3.0CS has the ability to automatically scan the different COM ports on your computer to find where the instrument is connected.

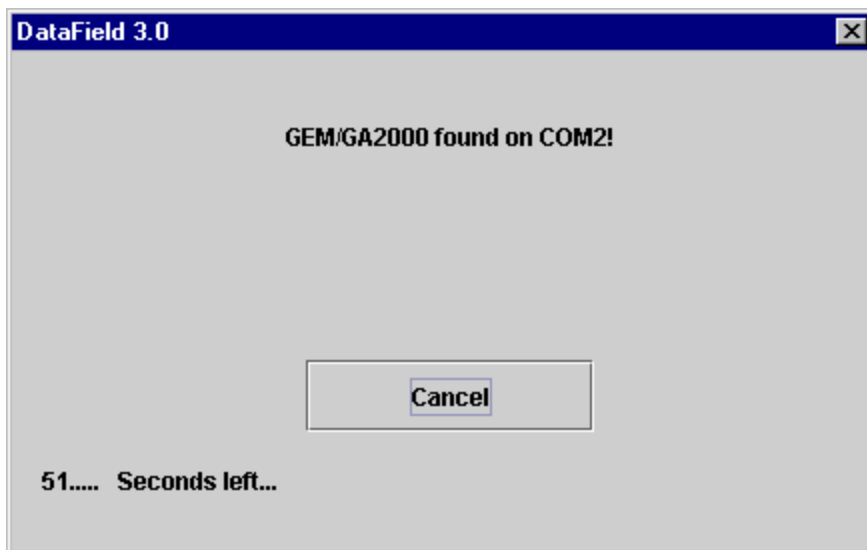
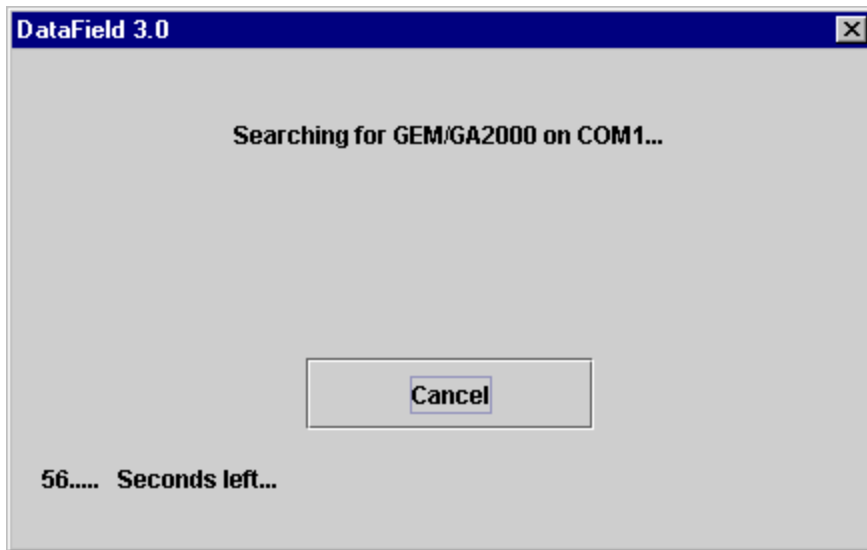
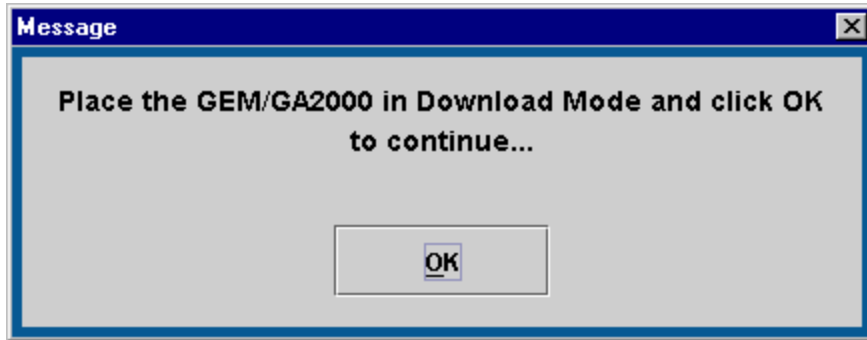
Turn the instrument On, wait for the self-test function to finish. The Gas Readings screen will display, if not, then turn off the GEM and re-start the instrument. The GEM™2000 must be in the Gas Reading screen in order to establish communications.

Once the instrument is in the proper communications mode, click on the Start menu then Programs menu. Scroll to DataField and then DataField 3.0CS to initialise the software. The following screen will appear on the computer.



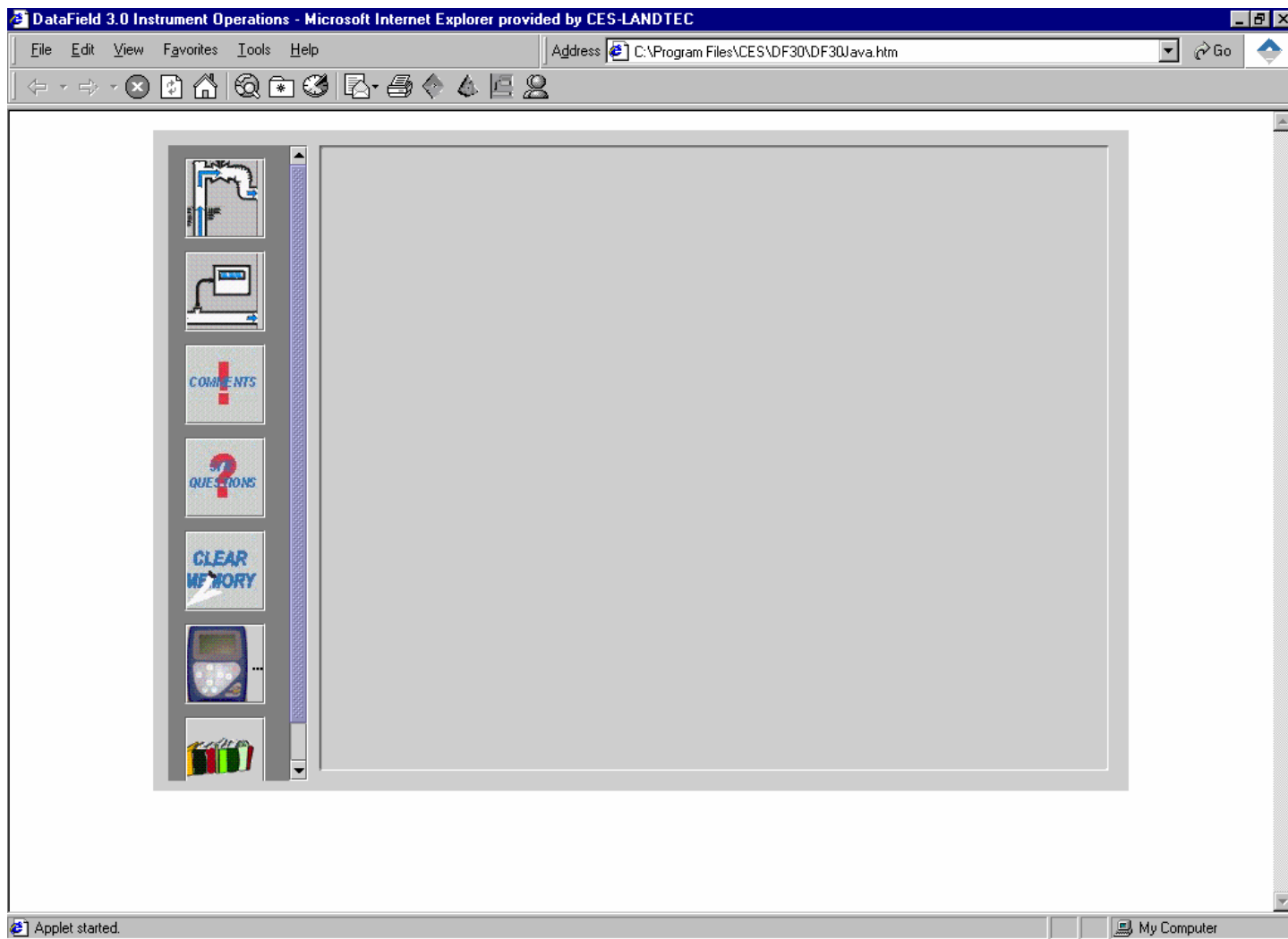
Click OK and DataField 3.0CS will automatically search for the instrument. This may take a few minutes. When an instrument is found and communications is established, the software will display a box that indicates what type of instrument was found. If the software does not find the instrument, it will display a box that indicates no instrument was found.





6.3 Main Screen

Once DataField 3.0CS establishes communications with the instrument, the main software screen will appear.



Seven main categories (buttons) are listed down the left side of the screen: ID Functions, Readings, Comments, Site Questions, Clear Memory, Instrument Settings and Resource Links. Clicking on any one of the buttons will take the user to that functionality of the application.

6.4 File

Clicking on the **File** heading will allow you to select **Exit** from program. This will close all files and exit the program.

6.5 Communications

It is not possible to change instruments and establish communications without re-starting the software.

6.6 Functions

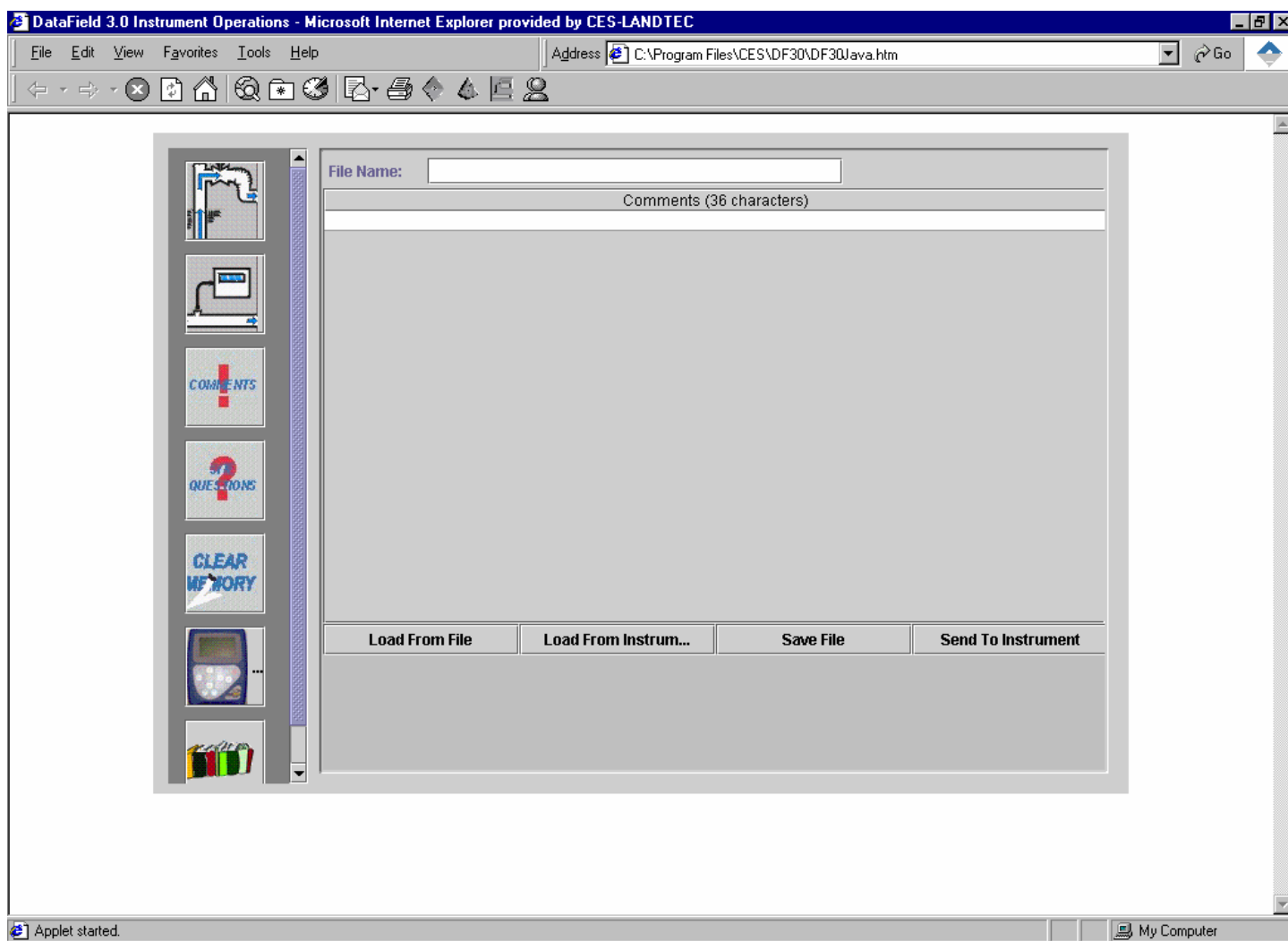
Each button has a specific function as listed below:

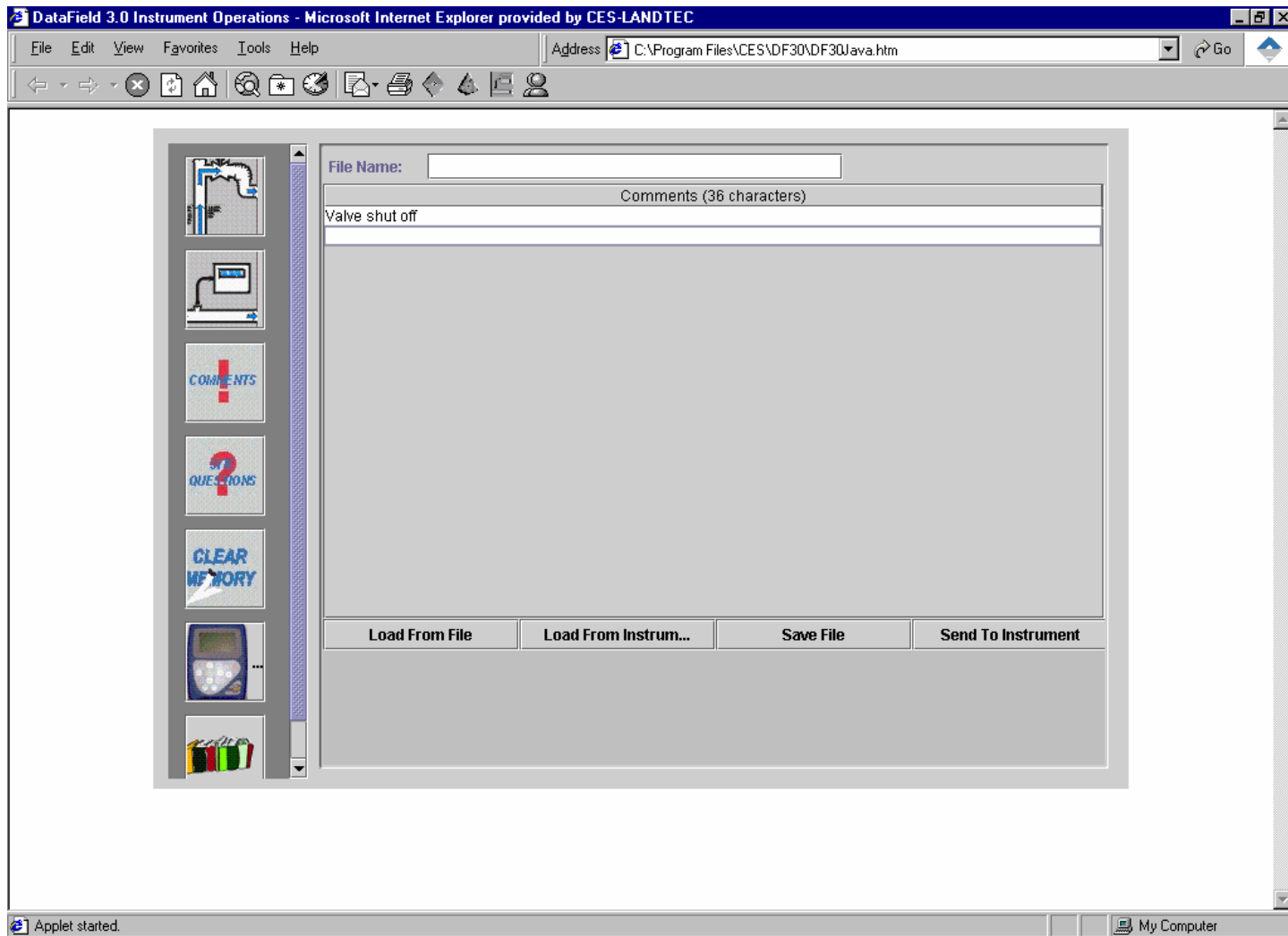
1. **Comments** – Allows entry of comments that may be selected for the ID's. A total of seven comments and one exclusive comment may be selected for each ID.
2. **IDS** – Used for adding new ID's, editing ID's or deleting ID's and entry of ID parameters such as pump run time, flow device, comments and questions for the ID.
3. **Readings** – Allows downloading and viewing data from instrument and uploading of previous data to the instrument.
4. **Site Questions** – DataField 3.0CS supports a total of five site questions that are answered by the technician and saved to the ID data.
5. **Clear Memory** – Allows the deletion if selective ID's, readings, comments, site questions or all memory loaded in instrument memory.
6. **Resource Links** – Allows the user to directly access information via the www.

6.6.1 Comments

DataField 3.0CS allows up to 64 comments to be created for upload to the GEM™2000. Each comment may be 36 characters in length and may be alphanumeric or any character on the computer keyboard.

Select Comment or **Exclusive Comment** must be turned on when the ID is created for comments to be selected for that ID. See section 6.6.1. From the opening screen, click on the **Comments** button to open the following screen.



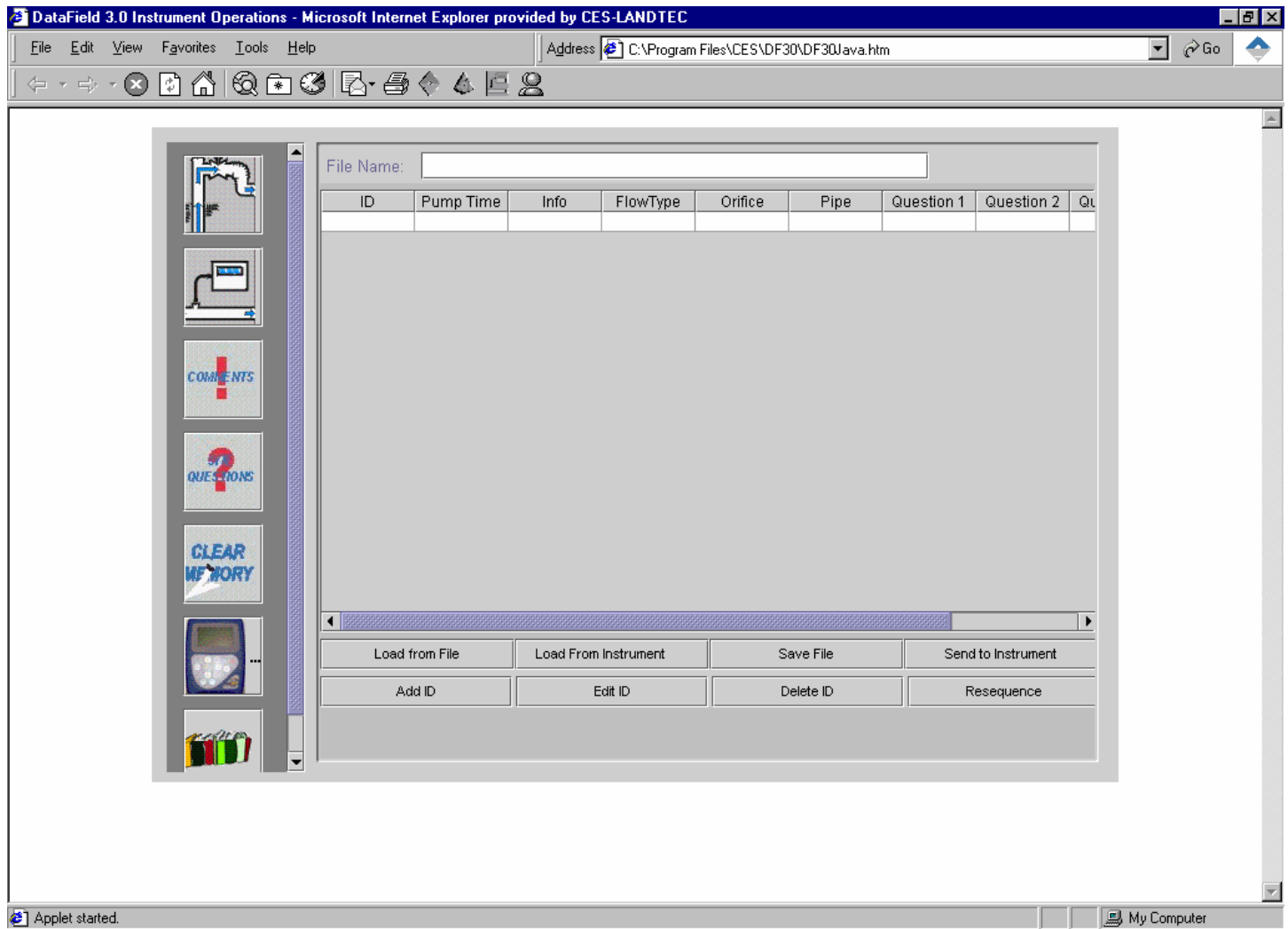


Enter the comment on the comment line and press **Enter** to continue entering comments until all the desired comments have been entered. Click on **Save File** to save the data to disk and then click on **Send to Instrument** to save the comments in the instrument. To delete a comment, click on the comment to highlight the comment and press the **Delete** key on the computer keyboard to remove the highlighted comment. It is always suggested to save the comment file because of the potential size and time required to recreate the comments. Once created, the comment file may be modified and saved under a different file name at any time.

Note: Comments must be created and sent to the instrument through the software. They can not be hand input into the instrument in the field.

6.6.2 Entering ID's

From the opening screen select the **ID** button. The following screen will open:



Selecting the **Save File** button will allow you to enter the name for the file you wish to save. The naming of files follows the extended naming convention for Windows.

Selecting the **Load from File** button will allow a previously created file to be loaded from the computer disk drive.

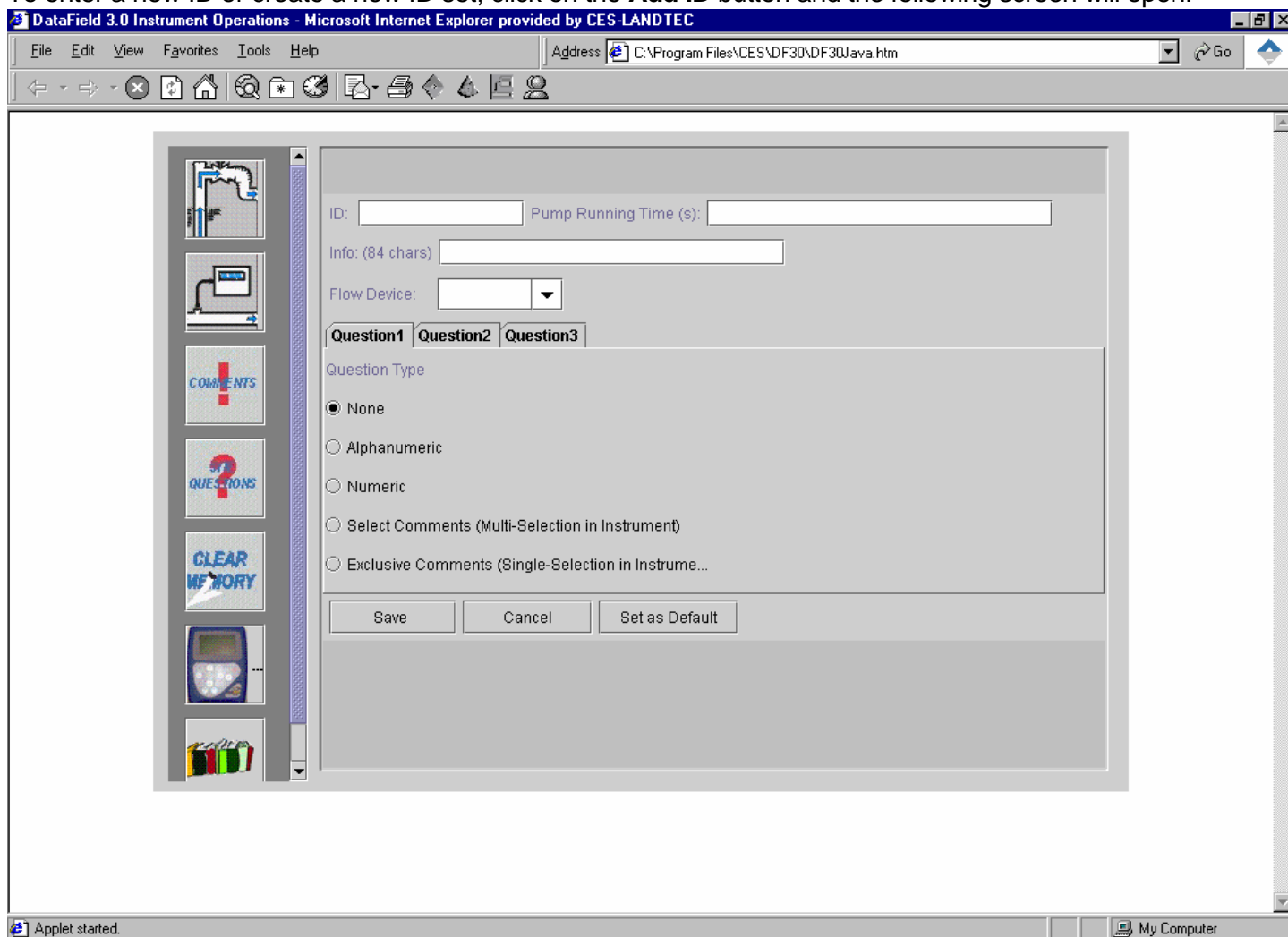
Selecting the **Load from Instrument** button will allow previously loaded ID's in the instrument to be downloaded for modification such as increasing the pump run time or adding additional comments to a specific ID. CAUTION: Loading ID's from an instrument can be a dangerous practice and is not



recommended if using DF3.0 online service. The possibility exists of introducing into a project ID's from another project. When the ID's are downloaded from the instrument and stored on line all ID's that are present in the instrument will be stored to the current project IRRESPECTIVE of if the ID's belong to the project.

Add ID button is used for the creation of a new ID or multiple ID's that may be sent to the instrument or saved to a new file for later use.

To enter a new ID or create a new ID set, click on the **Add ID** button and the following screen will open:



Enter the Well ID in any combination of alpha or numeric characters for a maximum of eight characters. **All eight characters must be used.** Enter the pump run time in seconds (maximum of 999 seconds), pump run time must be entered in order for the pump to be turned on for gas sampling. Enter information about the well, such as its location, previous problems, etc or leave blank. Enter the type of flow device used with the well (Accu-Flo wellhead, Pitot tube, or orifice plate); user input may also be selected. If Pitot tube or orifice plate is selected, the **inside** pipe diameter and **orifice diameter** must be entered. If the pump run time and the flow device are going to be the same for multiple wells, click on **Set as Default** to lock these two values. Three questions may be asked about the well for reply by the technician at the time a sample is taken. These can take the form of alphanumeric, numeric, selected comments or exclusive comments. If none is selected then no questions will be asked for this ID. Note: **If Select Comments or Exclusive Comments is selected, Comments must be created and sent to the instrument.** See Comments section.

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Click on **Add** to add this to the editor screen seen below. If additional ID's need to be entered, simply click on **Add ID** and enter the data as before.

The screenshot shows the DataField 3.0 Instrument Operations web application. The browser window title is "DataField 3.0 Instrument Operations - Microsoft Internet Explorer provided by CES-LANDTEC". The address bar shows "C:\Program Files\CES\DF30\DF30Java.htm". The application interface includes a "File Name:" input field, a table with the following data:

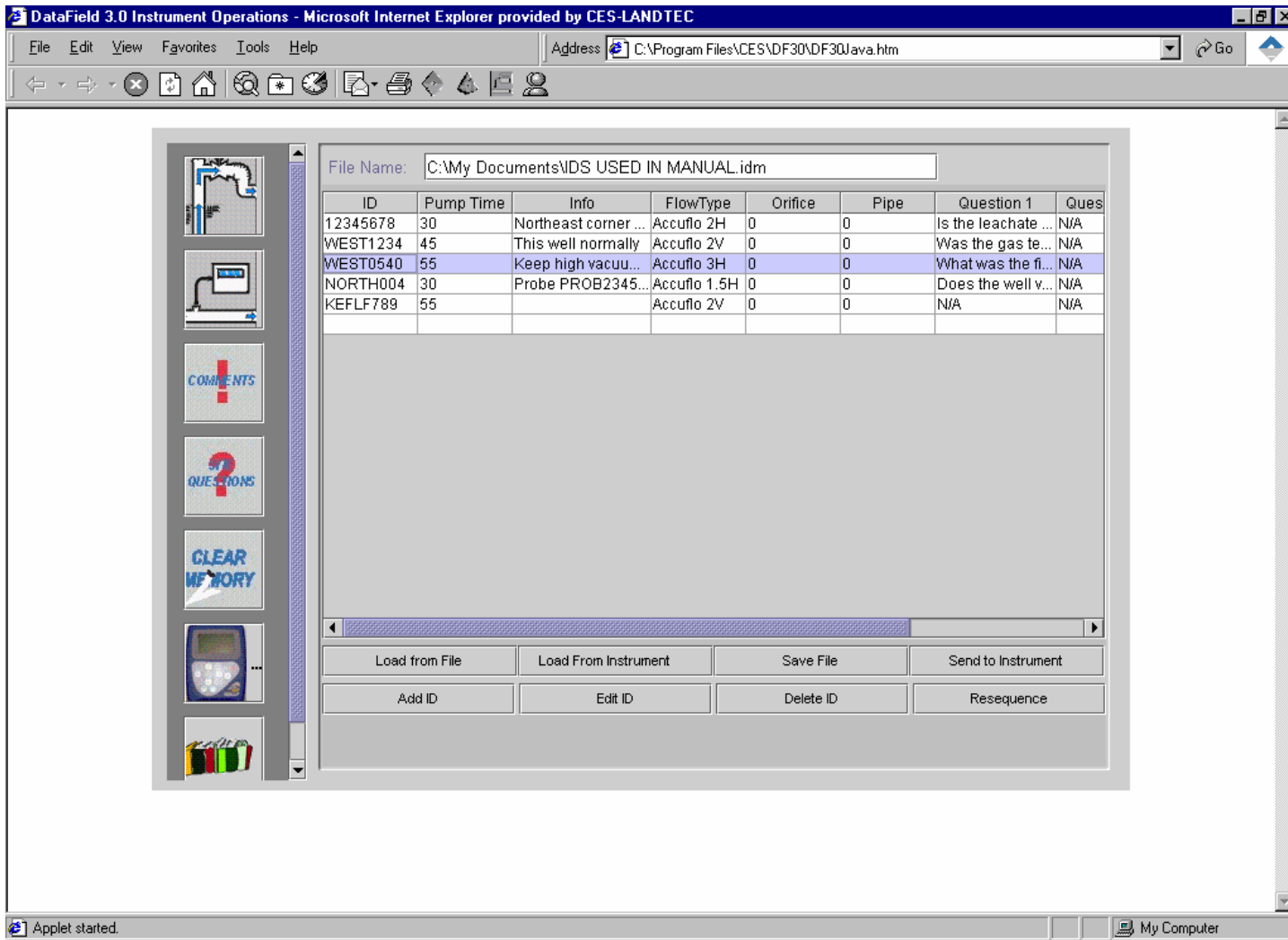
ID	Pump Time	Info	FlowType	Orifice	Pipe	Question 1	Ques
12345678	30	Northeast corner ...	Accuflo 2H	0	0	Is the leachate ...	N/A

Below the table are buttons for "Load from File", "Load From Instrument", "Save File", "Send to Instrument", "Add ID", "Edit ID", "Delete ID", and "Resequance". A vertical toolbar on the left contains icons for "COMMENTS", "QUESTIONS", "CLEAR MEMORY", and a device icon. The status bar at the bottom shows "Applet started." and "My Computer".

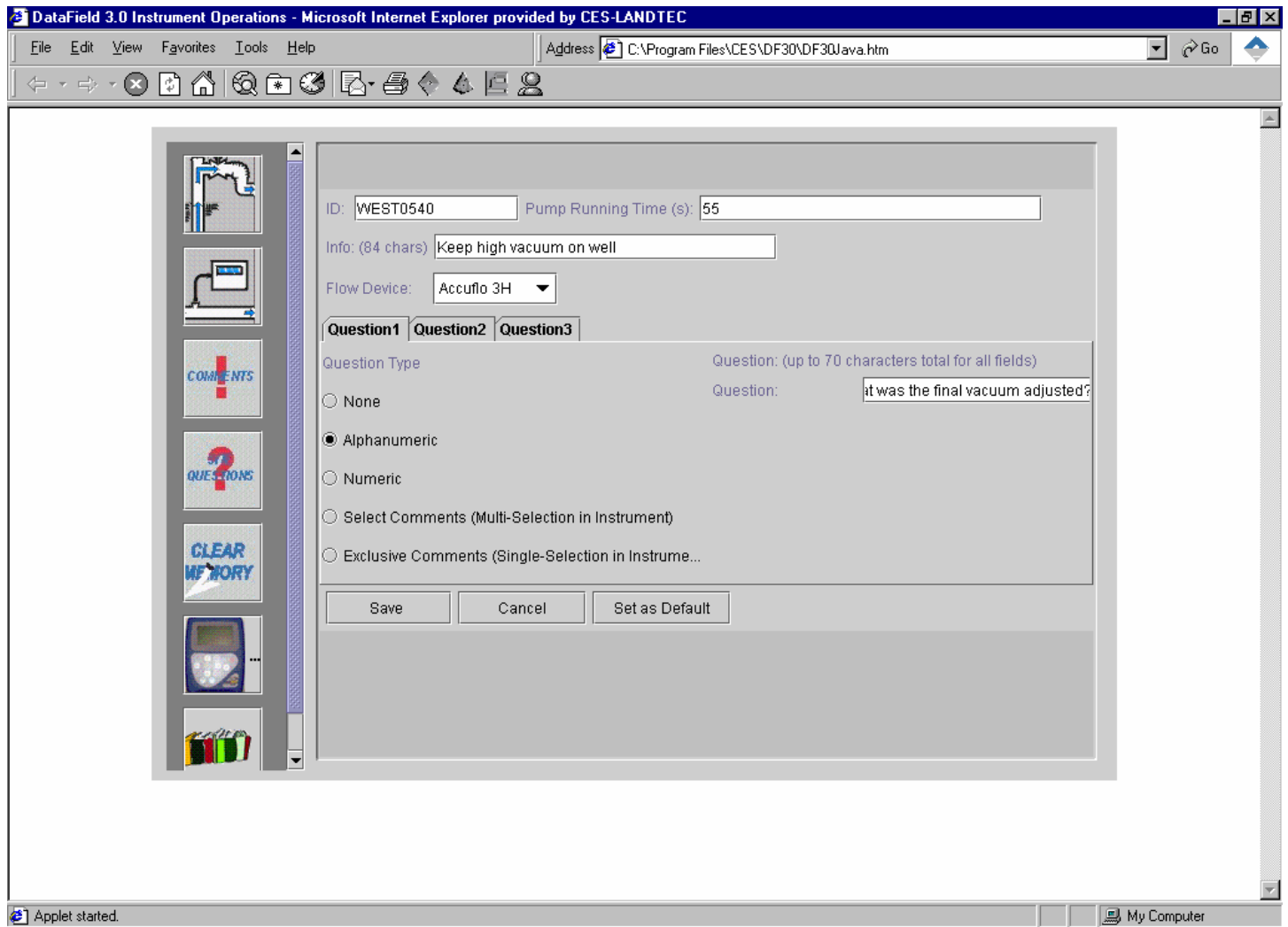
Once all the ID's have been entered, click **Save to File** button to save the ID data to a file or **Send to Instrument** button if data is to be uploaded to an instrument for field sampling.

6.6.3 Editing ID's

ID's may be edited in a similar manner to entering a new ID. Click on the **ID** button. Click on **Load from File** button if the ID's to be edited are in a saved file on disk or click on **Load from Instrument** if the ID's to be edited reside in the instrument. Once the ID's have been opened, the **ID Editor** screen will appear as below.

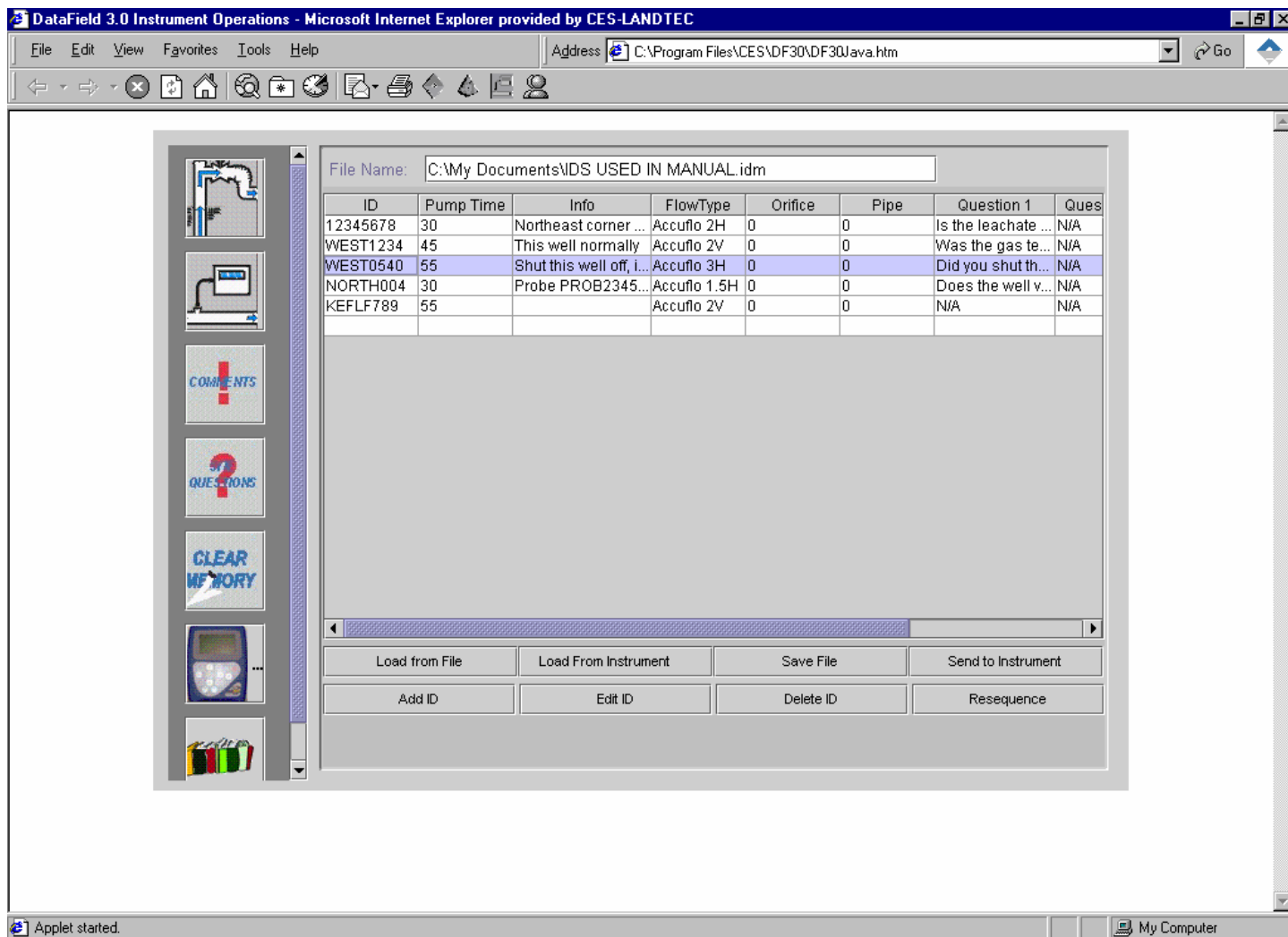


To select an ID for editing, click on the ID to highlight the ID, and then click on **Edit ID** at the bottom of the screen. The Edit ID screen will open and allow information for the selected ID to be changed. When finished with the changes, click on **Save** to save the edited ID to the ID list.



When editing is completed, click on **Save** to return to the previous screen. Click on save file to save the edited data to disk or click on **Send to Instrument** to append the ID's to the ID's in the instrument.

Note: ID's are only appended to the unit. It is strongly recommended to erase/clear ID's from unit prior to sending new ID's to the unit. One obvious exception is in the case of loading ID's for multiple sites in an instrument.



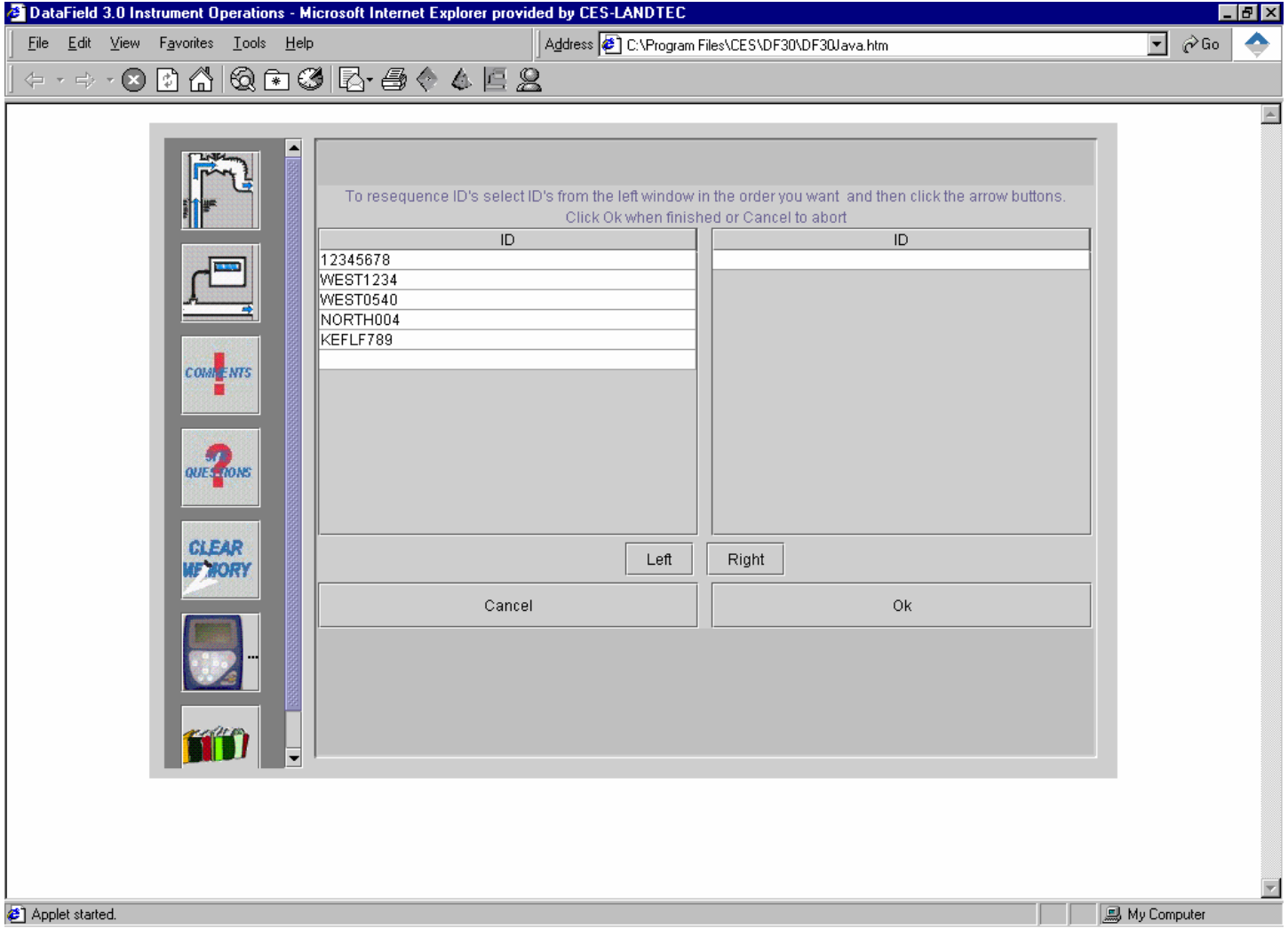
6.6.4 Delete ID's

To delete an ID select either **Load from File** (if the ID to be deleted is in a file saved on disk) or **Load from Instrument** (if the ID to be deleted is in the instrument). The **ID Editor** screen will open with the ID information listed. Select the ID to delete and click on the ID to highlight the ID. Click on **Delete ID** at the bottom of the screen. A prompt will appear to verify the action. Clicking **Yes** will delete the ID. Click on **Save File** to save the updated file to disk or click on **Send to Instrument** to update the instrument for field sampling.

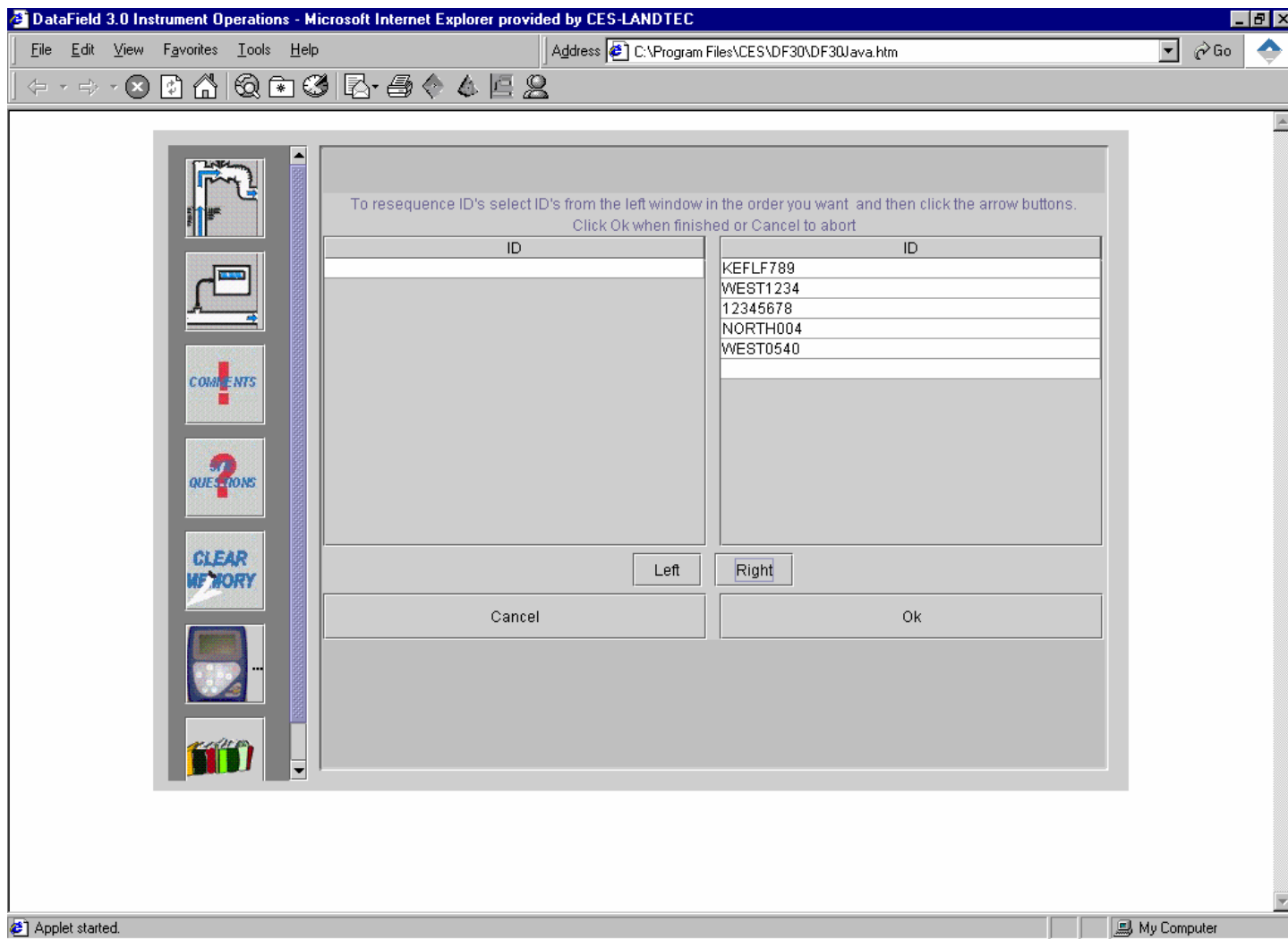
Note: It is suggested to clear ID information from the instrument prior to uploading the revised ID list. Otherwise the new ID list will be appended to the existing list. Clearing ID's in the instrument will clear ID's in the both GEM & GA modes of operation.

6.6.5 Re-sequencing

With DataField 3.0CS it is possible to change the order of the ID's in a file to be in the same order as they are sampled in the field, this is called **Re-sequencing**. To re-sequence an ID data set, click on the **ID** button to open the ID editor. Load the ID data set from a file or download the data set from the instrument. Click on the **Re-sequencing** button to open the screen shown below.



Select the ID from the left side window and click on the **Right** button to move ID to the right window to create the new sequence order. Repeat this process moving all ID's to the right side of the desired order.



Click OK when the desired new sequence is obtained, this will return you to the well ID screen. Click on the **Save File** button to save the new data set to a file on disk or click on **Send to Instrument** to upload the new data to the instrument.

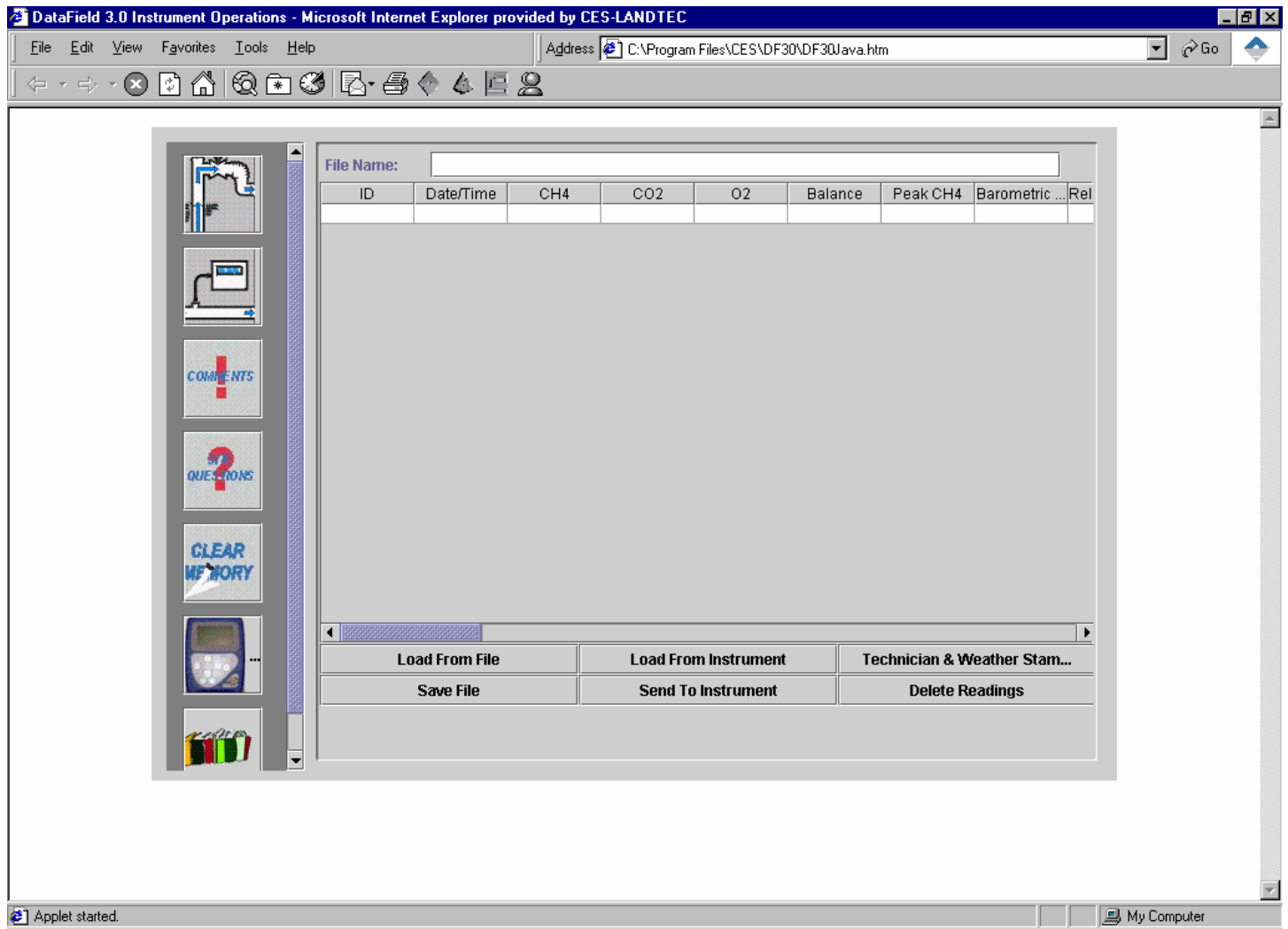
Note: It is suggested to clear ID information from the instrument prior to uploading the re-sequenced ID list. Otherwise the new ID list will be appended to the existing list. Clearing ID's in the instrument will clear ID's in the both GEM & GA modes of operation.

6.6.6 Readings

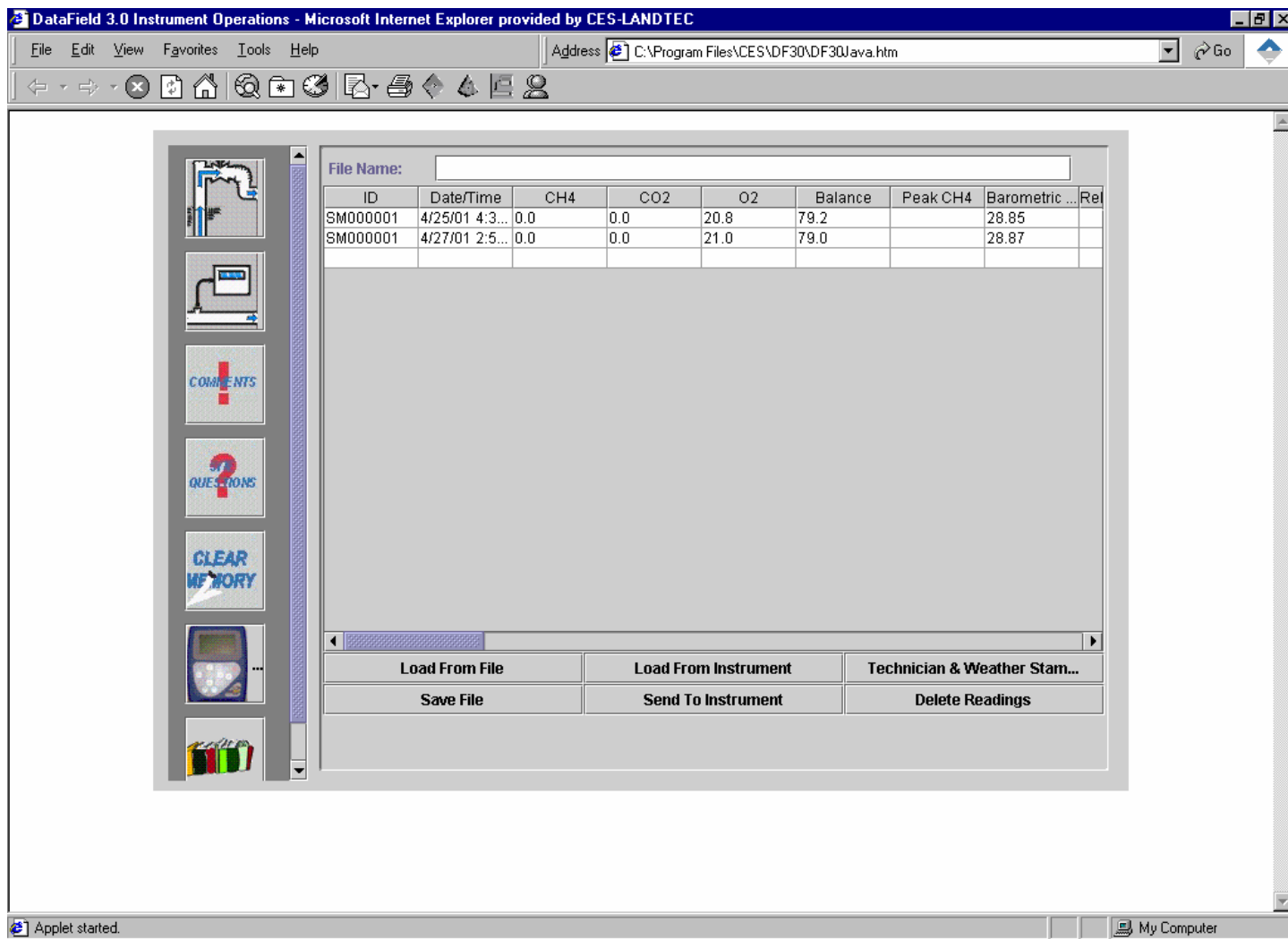
The Readings screen provides the capability to download, upload, view, save data to a file and delete individual or multiple readings from a data set.



Click on **Readings** to open the screen shown below.



Click on **Load from File** to open a file folder of saved data on the disk drive or click on **Load from Instrument** to download data from the instrument. Either action will open the following screen. All readings should be downloaded on a daily basis. While the instrument can hold readings for an extended period of time, it is recommended to download them to a non-volatile memory device (e.g. hard drive, CD, etc.).



Once the file has been opened or data downloaded from the instrument, either **Save File** or **Send to Instrument** may be selected. If an attempt is made to save the data to an existing file, a warning message will display indicating the file will be overwritten and data lost. Data sent to the instrument will be displayed as the previous sampled readings for the selected ID.

To delete data from the data set, click on the button to the left of the desired ID to highlight that ID and click on **Delete Readings**. If multiple consecutive readings need to be deleted, click and highlight the first reading, hold down the **Shift** key on the computer keyboard and click on the last reading to highlight all consecutive readings. (See figure 6.6A) Click on **Delete Readings** to delete the selected readings. If multiple separated readings need to be deleted, highlight the first reading; hold down the **Ctrl** key on the computer keyboard and click on subsequent readings to be deleted. (See figure 6.6B) When all the readings have been selected, click on **Delete Readings**.

Fig. 6-6A

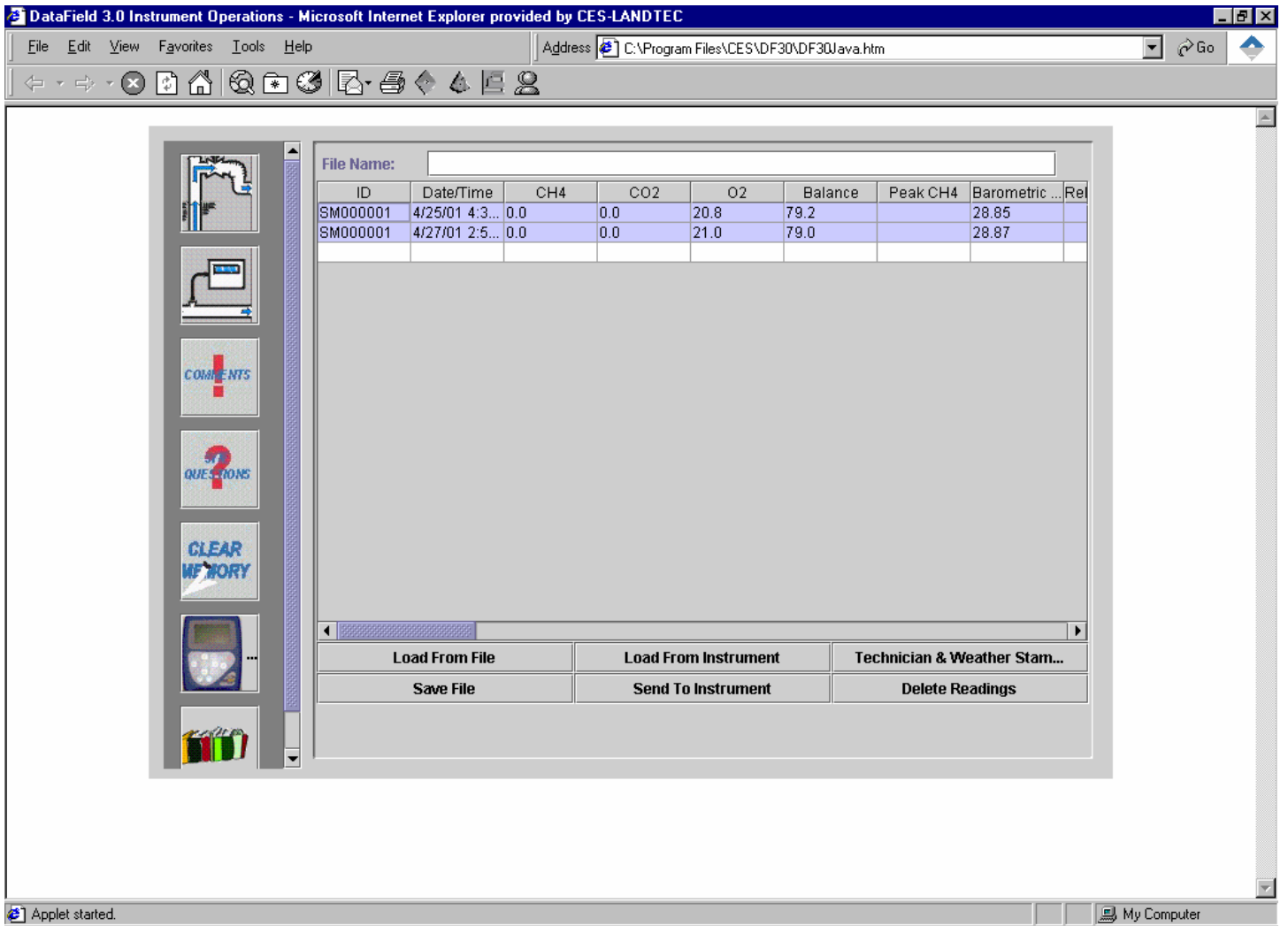
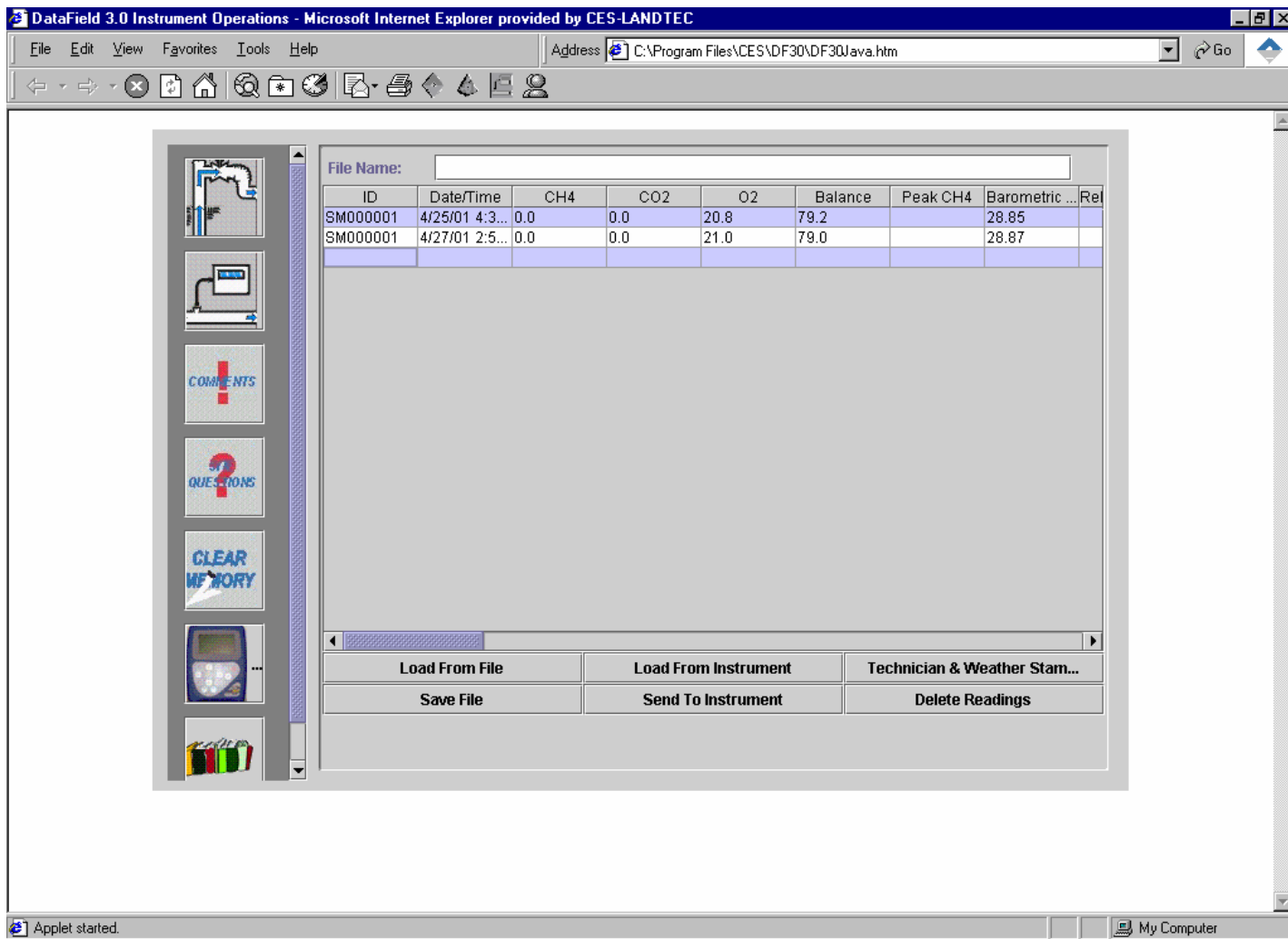


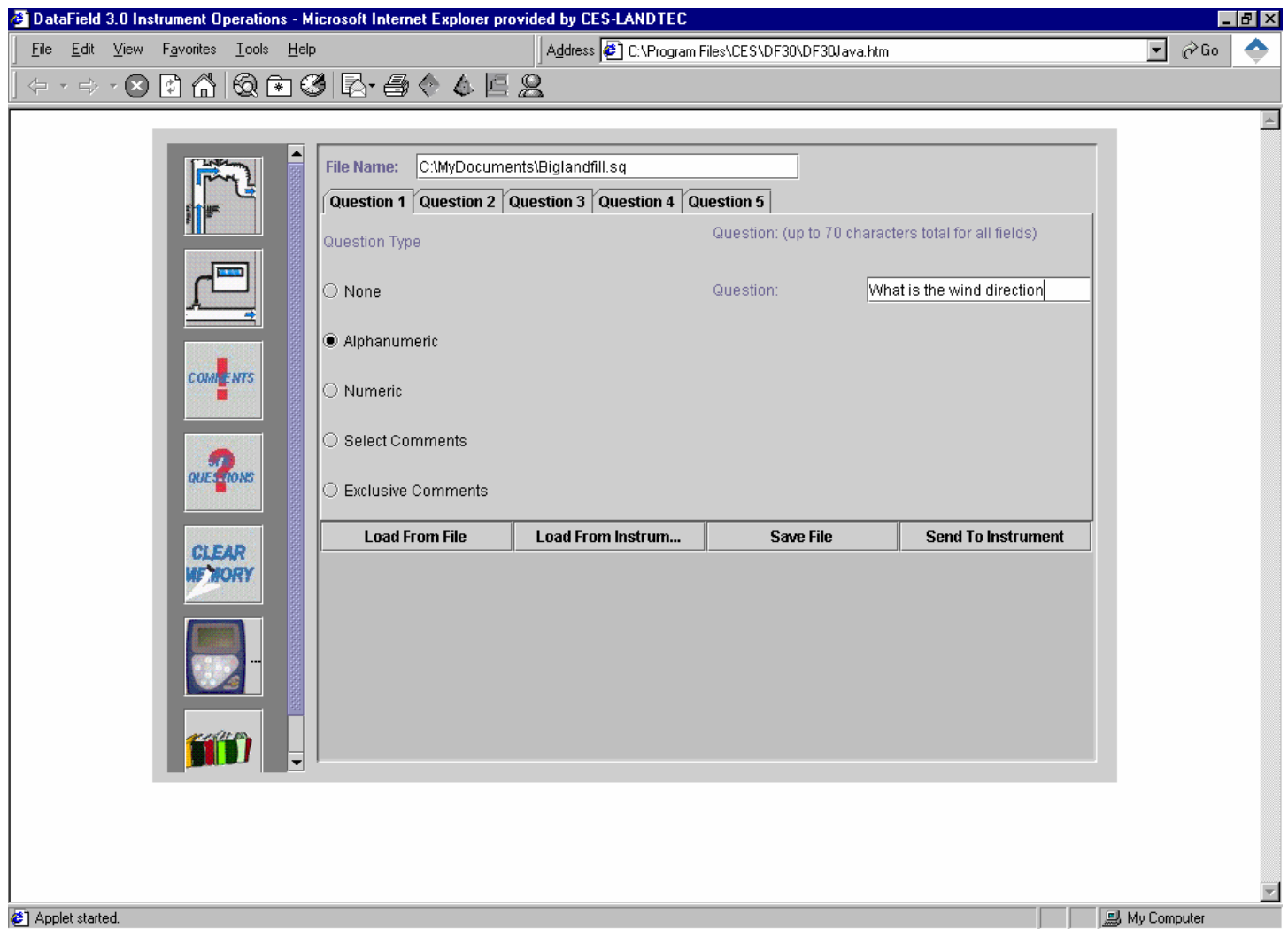
Fig. 6-6B



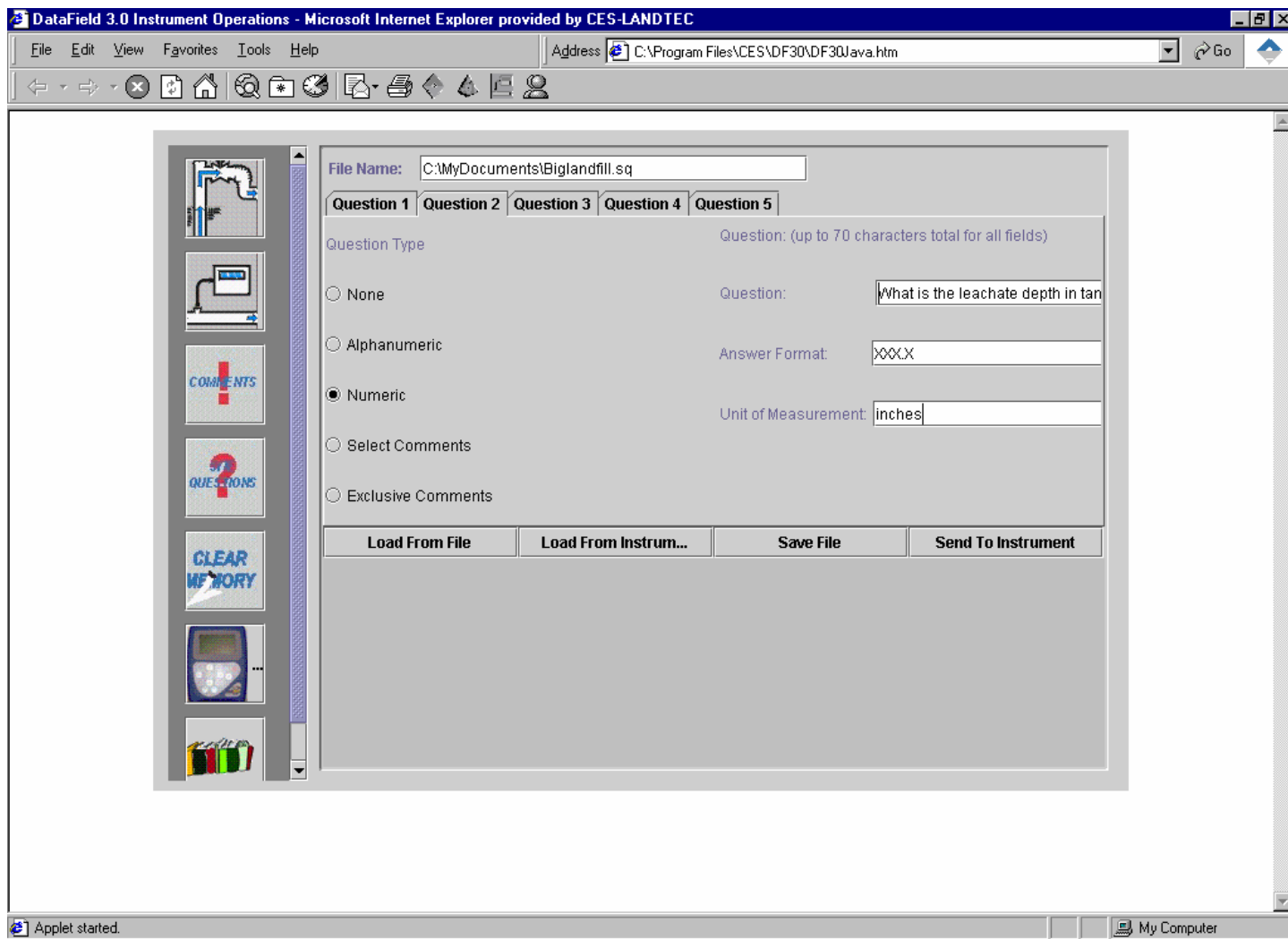
6.6.7 Site Questions

DataField 3.0CS supports up to five site questions. Site questions are answered only when **Update Site Data** is selected from the GEM menu screen and appended to all ID's taken thereafter until Update Site Data is again selected. This is a useful feature if conditions change in various locations on the landfill site or for selected wells/probes. Site questions can take the form of alphanumeric, numeric, select comment (the technician selects the comment from a list of ten answers) or exclusive comments (the technician may select only **ONE** exclusive question from a list of 10 answers). From the opening screen, click on the **Site Questions** button to open the following screen.

Note: Site questions must be created and sent to the instrument by the software prior to going into the field. They can not be hand input into the instrument in the field.

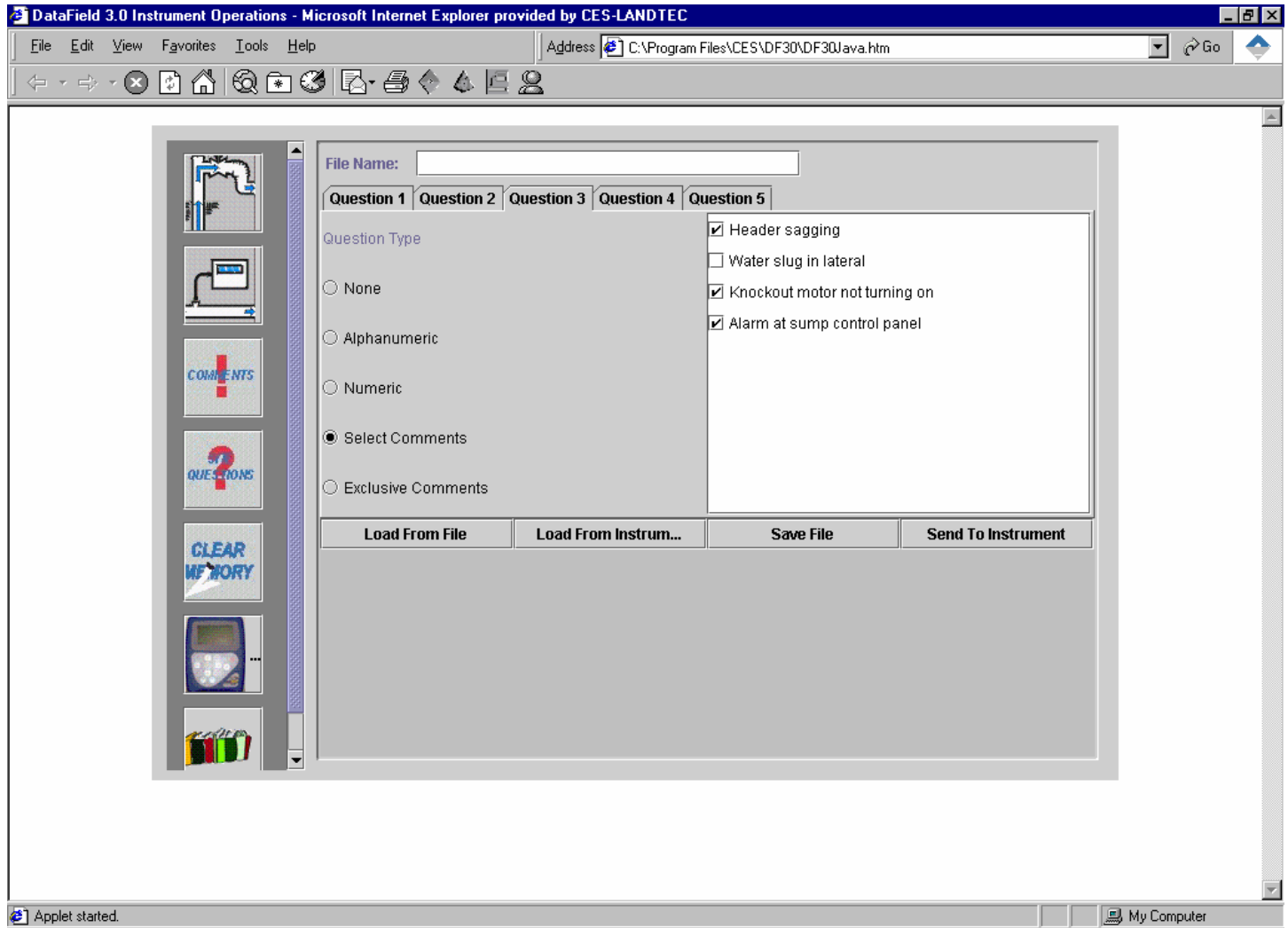


Click on the open spot, to the left of the alphanumeric category in **Question Type** to define Question 1 and type in the question.

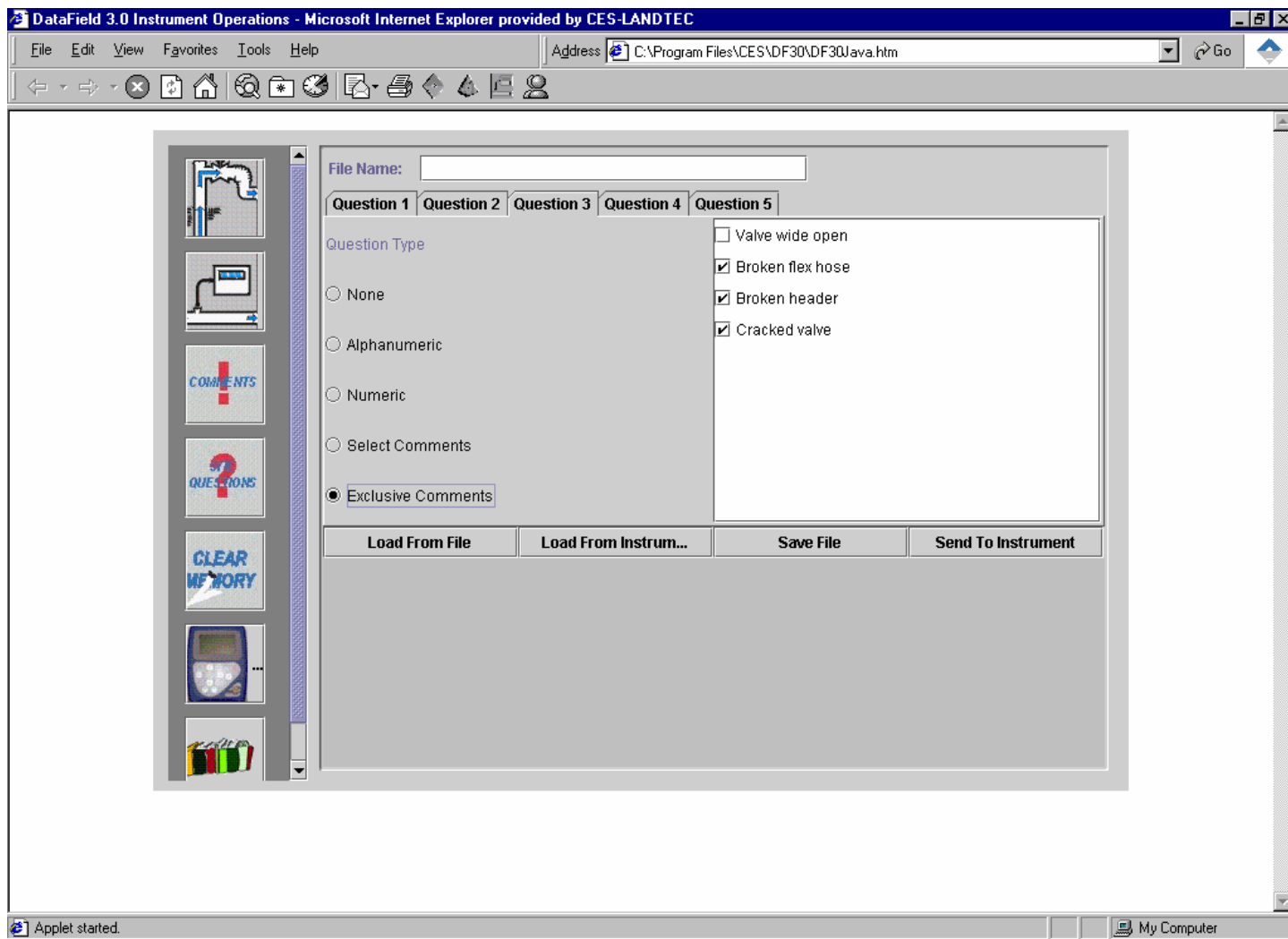


Click on Question 2 and then select Numeric as the Question Type. Note that Answer Format and Units of Measure fields appear with this type of question. Answer format refers to the number of digits and decimal places required for the answer. Units of Measure, refers to inches, feet, yards, etc for the answer. In this example, XXX.X could be equal to 020.5 Inches as per the question 'What is the leachate depth in tank'.

Comments may also be used as a site question, however comments must be downloaded from an instrument that has already had comments loaded in it. Connect the GEM™2000 and be sure it is in the read gas screen. Click on Select Comments and the list of comments from the instrument will open in the window for selection. Ten comments may be selected from the list to become **Site Questions**. Click on the box to the left of the comment to select it. The operator may choose any or all of the ten comments when **Update Site Data** is selected on the instrument.



Exclusive comments are treated in a similar manner as select comments in that they also must be downloaded from the instrument. Ten exclusive comments may be selected, however only **ONE** may be chosen by the operator to become an **Exclusive Comment**.



When all the desired questions have been entered, click on **Save File** to retain the information for later use and then click on **Send to Instrument** to update site data in the instrument.

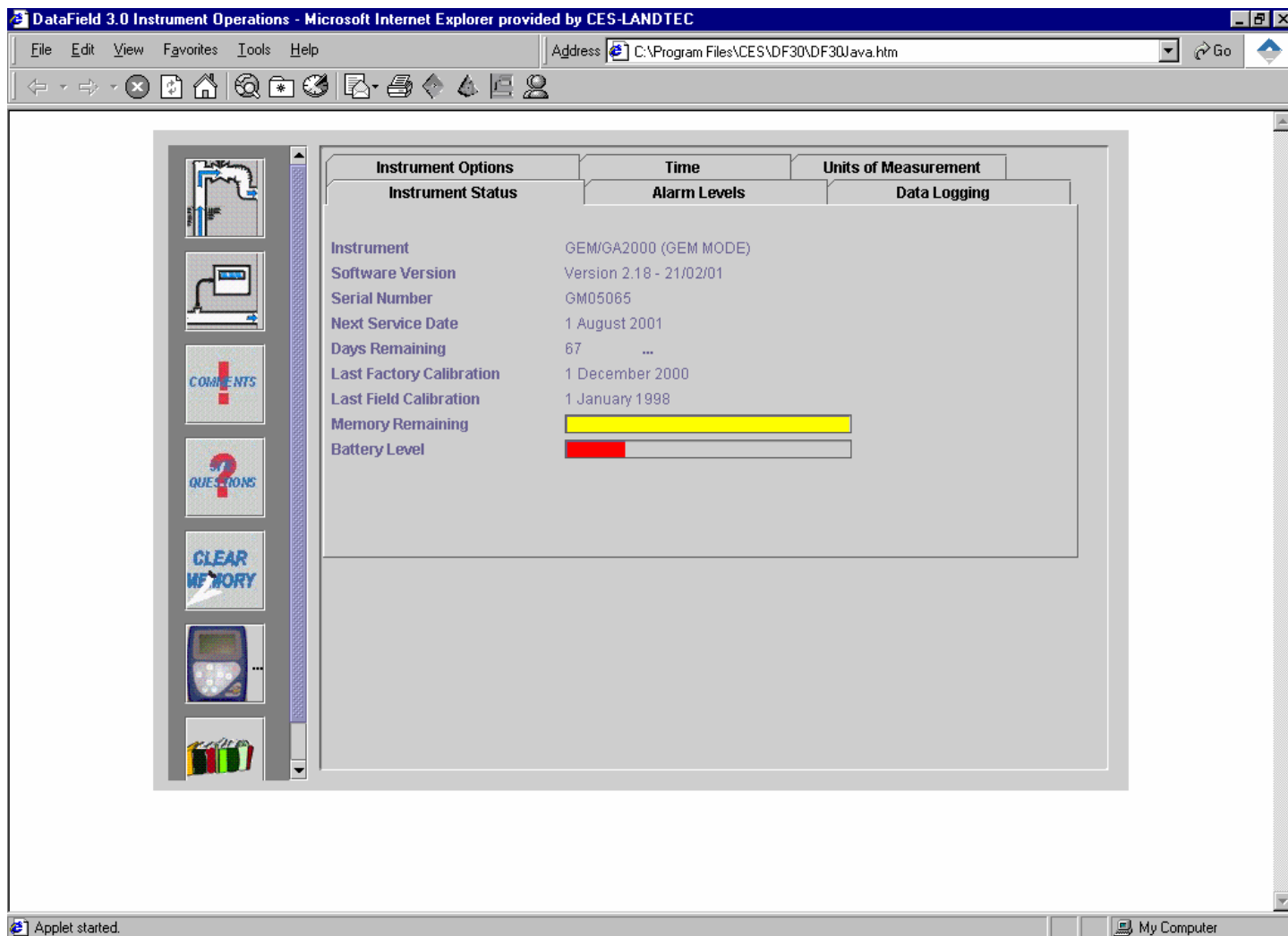
6.7 Settings

Clicking on the **Settings** button on the main screen will display the **Instrument Settings**. Instrument settings provides the capability to set or change optional controls in the instrument, such as time/date, data logging (GA mode only), purge times, etc.

6.7.1 Instrument Settings

Set the instrument for RS-232 communications and click on the **Settings** button and the following screen will open. The software will establish communications and download the current instrument settings.

Once the current settings have been obtained, the following screen will open.



There are six different “Menu Cards” under instrument settings. Each card provides different information or instrument settings that may be changed to update the operation of the GEM™2000. The instrument status card will always be shown first, providing calibration and maintenance information in addition to instrument serial number and software version number.

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Click on the card tab for **Alarm Levels** to open the alarm levels screen. Both a maximum alarm and a minimum alarm may be set. Note these are global settings and will be the same for all ID's entered in the instrument. Turn off the alarm by clicking off the check mark next to the gas. Click on **Update Alarm Levels** to send the new settings to the instrument.

The screenshot displays the 'DataField 3.0 Instrument Operations' web interface. The browser window title is 'DataField 3.0 Instrument Operations - Microsoft Internet Explorer provided by CES-LANDTEC'. The address bar shows 'C:\Program Files\CES\DF30\DF30Java.htm'. The interface features a vertical sidebar on the left with icons for 'Instrument Status', 'Comments', 'Questions', 'Clear Memory', and a device icon. The main content area has tabs for 'Instrument Options', 'Time', and 'Units of Measurement'. Under 'Instrument Options', there are sub-tabs for 'Instrument Status', 'Alarm Levels', and 'Data Logging'. The 'Alarm Levels' sub-tab is active, showing a table with columns for gas type, a checkmark, 'Max', and 'Min'. The table lists CH4(%), CO2(%), and O2(%), each with a checkmark, a '100' value in the 'Max' column, and a '0' value in the 'Min' column. Below the table is an 'Update Alarm Levels' button. The status bar at the bottom shows 'Applet started.' and 'My Computer'.

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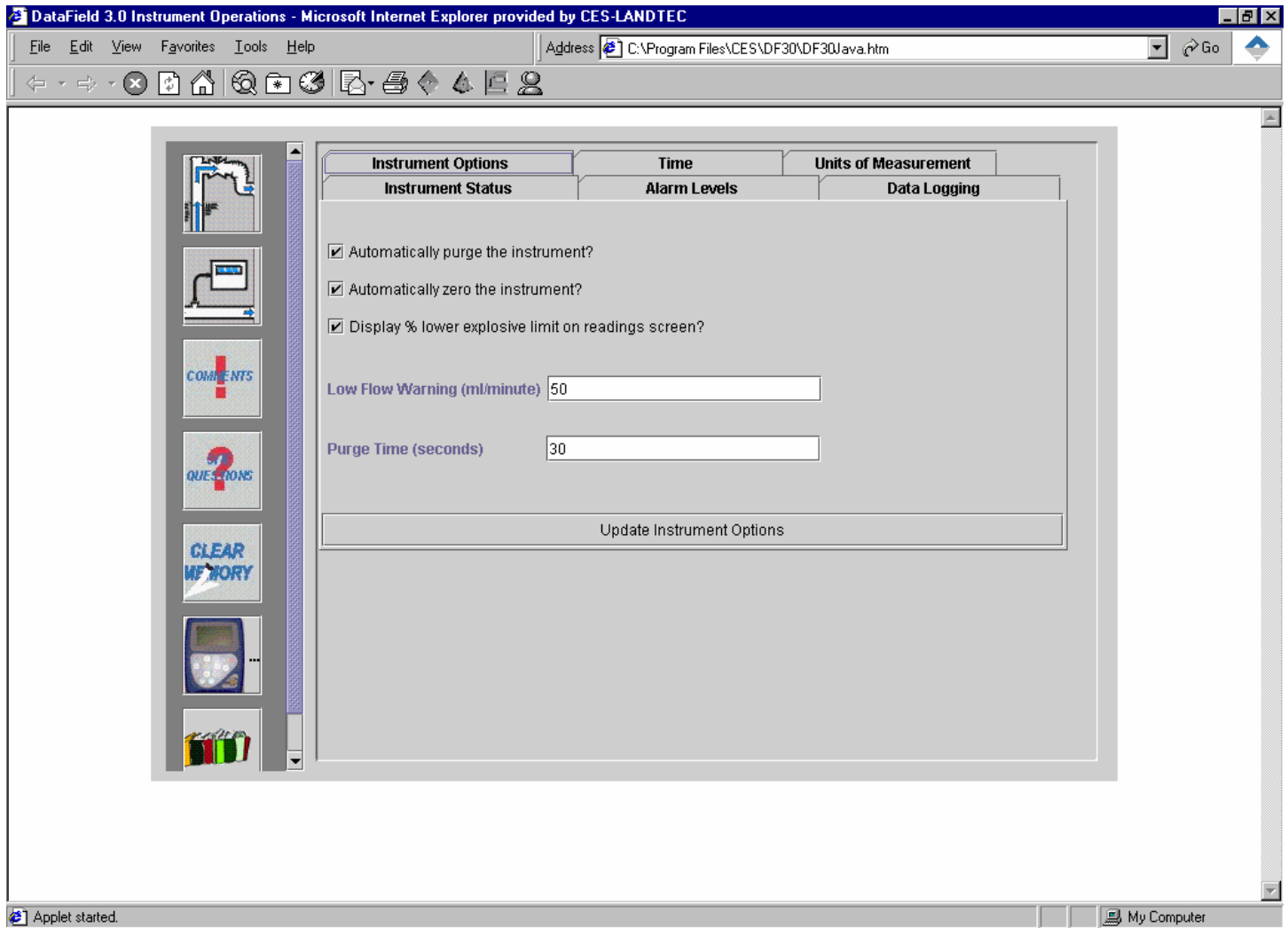
Click on the **Data Logging** card tab to open the data-logging screen. Data logging may only be used in the GA mode of operation. In this screen enter the Logging ID; this may be any alphanumeric combination of eight characters. Enter the interval between readings in minutes and pump run time in seconds. Click on **Update Logging Data** to send to instrument. Only one logging ID may be loaded in the instrument.

The screenshot shows a web browser window titled "DataField 3.0 Instrument Operations - Microsoft Internet Explorer provided by CES-LANDTEC". The address bar contains "C:\Program Files\CES\DF30\DF30Java.htm". The browser's menu bar includes "File", "Edit", "View", "Favorites", "Tools", and "Help". The main content area displays a control interface with a left sidebar and a main panel. The sidebar contains icons for "Data Logging", "Comments", "Questions", "Clear Memory", and "My Computer". The main panel has three tabs: "Instrument Options", "Time", and "Units of Measurement". The "Data Logging" tab is active, showing the following fields:

Field	Value
Logging ID	AUTO-LOG
Interval Between Readings (minutes)	1
Pump Running Time (seconds)	30

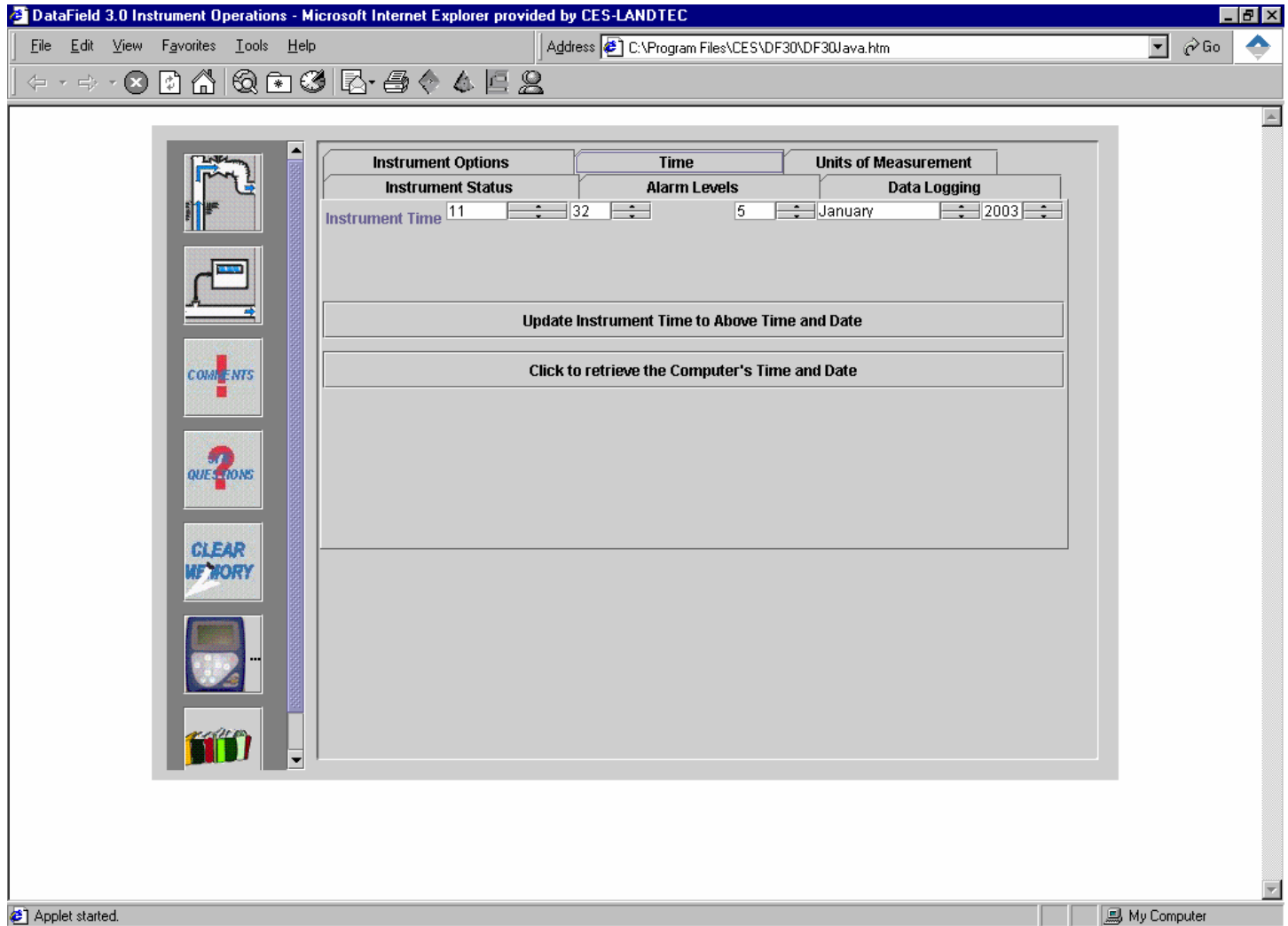
At the bottom of the main panel is a button labeled "Update Logging Data". The status bar at the bottom of the browser window shows "Applet started." and "My Computer".

Click on the **Instrument Options** card tab to open the instrument options screen. The settings in this screen affect different global functions of the instrument. Click on the check box to turn on or off automatic purge of the instrument during shut down, automatic pressure transducer zero and the percent lower explosive limit display. **Clicking OFF this feature will disable % LEL display in both GA and GEM modes of operation.** The **Low Flow Warning** setting controls the point at which the pump is shut off due to low flow conditions. The default setting for this feature is 50 milliliters per minute but may need to be set to a lower number or even zero, if sampling on high vacuum systems. The **Purge Time** default is 30 seconds and may be reset to any length required. Turning off this feature is not recommended. Click on **Update Instrument Options** to send the new settings to the instrument.

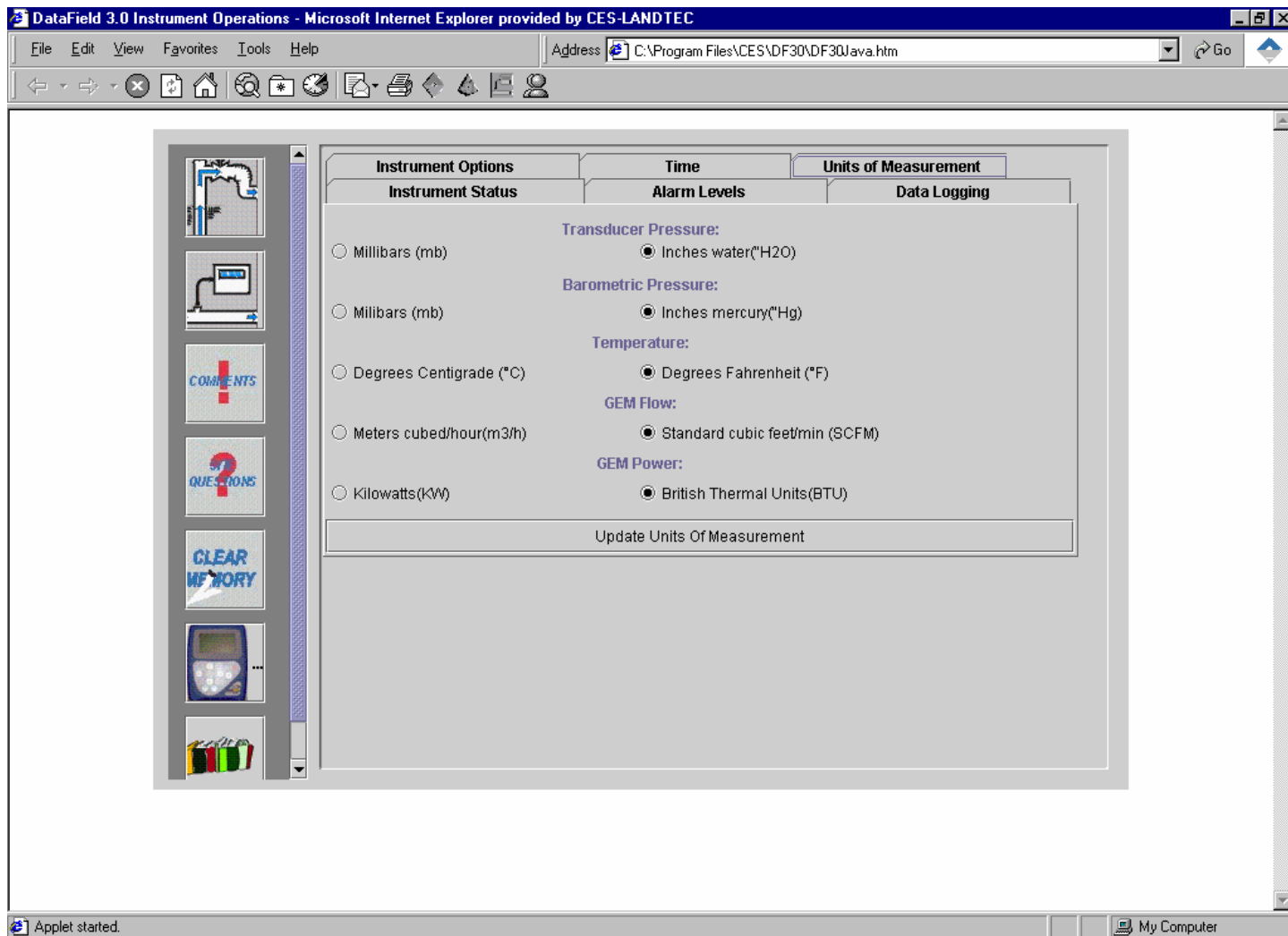


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Click on the Time card tab to open the time and date setting screen. Time and date may be set to the computer time and date settings by clicking on **Set Instrument to System time**. Manual setting of the time and date may be accomplished by clicking on **Update Instrument Time**. Any time updates must be done through the software. The instrument time can not be manually updated in the field.

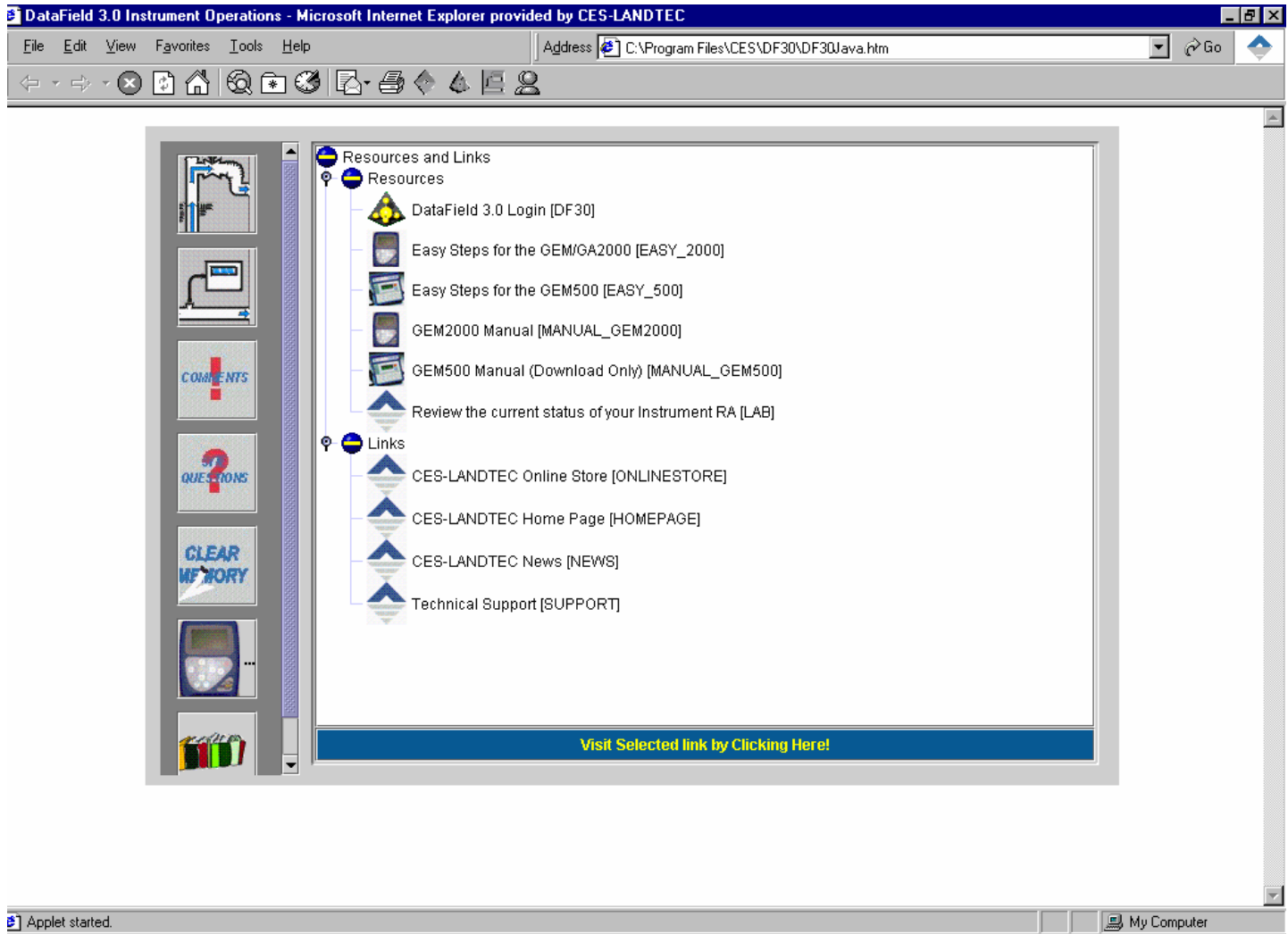


Units of Measurement screen allows the units to be changed.



Note: EXTREME CAUTION should be taken if changing the Units of Measure. All data in instrument should be downloaded and stored from both GEM and GA modes before updating the Units of Measure. Updating Units of Measure will erase readings from instrument. The instrument should be turned off and restarted once the units of measure have been updated.

6.7.2 Resource Links



By clicking on the supplied link the user is taken directly to the www and the information listed.

7 Field Operations

7.1 Landfill Gas Generation

A brief overview of the theory of landfill gas generation and methane recovery follows. Initially, when decomposable refuse is placed into a solid waste landfill, the refuse is entrained with air from the surrounding atmosphere. Through a natural process of bacterial decomposition, the oxygen from the air is consumed and an anaerobic (oxygen free) environment is created within the landfill. This anaerobic environment is one of several conditions necessary for the formation of methane-CH₄.

If oxygen is reintroduced into the landfill, those areas are returned to an aerobic (oxygen present) state and the methane-producing bacteria population are destroyed. A period of time must pass before the productive capacity is returned to normal. Since there is some methane of a given quality within the landfill void space, a decline in methane quality is only gradually apparent depending upon the size of the landfill.

Carbon Dioxide is also produced under either an aerobic or anaerobic condition. Under static conditions, the landfill gas will be composed of roughly half methane and half Carbon Dioxide with a little nitrogen.

As air is introduced into the landfill, the oxygen is initially converted to Carbon Dioxide and residual nitrogen remains. Measurement of residual nitrogen is usually a good indicator of the anaerobic state of the landfill; however, it cannot be directly measured. It can, however, be assumed and estimated using a subtraction basis as the balance gas. Hence, the measurement of Carbon Dioxide is an intermediary step. Because Carbon Dioxide levels may fluctuate depending on the changing concentrations of the other constituent gases, Carbon Dioxide levels are not evaluated directly but are considered in light of other data.

In evaluation of residual nitrogen, allowances must be made if there has been any air leakage into the gas collection system or if there has been serious over pull. If enough air is drawn into the landfill, not all oxygen is converted into Carbon Dioxide and the oxygen is apparent in the sample. It is ideal to perform routine analysis of individual wells, as well as an overall well field composite sample, by a gas chromatography. This is not always practical at every landfill.

Under some conditions there may be a small amount of hydrogen in the LFG, (about 1 percent, usually much less). This may affect field monitoring response factors, but otherwise it can be ignored.

7.2 Subsurface Fires

If very large quantities of air are introduced into the landfill, either through natural occurrence or overly aggressive operation of the LFG system, a partly unsupported subsurface combustion of the buried refuse may be initiated. Subsurface fire situations are difficult to control or extinguish once started, present health and safety hazards, and can be quite costly. Therefore, prevention by good operation of the collection system and maintenance of the landfill cover is the best course of action. The presence of Carbon Monoxide, Carbon Dioxide, and Hydrogen Sulphide are indicators of poorly supported combustion within the landfill.

7.3 Techniques for Controlling Landfill Gas

There are many techniques for controlling landfill gas extraction. These techniques represent tools, which are used together to control landfill gas. The Accu-Flo wellhead is designed to work with all of these techniques. Below is a discussion of the individual techniques, how to use them, and their limitations. Reliance on only a few of the techniques discussed can lead to misinterpretation of field data and improper operation of the well field. Later the best use of these techniques to optimize landfill gas control will be discussed.

7.3.1 Controlling by Wellhead Valve Position

Unless the valve handle is calibrated for a given flow rate, this method is unreliable. The position of the valve handle alone does not provide sufficient information about the well to control it. It is useful to note the relative position of the valve, and essential to know which valves are fully open or fully closed.

7.3.2 Controlling by Wellhead Vacuum

This technique relies on the relationship of well pressure/vacuum to flow for a given well. Reliance upon this method, however, can be misleading. This is because the square root relationship between flow and pressure is difficult to affect while performing day-to-day well field adjustments. As decomposition, moisture, and other conditions change, this method shows itself to be inadequate and imprecise.

7.3.3 Controlling by Gas Composition

This method determines methane, nitrogen (balance gas) and other gas composition parameters at wellheads and at recovery facilities using portable field instruments and, sometimes, analytical laboratory equipment. Complete knowledge of gas composition (i.e., major fixed gases: Methane, Carbon Dioxide, Oxygen and Nitrogen) is desirable. It is also necessary to check other gas parameters, such as Carbon Monoxide, to fully evaluate the condition of the well field. Reliance on this information can lead to improper operation of the well field. Indications of excessive extraction often do not show up right away. This method often leads to a cycle of damage to the methane producing bacteria population and then to over-correction. This cycling of the well and producing area of the landfill is not a good practice. It leads to further misinterpretation of the condition of the well field and has a disruptive effect on the operation of the well field. The use of analytical laboratory instrumentation such as a gas chromatograph is a valuable supplementary tool to verify gas composition. This normally requires collection of samples at the wellhead and analysis at some fixed location where the equipment is located. The drawbacks of this method as a primary means of obtaining information for well field adjustment are the time expended, cost, and probably most important, responsiveness to the needs of the well field for timely adjustment. The laboratory equipment required is also very costly. Some analysis is recommended for verification of field readings from time to time. It is recommended a monthly sample of the composite gas be taken at the inlet to the flare or gas recovery facility.

7.3.4 Controlling by Flow Rate

This is a more exacting technique for determining and adjusting gas flow at individual wells. It requires using a fixed or portable flow measurement device at each wellhead to obtain the data needed to calculate volumetric (or mass) flow rates. It is normally convenient to use cubic feet per minute or per day, as a standard unit of measure for volumetric flow. It is important to distinguish between the volumetric quantity of

landfill gas and the volumetric quantity of methane extracted from each well and the landfill in total. The two variables are somewhat independent of each other and it is the total quantity of methane extracted we are interested in. It is possible for the total quantity of landfill gas extracted to increase while the total quantity of methane extracted decreases. To monitor this, the quantity of methane extracted (LFG flow x percent methane) or the quantity of BTUs recovered per hour (LFG flow x percent methane x BTUs per cubic foot of methane x 60 minutes per hour) can be calculated. It is conventional to measure BTUs per hour as a unit of time. There are approximately 1012 BTUs of heat per cubic foot of pure methane (like natural gas), although this figure varies a little among reference texts.

Measuring flow is an essential part of monitoring and adjusting a well field. The well should be adjusted until the amount of methane recovered is maximized for the long term. A greater amount of methane or energy can usually be recovered over the short term; however, this ultimately leads to diminishing returns. This is seen in stages as increased CO₂ and gas temperature and later as increased oxygen from well over-pull. In time, the methane will also decline. This is the result of a portion of the landfill, usually at the surface, being driven aerobic. In this portion of the landfill, the methane-producing bacteria will have been destroyed (due to the presence of oxygen). With the methane-producing capacity of the landfill reduced, the pore space in the area no longer producing may become filled with landfill gas equilibrating (moving in) from an unaffected producing area. This leaves the impression that more gas can be recovered from this area, and may lead to the operator opening the well or increasing flow.

7.4 Well field Monitoring

The frequency of LFG well field monitoring varies depending upon field requirements and conditions. Normal monitoring frequency for a complete field monitoring session with full field readings (suggested normal and abbreviated field readings list follows) will vary from typically once a month to once a week. Well field monitoring should not normally be extended beyond one month. The importance of regular, timely monitoring cannot be overemphasized.

7.5 Typical Field Readings

- Name of person taking readings
- Date/time of each reading
- Methane (CH₄)
- Oxygen (O₂)
- Carbon Dioxide (CO₂)
- Balance Gas (primarily nitrogen N₂)
- Wellhead gas temperature (flowing)
- Ambient air temperature
- Static pressure (PS) (from GEM™2000 or magnehelic) or other device(anemometer/velometer)
- Velocity head (P or PT) (from GEM™2000 or pitot tube and magnehelic)
- Wellhead gas flow (from GEM™2000, or pitot tube & magnehelic, or anemometer/velometer)
- Wellhead adjustment valve position (initial and adjusted)
- New wellhead vacuum and flow information after adjustment
- Calculation of each well's LFG and methane flow and sum total
- Observations/comments

Additionally, Carbon Monoxide (CO) or Hydrogen Sulphide (H₂S) readings may be taken if problems are suspected. Supplementary monitoring once to several times a week may be performed using an abbreviated form of field readings.

7.6 Abbreviated Field Readings

- Name of person taking readings
- Date/time of each reading
- Methane (CH₄)
- Oxygen (O₂)
- Wellhead gas temperature (flowing)
- Ambient air temperature
- Static pressure (PS) (from GEM™2000 or magnehelic)
- Velocity head (P or Pt) (from GEM™2000 or pitot tube and magnehelic)
- Wellhead gas flow (from GEM™2000, or pitot tube and magnehelic, or anemometer/velometer)
- Wellhead adjustment valve position (initial and adjusted)
- New wellhead vacuum and flow information after adjustment
- Observations/comments

Line vacuums and gas quality may be taken at key points along the main gas collection header and at subordinate branches. This helps to identify locations of poor performance, excessive pressure drop, or leakage. Perform systematic monitoring of the well field, taking and logging measurements at each wellhead and major branch junction in the collection system.

During monitoring, examine landfill and gas collection system for maintenance issues. Record needed maintenance or unusual conditions. Examples of unusual occurrences or conditions are unusual settlement, signs of subsurface fires, cracks and fissures, liquid ponding, condensate/leachate weeping from side slopes, surface emissions and hot spots, and liquid surging and blockage in the gas collection system. Field readings should be kept in a chronological log and submitted to management on a timely basis.

7.7 Well field Adjustment Criteria

There are several criteria used in well field adjustment. The primary criterion is methane quality. Methane quality is an indicator of the healthy anaerobic state of the landfill and thus proper operation of the LFG collection system. However, a decline in the healthy productive state of the landfill is usually not immediately apparent from methane quality. Due to this, several criteria must be considered at once.

Conditions within the landfill favor methane production. Following are well field adjustment criteria and typical conditions for consideration:

- Methane quality (ranging from 26 percent upwards)
- pH
- Temperature
- General overall quality
- Moisture conditions
- Waste stream characteristics
- Placement chronology
- Insulation characteristics
- Oxygen quality (ranging below 1 percent, preferably less than ½ percent)
- Landfill cover porosity and depth in the proximity of the well
- Landfill construction factors including:
 - Type of fill
 - Size and shape of refuse mass
 - Depth of fill

- Compaction
- Leachate control methods
- Seasonal, climatic, geographical, and recent weather, or other considerations, including seasonally arid or wet conditions, precipitation, drainage, groundwater
- Surrounding topography and geologic conditions
- Proximity of the well to side slopes (within 150 to 200 feet and less may require conservative operation of the well)
- Nitrogen (typically 8 to 12 percent and less)
- Temperature (between ambient and about 130 °F)
- LFG and methane flow from the wellhead
- Design of the gas collection system
- Landfill perimeter gas migration and surface emission control, or energy recovery objectives
- Diurnal fluctuation (day to night) of atmospheric pressure

7.8 Establishing Target Flows

For a given individual well, a target flow is established which will likely support maintenance of methane and oxygen quality objectives while maximizing the recovery of landfill gas. Typically, small adjustments are made in flow to achieve and maintain quality objectives. The well must not be allowed to over pull. High well temperatures, (130° to 140°F and greater), are an indication of aerobic activity and, thus, well over-pull. These effects may not be immediately apparent.

Well adjustment should be made in as small an increment as possible, preferably an increment of ten percent of the existing flow or less. There may be obvious conditions when this is not appropriate, such as when first opening up a well or when serious over-pull is recognized. Every effort should be made to make adjustments and operations as smooth as possible. Dramatic adjustments, or operating while switching between a high flow mode and a well shutoff mode, should be avoided.

7.9 Well field Optimization

Every effort should be made to continuously locate and correct or eliminate conditions (e.g., gas condensate, surging and blockage, settlement, etc.), which inhibit efficient operation of the gas collection system. This allows well monitoring and adjustment to be significantly more effective.

7.10 Migration Control—Dealing with Poor Methane Quality

If methane and oxygen quality objectives cannot be maintained at a given well, such as a perimeter migration control well, then an attempt should be made to stabilize the well as closely as is practical, avoiding significant or rapid down trending of methane or up trending of oxygen.

It is not uncommon for perimeter migration control wells to be operated at less than 40 percent methane or greater than one-percent oxygen. It should be recognized that these wells are likely in a zone where some aerobic action is being induced, and that there is some risk of introducing or enhancing the spread of a subsurface fire. Sometimes a judicious compromise is necessary to achieve critical migration control objectives or because existing conditions do not allow otherwise. Such situations should be monitored closely.

7.11 Well field Adjustment—Purpose and Objectives

The objective of well field adjustment is to achieve a steady state of operation of the gas collection system by stabilizing the rate and quality of extracted LFG in order to achieve one or several goals. Typical reasons for recovery of LFG and close control of the well field are:

- Achieve and maintain effective subsurface gas migration control.
- Achieve and maintain effective surface gas emissions control.
- Assist with proper operation of control and recovery equipment.
- Avoid well “over-pull” and maintain of a healthy anaerobic state within the landfill.
- Optimize LFG recovery for energy recovery purposes.
- Control nuisance landfill gas odors.
- Prevent or control subsurface LFG fires.
- Protect structures on and near the landfill.
- Meet environmental and regulatory compliance requirements.

Well field adjustment is partly subjective and can be confusing because it involves judgment calls based on simultaneous evaluation of several variables, as well a general knowledge of site specific field conditions and historical trends. Well field evaluation and adjustment consist of a collection of techniques, which may be used, in combination, to achieve a steady state of well field operation.

8 Troubleshooting

Problem

Unit does not turn on or operation is erratic

“Flow Fail” is displayed and an audible alarm is heard

Readings taken are not what was expected

Unit displays***** or >>>>>

Oxygen reading is high on all wells

Unit will not download readings or an error occurs while downloading.

Methane and Carbon Dioxide readings drift

Oxygen readings drift

Black screen displayed when unit turned On

Nothing happens when the Gas Pod is installed

Temperature does not update when temperature probe is installed

Corrective Action/Reason

Battery charge is too low-recharge batteries.
Unit is too hot - cool down unit and try again.
Contact Factory Service.

The inlet is blocked.
Remove blockage and retry.
The particulate filter or water trap filter needs replacing.
Unit may be out of calibration. Calibrate unit with known gas concentration.

Water trap or particulate filters are clogged. Replace filter(s).

These symbols are substituted when the measured reading is out of range of the instruments capabilities in some fields or when a value needs to be entered manually such as temperature.

Check that the water trap housing is screwed on tight.
Check or replace O-rings on the water trap and instrument inlet.

Check the wellhead inset for cracks, replace O-ring on insert.

Field calibrate oxygen channel.

Verify that the communications software is the right version for the instrument being used.

Check that the proper serial port is selected in the software.

Contact Factory Service.

Perform a field calibration and check well again. Verify cal gas is flowing when regulator is turned on.

Verify all connections are tight and filters are not clogged.

Contact Factory Service.

Perform a field calibration - zero and span.

Contact Factory Service.

Charge unit over night and try again.

Unit too hot - cool down and try again.

Try adjusting contrast level.

Contact Factory Service.

Remove and re-seat the Gas Pod.

Contact Factory Service.

Check the probe fitting is fully seated.

Check the probe plug is screwed together tightly.

Contact Factory Service.

9 Technical Specifications

9.1 Physical

Weight	4.4 lbs.
Size	L 2.48" x W 7.48" x D 9.92".
Case material	Anti-static ABS.
Keys	Membrane panel.
Display	Liquid Crystal Display 40 x 16 characters. Fibre optic woven backlight for low light conditions.
Filters	User replaceable integral fibre filter at inlet port and an external PTFE water trap filter.

9.2 General

Temperature measurement	With optional probe 14°F to 167°F.
Temperature accuracy	±0.4°F (± probe accuracy).
Visual and audible alarm	User selectable CO ₂ , CH ₄ and O ₂ alarm levels via DataField 3.0.
Communications	RS232 protocol via download lead with variable baud rate.
Relative pressure	±250 mbar from calibration pressure

9.3 Power supply

Battery type	Rechargeable Nickel Metal Hydride battery pack containing six 4AH cells. Not user replaceable. Lithium Manganese battery for data retention.
Battery life	Typical use 10 hours from fully charged condition.
Battery charger	Separate intelligent 2A battery charger powered from AC voltage supply (110-230V).
Charge time	Approximately 2 hours from complete discharge.
Alternative power	Can be powered externally for fixed-in-place applications only. Contact CES-LANDTEC for further information.
Battery lifetime	Up to 1,000 charge/discharge cycles.

9.4 Gas Ranges

Detection principle	CO ₂ and CH ₄ by dual wavelength infrared cell with reference channel. O ₂ by internal electrochemical cell.			
Oxygen cell lifetime	Approximately 3 years in air.			
Typical Accuracy 0 - Full Scale	Gas	0-5% volume	5-15% volume	15%-FS
	CH ₄	±0.5%	±1%	±3% (100%)
	CO ₂	±0.5%	±1%	±3% (60%)
	O ₂	±1%	±1%	±1% (21%)
Response time, T90	CH ₄	≤20 seconds		
	CO ₂	≤20 seconds		
	O ₂	≤20 seconds		
Range	CH ₄	0-70% to specification, 0-100% reading.		
	CO ₂	0-40% to specification, 0-100% reading.		
	O ₂	0-25%		

9.5 Pump

Typical flow	300 cc/min.
Flow fail point	50 cc/min approximately.
Flow with 200 mbar vacuum	250 cc/min approximately.
Vacuum	70 inches H ₂ O.

9.6 Operating Conditions

Operating temp range	32°F to 104°F.
Relative humidity	0-95% non-condensing.
Atmospheric pressure range	700-1200 mbar. Displayed in Inches of Mercury (5.9 – 35.4“Hg). Not corrected for sea level.
Atmospheric pressure accuracy	±5 mbar approximately.
Case seal	IP65.

9.7 Optional Gas Pods

Typical Accuracy (Subject to User calibration).	Gas	0-Full Scale
	CO	±10% FS
	H ₂ S	±10% FS
	SO ₂	±10% FS
	NO ₂	±10% FS
	CL ₂	±10% FS
	H ₂	±10% FS
	H ₂ CO	±10% FS
Response time, T90	CO	≤60 seconds
	H ₂ S	≤60 seconds
	SO ₂	≤60 seconds
	NO ₂	≤60 seconds
	CL ₂	≤60 seconds
	H ₂	≤60 seconds
Range	CO	0-500ppm
	H ₂ S	0-50 or 0-200ppm
	SO ₂	0-20 or 0-100ppm
	NO ₂	0-20ppm
	CL ₂	0-20ppm
	H ₂	0-1000ppm
	H ₂ CO	0-100ppm