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November 2, 2011

Mr. Steve Reents, LEED AP
Vice President, Asset Management
Bentall Kennedy
1215 Fourth Ave., Suite 2400
Seattle, Washington 98161

Mr. Paul Marucci
Vice President
M&R Development LLC
555 West Pierce Road, Suite 180
Itasca, Illinois 60143

RE: **Thorium Walkover Survey Summary Report**
McClurg Court Center
333 East Ontario Street
Chicago, IL 60611
ATC Project Number 11.28570.0007 (11002)

Dear Mr. Reents:

ATC Associates Inc. (ATC) is pleased to submit this summary report to Bentall Kennedy documenting the Thorium Walkover Survey conducted at the above-referenced site. These activities were conducted in coordination with the United States Environmental Protection Agency (USEPA) in an effort to identify any elevated concentrations of thorium beneath the sidewalks. The Thorium Walkover Survey was conducted to assist with the evaluation of proposed sidewalk repair/replacement activities under consideration for the Spring of 2012. The field activities were conducted in general accordance with ATC Proposal Number 011-2011-0241, dated July 22, 2011.

## BACKGROUND

It is ATC's understanding that the building owner is considering the repair/replacement of sidewalks along the north, east and south sides of the McClurg Court Center Building sometime in the Spring of 2012. According to information provided to ATC, the proposed repair/replacement activities could include removing and replacing the concrete cover. Consequently, surface grading or replacing the sub-base materials are not anticipated. However, soil covered planters with small trees and foliage are located along the north, east and south sidewalks of the building. ATC has been informed that the planters will not be removed. Also, the underground utility vaults that are located beneath the sidewalks along the north and south sides of the building will not be disturbed.

The McClurg Court Center property consists of an approximate 2.372-acre parcel of land developed with an approximate 1,250,000 gross square-foot twin tower residential/commercial complex that is located in an area of Chicago known as "Streeterville". While the primary address for the McClurg Court Center is 333 East Ontario Street, individual addresses for the tenant spaces are maintained along East Ontario Street to the north, East Ohio Street to the south, and North McClurg Street to the east.

Each residential tower is a 45-story structure situated over a common two-story portion of the McClurg Court Center that contains various office space, hallways, various commercial tenants and mechanical rooms, which are situated atop a full basement (including a multi-level parking garage) and a partial sub-basement. A Site Plan is included as **Figure 1** in **Appendix B**.

The McClurg Court Center property is located within an area of Streeterville known as the Chicago Environmental Permit Restriction Zone (C.E.P.R.). In the 1990's, the USEPA became involved in Streeterville due to the discovery and excavation of approximately 40,000-tons of radioactive thorium impacted soils that were located during the development of the nearby former Lindsey Light and Chemical Company (Lindsay Light) property and utilities installation and maintenance. Thorium is a radioactively decaying element (metal) that is part of the Thorium Decay Series. Additional subsurface thorium impact has since been found in other Streeterville locations. This radioactively impacted material must be managed in accordance with State and Federal environmental requirements. The USEPA believes that radioactive thorium waste from Lindsay Light was disposed of in the Streeterville area, but there are no historic records describing where Lindsay Light disposed of its waste. USEPA historical research indicates that beginning in about 1904 and continuing through the mid 1930's, Lindsay Light manufactured gas light mantles impregnated with thorium in the City of Chicago. The Lindsay Light operation reportedly originated at 22 West Hubbard and later moved to 161 East Grand and 316 East Illinois in Chicago. Thorium-containing ore apparently was processed at 316 East Illinois into liquid thorium nitrate, which was used to make gas light mantles at 161 East Grand. From the early 1900s until the early 1920s, Lindsay Light occupied the five-story building at 22 West Hubbard. Lindsay Light moved to the City of West Chicago, Illinois and closed its Streeterville operations by about 1936.

The USEPA has set a standard of five (5) picocuries per gram (pCi/g) of total radium (radium-226 + radium-228) over background concentrations for each 6-inch layer below the surface. This standard is equivalent to 11 radioactive decays per minute per gram of soil. Since the background concentrations of total radium within the C.E.P.R. is 2.1 pCi/g, the USEPA has established the action level for thorium of 7.1 pCi/g.

The USEPA has determined that as long as impacted soils remain covered by concrete and/or asphalt, they do not present a health and safety concern. However, if subsurface thorium wastes are uncovered without proper environmental controls, workers and the public may be exposed to elevated radiation levels. Consequently, and based on the USEPA's recommendation, the Chicago Department of Environment, requires radiation surveillance if work in the C.E.P.R. involves the removal of asphalt, concrete or other materials covering subsurface soils. The radiation survey testing procedures must be performed by a qualified person under the direction of a radiation health physicist.

## THORIUM WALKOVER SURVEY

On October 3 and 4, 2011, ATC conducted a survey of the sidewalks surrounding the north (East Ontario Street), east (North McClurg Street) and south (East Ohio Street) sides of the McClurg Court Center property. The survey was conducted to identify any areas of elevated thorium concentrations. The survey was conducted utilizing a Ludlum Model 2241 Digital Scaler/Ratemeter equipped with a pancake style Geiger-Mueller 44-9 probe detector that was calibrated on March 30, 2011. This detector is used for the measurement of alpha, beta and gamma radiation. Typical background readings for this probe range between 25 and 50 counts per minute (cpm). The survey with the 44-9 probe detector was conducted via the collection of readings from data points within 4-foot by 4-foot grids. Readings were collected by holding the detector probe approximately 6-inches off the ground within each grid. The highest reading within each grid was noted on field logs. Areas that contain underground structures (i.e., electrical vaults or manhole sewers) were not surveyed.

On October 12, 2011, ATC returned to conduct a survey sweep of the sidewalks surrounding the north (East Ontario Street), east (North McClurg Street) and south (East Ohio Street) sides of the McClurg Court Center property for QA/QC purposes. The survey was conducted utilizing a Ludlum Model 2221 Scaler/Ratemeter with an attached 2”x2” 44-10 Sodium Iodide (NaI) probe that was calibrated on October 11, 2011. This detector is used for the measurement of gamma radiation for comparison purposes. The manufacturer specifications lists the typical backgrounds readings for this probe to range between 4,000 and 10,000 cpm at 8 to 15 micro roentgens per hour (uR/hr) and the typical sensitivity at 900 cpm per uR/hr. For this particular instrument, the gamma count indicative of the 7.1 pCi/g threshold was 18,728 cpm. Areas that contained underground structures (i.e., electrical vaults or manhole sewers) were not surveyed.

The QA/QC Thorium Walkover Survey with the 44-10 probe detector was conducted by holding the detector probe approximately 6-inches off the ground and sweeping the surface. These sweeps were conducted within segments of the ground that were spaced 8-feet apart within the sidewalk on East Ohio Street and 12-feet apart within the respective sidewalks on North McClurg Street and East Ontario Street. The highest reading within each line spacing was noted on a field log.

A tabular summary of the Thorium Walkover Survey results are included in **Tables 1 - 4** of **Appendix A**. Figures illustrating the grids within the current layout of the McClurg Court Center property sidewalks are included as **Figures 2 - 7** in **Appendix B**. Copies of the field logs are included in **Appendix C**. Copies of the respective instrument manuals and current Certificates of Calibrations are included in **Appendix D**.

## THORIUM WALKOVER SURVEY RESULTS

### ***East Ohio Street***

During the surveys that were conducted with the Geiger-Mueller 44-9 and 2”x2” 44-10 Sodium Iodide (NaI) probes, a total of 349 and 60 readings were collected from the East Ohio Street sidewalk, respectively. The lowest and highest readings collected with the Geiger-Mueller 44-9 probe detector were 21.7 and 66.3 cpm, respectively. Overall, the average alpha/gamma/beta readings along the East Ohio Street sidewalk were calculated at 43.5 cpm within the concrete covered areas and 45.1 cpm within the soil covered planters. The lowest and highest gamma count rates collected with the 2”x2” 44-10 Sodium Iodide (NaI) probe were 5,124 and 10,442 cpm, respectively. The average low and high gamma count rates were calculated at 7,252 and 8,007 cpm, respectively.

### ***North McClurg Street***

During the surveys that were conducted with the Geiger-Mueller 44-9 and 2”x2” 44-10 Sodium Iodide (NaI) probes, a total of 121 and 21 readings were collected from the North McClurg Street sidewalk, respectively. The lowest and highest readings collected with the Geiger-Mueller 44-9 probe detector were 13.5 and 71.4 cpm, respectively. Overall, the average alpha/gamma/beta readings along the North McClurg Street sidewalk were calculated at 42.8 cpm within the concrete covered areas and 45.1 cpm within the soil covered planters. The lowest and highest gamma count rates collected with the 2”x2” 44-10 Sodium Iodide (NaI) probe were 6,101 and 10,421 cpm, respectively. The average low and high gamma count rates were calculated at 7,424 and 8,476 cpm, respectively.

### ***East Ontario Street***

During the surveys that were conducted with the Geiger-Mueller 44-9 and 2”x2” 44-10 Sodium Iodide (NaI) probes, a total of 437 and 37 readings were collected from the East Ontario Street sidewalk, respectively. The lowest and highest readings collected with the Geiger-Mueller 44-9 probe detector were 16.4 and 66.3 cpm, respectively. Overall, the average alpha/gamma/beta readings along the East Ontario Street sidewalk were lower than those observed on the North McClurg Street and East Ohio Street sidewalks. The averages were calculated at 39.06 cpm within the concrete covered areas and 38.09 cpm within the soil covered planters. The lowest and highest gamma count rates collected with the 2”x2” 44-10 Sodium Iodide (NaI) probe were

5,688 and 8,577 cpm, respectively. The average low and high gamma count rates were calculated at 6,522 and 7,738 cpm, respectively.

**CONCLUSION AND RECOMMENDATIONS**

The survey with the Geiger-Mueller 44-9 probe detector revealed an overall average radiation count rate of 41.2 cpm, which was within the range (25 to 50 cpm) of the instrument's typical background readings. The overall low and high average gamma count reading that were collected with the 2"x2" 44-10 Sodium Iodide (NaI) probe were 7,040 and 8,000 cpm, respectively. These average readings appear to be within the range of typical background readings (4,000 to 10,000 cpm) for this instrument. No count rates were observed at any time that exceeded the USEPA's threshold limit of 18,728 cpm for the 2"x2" 44-10 Sodium Iodide (NaI) probe. Consequently, based on the findings of the surface scan, no areas of elevated thorium concentrations were identified.

Additionally, none of the individual gamma count rates were observed above 11,076 cpm, which is twice the calculated background reading of 2.1 pCi/g for the 2"x2" 44-10 Sodium Iodide (NaI) probe. However, it should be noted that based on technological limitations of gamma radiation detection equipment, the ability to identify elevated thorium concentrations areas beneath engineered barriers (i.e., concrete sidewalks, asphalt pavement, etc.) is limited. Gamma radiation detection equipment is only effective in monitoring excess gamma radiation to a depth of approximately 18-inches in uncapped soils.

Although no evidence of elevated concentrations of thorium was encountered during the Thorium Walkover Survey, based on the aforementioned limitations, ATC recommends additional background radiation surveillance and personnel monitoring if the sidewalk repair/replacement activities occur. ATC also recommends surface scans immediately upon the removal of the concrete surfaces of the adjacent right-of-way, if any such work is undertaken. If the work involves the removal of any thorium impacted sub-base fill materials, these materials would be required to be handled in accordance with USEPA and Chicago Department of Environment's requirements, as well as ATC's Soil Management Plan, dated October 18, 2006.

**CLOSING**

ATC appreciates the opportunity to perform these services and looks forward to continuing work with Bentall Kennedy and M&R Development LLC on this project. If you have questions or comments regarding the information in this report, or if we can provide further assistance, please do not hesitate to contact the undersigned at (630) 916-7272.

Sincerely,
**ATC Associates Inc.**

Jose M. Gonzalez
Project Scientist

J. David Patton, PG, CHMM
Chicago Operations Manager

John N. Sabovcik, Jr., REM
Manager, Environmental Due Diligence Services

cc: Ms. Verneta Simon – USEPA Region 5

**APPENDIX A**

Table 1

**Thorium Walkover Survey**

Ludlum 2221 with 44-10 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| Location | Radiation Count (cpm) | | Location | Radiation Count (cpm) | | Location | Radiation Count (cpm) | | Location | Radiation Count (cpm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low | High | | Low | High | | Low | High | | Low | High |
| **EAST OHIO STREET** | | | | | | | | | | | |
| 1 | 6,980 | 8,065 | 16 | 5,871 | 7,324 | 31 | 6,518 | 7,245 | 46 | 6,902 | 8,531 |
| 2 | 8,520 | 10,007 | 17 | 7,085 | 8,205 | 32 | 7,184 | 7,909 | 47 | 7,701 | 8,671 |
| 3 | 9,510 | 9,636 | 18 | 8,006 | 8,451 | 33 | **5,124** | 5,705 | 48 | 7,834 | 7,952 |
| 4 | 7,695 | 9,666 | 19 | 7,961 | 8,680 | 34 | 5,484 | 6,458 | 49 | 7,378 | 7,778 |
| 5 | 8,800 | **10,442** | 20 | 6,974 | 8,582 | 35 | 6,608 | 7,075 | 50 | 7,264 | 8,368 |
| 6 | 6,894 | 7,362 | 21 | 6,727 | 8,357 | 36 | 6,861 | 7,731 | 51 | 7,909 | 9,340 |
| 7 | 7,061 | 7,424 | 22 | 5,271 | 6,426 | 37 | 7,608 | 7,977 | 52 | 8,464 | 9,934 |
| 8 | 7,138 | 7,652 | 23 | 5,601 | 6,349 | 38 | 8,796 | 9,261 | 53 | 6,707 | 7,253 |
| 9 | 8,892 | 9,536 | 24 | 5,996 | 7,134 | 39 | 7,384 | 8,876 | 54 | 7,918 | 8,266 |
| 10 | 9,037 | 9,513 | 25 | 5,404 | 5,844 | 40 | 8,294 | 8,312 | 55 | 7,268 | 8,444 |
| 11 | 9,081 | 9,533 | 26 | 5,900 | 5,983 | 41 | 8,067 | 9,035 | 56 | 7,386 | 7,594 |
| 12 | 8,556 | 8,636 | 27 | 7,438 | 7,832 | 42 | 6,904 | 7,632 | 57 | 8,181 | 8,415 |
| 13 | 8,282 | 9,060 | 28 | 6,707 | 7,401 | 43 | 6,148 | 6,444 | 58 | 7,284 | 7,415 |
| 14 | 7,833 | 8,264 | 29 | 7,661 | 7,832 | 44 | 6,280 | 7,011 | 59 | 6,821 | 7,249 |
| 15 | 6,678 | 8,124 | 30 | 5,982 | 6,404 | 45 | 6,720 | 7,441 | 60 | 6,564 | 7,399 |
| | | | | | | | | | | **Total Average Low (cpm):** | **7,252** |
| | | | | | | | | | | **Total Average High (cpm):** | **8,007** |
| **NORTH MCCLURG STREET** | | | | | | | | | | | |
| 1 | 6,205 | 8,415 | 7 | 7,337 | 8,324 | 13 | 7,158 | 8,142 | 19 | 7,116 | 7,326 |
| 2 | 7,277 | 8,943 | 8 | 8,494 | 10,455 | 14 | 9,225 | 8,492 | 20 | 6,704 | 7,408 |
| 3 | 8,228 | 10,282 | 9 | 7,567 | 8,594 | 15 | 7,581 | 8,359 | 21 | 6,960 | 7,316 |
| 4 | 8,741 | 9,012 | 10 | 6,519 | 8,244 | 16 | 7,972 | 8,475 | | | |
| 5 | 7,605 | 8,256 | 11 | 7,328 | 7,445 | 17 | 7,464 | 7,925 | | | |
| 6 | **6,101** | 8,824 | 12 | 6,985 | 7,344 | 18 | 7,338 | **10,421** | | | |
| | | | | | | | | | | **Total Average Low (cpm):** | **7,424** |
| | | | | | | | | | | **Total Average High (cpm):** | **8,476** |
| **EAST ONTARIO STREET** | | | | | | | | | | | |
| 1 | 6,316 | 7,163 | 11 | 6,793 | 7,844 | 21 | 7,315 | 8,061 | 31 | 5,748 | 6,942 |
| 2 | 6,704 | 7,304 | 12 | 6,155 | 8,334 | 22 | 7,104 | 8,432 | 32 | **5,688** | 8,200 |
| 3 | 6,214 | 7,974 | 13 | 6,344 | 8,514 | 23 | 6,527 | 7,281 | 33 | 6,338 | 7,904 |
| 4 | 6,808 | 8,414 | 14 | 6,101 | 8,111 | 24 | 6,236 | 6,818 | 34 | 7,248 | 8,349 |
| 5 | 6,388 | 8,400 | 15 | 6,687 | 7,904 | 25 | 6,510 | 6,700 | 35 | 6,181 | 8,134 |
| 6 | 6,594 | 8,391 | 16 | 6,944 | 8,621 | 26 | 6,624 | 6,641 | 36 | 6,571 | 8,236 |
| 7 | 6,515 | 7,441 | 17 | 7,214 | **8,577** | 27 | 6,411 | 6,942 | 37 | 7,708 | 8,179 |
| 8 | 6,342 | 7,011 | 18 | 5,963 | 6,118 | 28 | 6,304 | 8,200 | 38 | 7,610 | 8,455 |
| 9 | 6,116 | 7,414 | 19 | 6,177 | 7,461 | 29 | 5,904 | 7,904 | 39 | 6,904 | 7,904 |
| 10 | 6,741 | 7,121 | 20 | 5,784 | 6,042 | 30 | 5,881 | 8,349 | 40 | 7,154 | 7,745 |
| | | | | | | | | | | **Total Average Low (cpm):** | **6,522** |
| | | | | | | | | | | **Total Average High (cpm):** | **7,738** |
| | | | | | | | | | | **Site Total Average Low (cpm):** | **7,040** |
| | | | | | | | | | | **Site Total Average High (cpm):** | **8,000** |

(blue shading) Indicates that survey included data from portions of the soil covered planter.

cpm = Counts per minute

Readings in **BOLD** depict the low and high readings observed on each sidewalk.

Table 2 (Page 1 of 2)

**Thorium Walkover Survey - East Ohio Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** |
|---|---|---|---|---|---|---|---|---|---|
| 1 -1 | 64.9 | 14 -1 | 44 | 27 -1 | 61.8 | 40 -1 | 47.5 | 53 -1 | 52 |
| 1 -2 | 45.4 | 14 -2 | 58.4 | 27 -2 | 40.3 | 40 -2 | 48.7 | 53 -2 | 39.3 |
| 1 -3 | 50.1 | 14 -3 | 38.9 | 27 -3 | 36.5 | 40 -3 | 45.4 | 53 -3 | 27.8 |
| 2 -1 | 40.5 | 15 -1 | 38.4 | 28 -1 | 38.1 | 41 -1 | 41.4 | 54 -1 | 61.1 |
| 2 -2 | 55.5 | 15 -2 | 50.8 | 28 -2 | 31.6 | 41 -2 | 29.7 | 54 -2 | 60.2 |
| 2 -3 | 48.2 | 15 -3 | 44.4 | 28 -3 | 57.4 | 41 -3 | 27.6 | 54 -3 | 43.5 |
| 3 -1 | 35.3 | 16 -1 | 52.2 | 29 -1 | 35.3 | 42 -1 | 41.2 | 55 -1 | 53.1 |
| 3 -2 | 46.8 | 16 -2 | 48.5 | 29 -2 | 52.4 | 42 -2 | Vault | 55 -2 | 54.6 |
| 3 -3 | 37.1 | 16 -3 | 40.5 | 29 -3 | 36.5 | 42 -3 | 34.4 | 55 -3 | 35.6 |
| 4 -1 | 38.6 | 17 -1 | 49.4 | 30 -1 | 31.1 | 43 -1 | 41.2 | 56 -1 | 56.4 |
| 4 -2 | 37.2 | 17 -2 | 65.3 | 30 -2 | 43.8 | 43 -2 | Vault | 56 -2 | 32.8 |
| 4 -3 | 58.8 | 17 -3 | 42.4 | 30 -3 | 62.8 | 43 -3 | 25.7 | 56 -3 | 56.7 |
| 5 -1 | 49.6 | 18 -1 | 49.9 | 31 -1 | 50.1 | 44 -1 | 44.1 | 57 -1 | 35.3 |
| 5 -2 | 49.2 | 18 -2 | 53.6 | 31 -2 | 48.2 | 44 -2 | Vault | 57 -2 | 34.2 |
| 5 -3 | 37.2 | 18 -3 | 36.5 | 31 -3 | 47.4 | 44 -3 | 31.1 | 57 -3 | 43.8 |
| 6 -1 | 45.4 | 19 -1 | 37.2 | 32 -1 | 32.1 | 45 -1 | 39.6 | 58 -1 | 40.7 |
| 6 -2 | 40.5 | 19 -2 | 44.1 | 32 -2 | 37 | 45 -2 | Vault | 58 -2 | 54.3 |
| 6 -3 | 35.3 | 19 -3 | 29.2 | 32 -3 | 50.3 | 45 -3 | 45.2 | 58 -3 | 30.4 |
| 7 -1 | 34.2 | 20 -1 | 46.8 | 33 -1 | 46.6 | 46 -1 | 42.6 | 59 -1 | 46.3 |
| 7 -2 | 41.2 | 20 -2 | 38.4 | 33 -2 | 52.1 | 46 -2 | Vault | 59 -2 | **21.7** |
| 7 -3 | 38.4 | 20 -3 | 46.3 | 33 -3 | 54.3 | 46 -3 | 57.8 | 59 -3 | 38.4 |
| 8 -1 | 73.3 | 21 -1 | 54.6 | 34 -1 | 34.4 | 47 -1 | 56 | 60 -1 | 36.3 |
| 8 -2 | 53.4 | 21 -2 | 29.7 | 34 -2 | 37.4 | 47 -2 | Vault | 60 -2 | 50.6 |
| 8 -3 | 48.4 | 21 -3 | 46.8 | 34 -3 | 45.2 | 47 -3 | 52.4 | 60 -3 | 41.1 |
| 9 -1 | 57.6 | 22 -1 | 45.6 | 35 -1 | 43.3 | 48 -1 | 31.1 | 61 -1 | 38.1 |
| 9 -2 | 43.3 | 22 -2 | 63.5 | 35 -2 | 43.5 | 48 -2 | Vault | 61 -2 | 28.5 |
| 9 -3 | 63.7 | 22 -3 | 31.6 | 35 -3 | 53.6 | 48 -3 | 27.1 | 61 -3 | 35.8 |
| 10 -1 | 33 | 23 -1 | 52 | 36 -1 | 37.7 | 49 -1 | 52.2 | 62 -1 | 39.3 |
| 10 -2 | 25.7 | 23 -2 | 43.8 | 36 -2 | 50.8 | 49 -2 | Vault | 62 -2 | 42.6 |
| 10 -3 | 59.5 | 23 -3 | 58.1 | 36 -3 | 52.9 | 49 -3 | 36.5 | 62 -3 | 47.8 |
| 11 -1 | 43.1 | 24 -1 | 46.3 | 37 -1 | 53.8 | 50 -1 | 48.2 | 63 -1 | 33.5 |
| 11 -2 | 37.1 | 24 -2 | 51.5 | 37 -2 | 32.3 | 50 -2 | 45.6 | 63 -2 | 41.7 |
| 11 -3 | 45.4 | 24 -3 | 41.4 | 37 -3 | 57.2 | 50 -3 | 49.9 | 63 -3 | 47.5 |
| 12 -1 | 52.4 | 25 -1 | 41 | 38 -1 | 34.4 | 51 -1 | 31.1 | 64 -1 | 39.3 |
| 12 -2 | 44.4 | 25 -2 | 56.2 | 38 -2 | 52.4 | 51 -2 | 42.6 | 64 -2 | 41.2 |
| 12 -3 | 44.5 | 25 -3 | 35.8 | 38 -3 | 46.6 | 51 -3 | 52.2 | 64 -3 | 23.6 |
| 13 -1 | 43.4 | 26 -1 | 51.5 | 39 -1 | 55.3 | 52 -1 | 50.6 | 65 -1 | 40.3 |
| 13 -2 | 56.7 | 26 -2 | 55.3 | 39 -2 | 39.1 | 52 -2 | 57.4 | 65 -2 | 32.5 |
| 13 -3 | 44.3 | 26 -3 | 54.3 | 39 -3 | 28.3 | 52 -3 | 59 | 65 -3 | 37 |
| | | | | | | | | | |

cpm = Counts per minute

Indicates that data point was in soil covered planter.

Reading in **BOLD** depicts the lowest reading observed on East Ohio Street.

Table 2 (Page 2 of 2)

**Thorium Walkover Survey - East Ohio Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) |
|---|---|---|---|---|---|---|---|---|---|
| 66 -1 | 52.2 | 79 -1 | 51.3 | 92 -1 | 41.1 | 105 -1 | 32.3 | 118 -1 | 51.7 |
| 66 -2 | 46.8 | 79 -2 | 51.2 | 92 -2 | 41.7 | 105 -2 | 37 | 118 -2 | 24.3 |
| 66 -3 | 57.4 | 79 -3 | **66.3** | 92 -3 | 44.7 | 105 -3 | 60.2 | 118 -3 | 44 |
| 67 -1 | 53.4 | 80 -1 | 58.6 | 93 -1 | 34.6 | 106 -1 | 45.9 | 119 -1 | 37.7 |
| 67 -2 | 31.4 | 80 -2 | 44.9 | 93 -2 | 26 | 106 -2 | 48.9 | 119 -2 | Manhole |
| 67 -3 | 30.2 | 80 -3 | 58.8 | 93 -3 | Vault | 106 -3 | 39.8 | 119 -3 | 30.4 |
| 68 -1 | 37.4 | 81 -1 | 47.8 | 94 -1 | 46.3 | 107 -1 | 51.3 | 120 -1 | 34.4 |
| 68 -2 | 48.2 | 81 -2 | 46.3 | 94 -2 | 47.3 | 107 -2 | 52.7 | 120 -2 | 50.1 |
| 68 -3 | 40.3 | 81 -3 | 25.3 | 94 -3 | 39.9 | 107 -3 | 37.7 | 120 -3 | 43.3 |
| 69 -1 | 43.8 | 82 -1 | 53.6 | 95 -1 | 56.9 | 108 -1 | 42.6 | 120 -4 | 39.1 |
| 69 -2 | 37.7 | 82 -2 | 34.2 | 95 -2 | 36.3 | 108 -2 | 40.6 | | |
| 69 -3 | 42.8 | 82 -3 | 50.3 | 95 -3 | 32.3 | 108 -3 | 36 | | |
| 70 -1 | 26.9 | 83 -1 | 50.6 | 96 -1 | 54.6 | 109 -1 | 59 | | |
| 70 -2 | 23.9 | 83 -2 | 52.2 | 96 -2 | 42.4 | 109 -2 | 45.2 | | |
| 70 -3 | 38.6 | 83 -3 | 30.6 | 96 -3 | 36.7 | 109 -3 | 41.9 | | |
| 71 -1 | 38.9 | 84 -1 | 44.2 | 97 -1 | 45.2 | 110 -1 | 40.7 | | |
| 71 -2 | 35.8 | 84 -2 | 47.8 | 97 -2 | 64.4 | 110 -2 | 41.2 | | |
| 71 -3 | 42.4 | 84 -3 | 37.9 | 97 -3 | 57.6 | 110 -3 | 44.7 | | |
| 72 -1 | 30.2 | 85 -1 | 43.1 | 98 -1 | 36.3 | 111 -1 | 38.1 | | |
| 72 -2 | 33.7 | 85 -2 | 49.1 | 98 -2 | 32.1 | 111 -2 | 48.9 | | |
| 72 -3 | 42.4 | 85 -3 | 48.9 | 98 -3 | 31.8 | 111 -3 | 38.6 | | |
| 73 -1 | 22.1 | 86 -1 | 22.1 | 99 -1 | 47.8 | 112 -1 | 37 | | |
| 73 -2 | 43.1 | 86 -2 | 35.8 | 99 -2 | 45.6 | 112 -2 | 36.3 | | |
| 73 -3 | 32.5 | 86 -3 | 59.5 | 99 -3 | 24.1 | 112 -3 | 56.9 | | |
| 74 -1 | 33 | 87 -1 | 50.1 | 100 -1 | 43.5 | 113 -1 | 39.6 | | |
| 74 -2 | 41.4 | 87 -2 | 45.4 | 100 -2 | 50.6 | 113 -2 | 37.2 | | |
| 74 -3 | 33.2 | 87 -3 | 44.4 | 100 -3 | 42.4 | 113 -3 | 38.6 | | |
| 75 -1 | 28.3 | 88 -1 | 34.6 | 101 -1 | 44.2 | 114 -1 | 32.8 | | |
| 75 -2 | 26 | 88 -2 | 45.6 | 101 -2 | 58.5 | 114 -2 | 45.6 | | |
| 75 -3 | 36.5 | 88 -3 | 33 | 101 -3 | 40.1 | 114 -3 | 39.8 | | |
| 76 -1 | 39.8 | 89 -1 | 41.2 | 102 -1 | 39.6 | 115 -1 | 32.3 | | |
| 76 -2 | 52.4 | 89 -2 | 38.7 | 102 -2 | 23.1 | 115 -2 | 52.7 | | |
| 76 -3 | 59.1 | 89 -3 | 34.9 | 102 -3 | 58.2 | 115 -3 | 46.3 | | |
| 77 -1 | 44.5 | 90 -1 | 53.8 | 103 -1 | 23.4 | 116 -1 | 39.3 | | |
| 77 -2 | 33.1 | 90 -2 | Manhole | 103 -2 | 45.6 | 116 -2 | 53.4 | | |
| 77 -3 | 31.6 | 90 -3 | 48.2 | 103 -3 | Vault | 116 -3 | 45.9 | | |
| 78 -1 | 50.8 | 91 -1 | 54.3 | 104 -1 | 43.8 | 117 -1 | 31.1 | | |
| 78 -2 | 33.5 | 91 -2 | 42.7 | 104 -2 | 49.6 | 117 -2 | 45.2 | | |
| 78 -3 | 53.6 | 91 -3 | 35.4 | 104 -3 | 49.9 | 117 -3 | 53.1 | | |

cpm = Counts per minute

Indicates that data point was in soil covered planter.

Reading in **BOLD** depicts the highest reading observed on East Ohio Street.

Table 3

**Thorium Walkover Survey - North McClurg Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) |
|---|---|---|---|---|---|---|---|
| 1 -1 | Ramp* | 17 -1 | 43.3 | 33 -1 | 56.2 | 49 -1 | 48.5 |
| 1 -2 | Ramp* | 17 -2 | 46.3 | 33 -2 | 45.2 | 49 -2 | 42.8 |
| 2 -1 | 18.5 | 18 -1 | 41 | 34 -1 | 38.6 | 50 -1 | 43.1 |
| 2 -2 | 22 | 18 -2 | 39.8 | 34 -2 | 31.4 | 50 -2 | 46.8 |
| 3 -1 | 37.7 | 19 -1 | 37.2 | 35 -1 | 23.1 | 51 -1 | 40.3 |
| 3 -2 | 29.9 | 19 -2 | 38.4 | 35 -2 | 37.4 | 51 -2 | 55.3 |
| 4 -1 | 36.5 | 20 -1 | 27.4 | 36 -1 | 41 | 52 -1 | 43.3 |
| 4 -2 | 46.8 | 20 -2 | 53.1 | 36 -2 | 31.4 | 52 -2 | 57.8 |
| 5 -1 | 34.4 | 21 -1 | **71.4** | 37 -1 | 38.9 | 53 -1 | 27.8 |
| 5 -2 | 31.6 | 21 -2 | 43.3 | 37 -2 | 25.5 | 53 -2 | 46.6 |
| 6 -1 | 37.7 | 22 -1 | 27.8 | 38 -1 | 51.3 | 54 -1 | 44.7 |
| 6 -2 | 24.1 | 22 -2 | 37.9 | 38 -2 | 56 | 54 -2 | 44.2 |
| 7 -1 | 54.3 | 23 -1 | 55.5 | 39 -1 | 49.2 | 55 -1 | 54.1 |
| 7 -2 | 42.6 | 23 -2 | 42.1 | 39 -2 | 51.3 | 55 -2 | 46.6 |
| 8 -1 | 40 | 24 -1 | 41.2 | 40 -1 | 38.6 | 56 -1 | 48.5 |
| 8 -2 | 36.7 | 24 -2 | 50.3 | 40 -2 | 53.8 | 56 -2 | 44.2 |
| 9 -1 | 49.4 | 25 -1 | 34.9 | 41 -1 | 44 | 57 -1 | 42.4 |
| 9 -2 | 43.8 | 25 -2 | 38.6 | 41 -2 | Manhole | 57 -2 | 44.5 |
| 10 -1 | 51 | 26 -1 | 43.3 | 42 -1 | 44.7 | 58 -1 | 27.4 |
| 10 -2 | 48.2 | 26 -2 | 58.8 | 42 -2 | 42.6 | 58 -2 | 29.2 |
| 11 -1 | 44.2 | 27 -1 | 56.7 | 43 -1 | 31.1 | 59 -1 | 44.9 |
| 11 -2 | 43.3 | 27 -2 | 60.9 | 43 -2 | 41.1 | 59 -2 | 44.2 |
| 12 -1 | 39.6 | 28 -1 | 41.2 | 44 -1 | 52.2 | 60 -1 | NA |
| 12 -2 | 62.5 | 28 -2 | 33 | 44 -2 | 53.4 | 60 -2 | 35.6 |
| 13 -1 | 42.1 | 29 -1 | 53.6 | 45 -1 | 34.9 | 61 -1 | 22.2 |
| 13 -2 | 29.5 | 29 -2 | 54.8 | 45 -2 | 50.3 | 61 -2 | **13.5** |
| 14 -1 | 42.1 | 30 -1 | 35.3 | 46 -1 | 51.7 | 62 -1 | 49.3 |
| 14 -2 | 29 | 30 -2 | 50.3 | 46 -2 | 40 | 62 -2 | NA |
| 15 -1 | 35.8 | 31 -1 | 45.4 | 47 -1 | 47.1 | 63 -1 | 46.6 |
| 15 -2 | 59.2 | 31 -2 | 43.8 | 47 -2 | 49.4 | | |
| 16 -1 | 38.6 | 32 -1 | 25.3 | 48 -1 | 53.4 | | |
| 16 -2 | 66.5 | 32 -2 | 33.2 | 48 -2 | 50.1 | | |
| | | | | | | | |

* Data point was on rubber mat for the crosswalk.

NA = Data point was not accessible.

Indicates that data point was in soil covered planter.

cpm = Counts per minute

Readings in **BOLD** depict the lowest and highest readings observed on North McClurg Street.

Table 4 (Page 1 of 3)

**Thorium Walkover Survey - East Ontario Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) | Location | Radiation Count (cpm) |
|---|---|---|---|---|---|---|---|
| 1 -1 | 32.5 | 14 -1 | 26.2 | 24 -1 | 22.4 | 34 -1 | Vault |
| 1 -2 | 45.6 | 14 -2 | 53.6 | 24 -2 | 23.9 | 34 -2 | 24.1 |
| 1 -3 | 51 | 14 -3 | 42.6 | 24 -3 | 27.1 | 34 -3 | 52 |
| 2 -1 | 45.6 | 15 -1 | 39.1 | 24 -4 | 22.9 | 34 -4 | 45.9 |
| 2 -2 | 53.8 | 15 -2 | 40.5 | 25 -1 | 29.2 | 35 -1 | Vault |
| 2 -3 | 36.5 | 15 -3 | 25.5 | 25 -2 | 34.9 | 35 -2 | 37.7 |
| 3 -1 | 55.3 | 15 -4 | 38.6 | 25 -3 | 19.9 | 35 -3 | 36 |
| 3 -2 | 48.5 | 16 -1 | 42.6 | 25 -4 | 32.3 | 35 -4 | 42.8 |
| 3 -3 | 52.7 | 16 -2 | 36.5 | 26 -1 | 33.5 | 36 -1 | Vault |
| 4 -1 | **66.3** | 16 -3 | 39.6 | 26 -2 | 28.3 | 36 -2 | 43.8 |
| 4 -2 | 43.5 | 16 -4 | 40.7 | 26 -3 | 39.8 | 36 -3 | 39.6 |
| 4 -3 | 28.1 | 17 -1 | 27.4 | 26 -4 | 44 | 36 -4 | 44.9 |
| 5 -1 | 52.7 | 17 -2 | 45.9 | 27 -1 | NA | 37 -1 | Vault |
| 5 -2 | 23.4 | 17 -3 | 35.6 | 27 -2 | 24.6 | 37 -2 | 49.4 |
| 5 -3 | 25 | 17 -4 | 51.5 | 27 -3 | 31.1 | 37 -3 | 37.9 |
| 6 -1 | 39.3 | 18 -1 | 47.3 | 27 -4 | 37.7 | 37 -4 | 65.1 |
| 6 -2 | 23.9 | 18 -2 | 32.3 | 28 -1 | NA | 38 -1 | Vault |
| 6 -3 | 49.6 | 18 -3 | 31.1 | 28 -2 | 29.2 | 38 -2 | 50.8 |
| 7 -1 | 37 | 18 -4 | 43.1 | 28 -3 | 47.3 | 38 -3 | 38.4 |
| 7 -2 | 41.4 | 19 -1 | 46.6 | 28 -4 | 40 | 38 -4 | 22.2 |
| 7 -3 | 30.9 | 19 -2 | 39.6 | 29 -1 | 37.2 | 39 -1 | Vault |
| 8 -1 | 44.5 | 19 -3 | 22 | 29 -2 | Manhole | 39 -2 | 35.1 |
| 8 -2 | 41.9 | 19 -4 | 39.1 | 29 -3 | 22.9 | 39 -3 | 27.1 |
| 8 -3 | 24.8 | 20 -1 | 51.5 | 29 -4 | 34.2 | 39 -4 | 56.2 |
| 9 -1 | 41.9 | 20 -2 | 43.5 | 30 -1 | 33.7 | 40 -1 | Vault |
| 9 -2 | 22.9 | 20 -3 | 53.4 | 30 -2 | 28.5 | 40 -2 | 38.6 |
| 9 -3 | 34.2 | 20 -4 | 54.8 | 30 -3 | 44.2 | 40 -3 | 37.2 |
| 10 -1 | 44.2 | 21 -1 | 46.8 | 30 -4 | 37.2 | 40 -4 | 36.3 |
| 10 -2 | 42.8 | 21 -2 | 40.7 | 31 -1 | 39.1 | 41 -1 | Vault |
| 10 -3 | 29 | 21 -3 | 27.6 | 31 -2 | 46.3 | 41 -2 | 26.9 |
| 11 -1 | 25.3 | 21 -4 | 37.1 | 31 -3 | 40 | 41 -3 | 35.1 |
| 11 -2 | 41.2 | 22 -1 | 52.9 | 31 -4 | 37.4 | 41 -4 | 54.6 |
| 11 -3 | 38.6 | 22 -2 | 39.1 | 32 -1 | 26.9 | 42 -1 | Vault |
| 12 -1 | 47.5 | 22 -3 | 38.1 | 32 -2 | 35.8 | 42 -2 | 29.9 |
| 12 -2 | 50.1 | 22 -4 | 35.6 | 32 -3 | 26.7 | 42 -3 | 30.6 |
| 12 -3 | 30.2 | 23 -1 | 27.1 | 32 -4 | 28.8 | 42 -4 | 43.3 |
| 13 -1 | 38.6 | 23 -2 | 27.8 | 33 -1 | 45.4 | 43 -1 | Vault |
| 13 -2 | 37.2 | 23 -3 | 27.6 | 33 -2 | 38.4 | 43 -2 | 50.6 |
| 13 -3 | 33.2 | 23 -4 | 29 | 33 -3 | 26.7 | 43 -3 | 51.3 |
| | | | | 33 -4 | 28.8 | 43 -4 | 39.1 |
| | | | | | | | |

cpm = Counts per minute

NA = Data point was not accessible (Car over data area).

Indicates that data point was in soil covered planter.

Reading in **BOLD** depicts the highest reading observed on East Ontario Street.

Table 4 (Page 2 of 3)

**Thorium Walkover Survey - East Ontario Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

Chicago, IL

| **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** |
|---|---|---|---|---|---|---|---|
| 44 -1 | Vault | 54 -1 | Vault | 64 -1 | 46.8 | 74 -1 | 46.3 |
| 44 -2 | 36.3 | 54 -2 | 48.9 | 64 -2 | 38.4 | 74 -2 | 36 |
| 44 -3 | 22.9 | 54 -3 | 37 | 64 -3 | 30.2 | 74 -3 | 35.1 |
| 44 -4 | 46.8 | 54 -4 | 30.4 | 64 -4 | 44.2 | 74 -4 | 46.6 |
| 45 -1 | Vault | 55 -1 | Vault | 65 -1 | 35.1 | 75 -1 | 35.8 |
| 45 -2 | 35.6 | 55 -2 | 34.6 | 65 -2 | 47.8 | 75 -2 | 43.3 |
| 45 -3 | 52.2 | 55 -3 | 28.8 | 65 -3 | 45.9 | 75 -3 | 43.5 |
| 45 -4 | 36.5 | 55 -4 | 38.4 | 65 -4 | 43.8 | 75 -4 | 37.2 |
| 46 -1 | Vault | 56 -1 | Vault | 66 -1 | 40 | 76 -1 | 51 |
| 46 -2 | 40.5 | 56 -2 | 44.2 | 66 -2 | 35.3 | 76 -2 | 38.9 |
| 46 -3 | 51.3 | 56 -3 | 47.3 | 66 -3 | 33.5 | 76 -3 | 39.1 |
| 46 -4 | 34.4 | 56 -4 | 38.6 | 66 -4 | 30.2 | 76 -4 | 47.5 |
| 47 -1 | Vault | 57 -1 | 36.7 | 67 -1 | 52.2 | 77 -1 | 53.1 |
| 47 -2 | 38.9 | 57 -2 | 42.8 | 67 -2 | 55.4 | 77 -2 | 41.4 |
| 47 -3 | 29.5 | 57 -3 | 30.2 | 67 -3 | 51.3 | 77 -3 | 36.3 |
| 47 -4 | 54.8 | 57 -4 | 37.9 | 67 -4 | 48.2 | 77 -4 | 43.1 |
| 48 -1 | Vault | 58 -1 | 43.8 | 68 -1 | 63 | 78 -1 | 48 |
| 48 -2 | 37.7 | 58 -2 | 42.6 | 68 -2 | 29.4 | 78 -2 | 40.3 |
| 48 -3 | 60.2 | 58 -3 | 37.4 | 68 -3 | 25.3 | 78 -3 | 35.5 |
| 48 -4 | 27.6 | 58 -4 | 38.9 | 68 -4 | 58.8 | 78 -4 | 29.5 |
| 49 -1 | Vault | 59 -1 | 36.3 | 69 -1 | 38.4 | 79 -1 | 45.6 |
| 49 -2 | 54.8 | 59 -2 | 32.1 | 69 -2 | 39.8 | 79 -2 | 36.5 |
| 49 -3 | 38.6 | 59 -3 | 33 | 69 -3 | 43.8 | 79 -3 | 39.8 |
| 49 -4 | 26.4 | 59 -4 | 43.3 | 69 -4 | 40.3 | 79 -4 | 33.9 |
| 50 -1 | Vault | 60 -1 | 35.1 | 70 -1 | 55.3 | 80 -1 | 39.8 |
| 50 -2 | 22 | 60 -2 | 36 | 70 -2 | 37 | 80 -2 | 36.7 |
| 50 -3 | 50.6 | 60 -3 | 37.7 | 70 -3 | 38.4 | 80 -3 | 41.2 |
| 50 -4 | 44.7 | 60 -4 | 38.4 | 70 -4 | 26.7 | 80 -4 | 44.9 |
| 51 -1 | Vault | 61 -1 | 41.4 | 71 -1 | 35.8 | 81 -1 | 59.2 |
| 51 -2 | 41.4 | 61 -2 | 35.8 | 71 -2 | 43.5 | 81 -2 | 43.8 |
| 51 -3 | 36.5 | 61 -3 | 33.4 | 71 -3 | 40.5 | 81 -3 | 34.4 |
| 51 -4 | 52.9 | 61 -4 | 27.6 | 71 -4 | 34.4 | 81 -4 | 39.6 |
| 52 -1 | Vault | 62 -1 | 35.1 | 72 -1 | 40.3 | 82 -1 | 32.8 |
| 52 -2 | 23.6 | 62 -2 | 37.2 | 72 -2 | 42.1 | 82 -2 | 22 |
| 52 -3 | 29.2 | 62 -3 | 34.6 | 72 -3 | 39.6 | 82 -3 | 26 |
| 52 -4 | 33 | 62 -4 | 25 | 72 -4 | 24.8 | 82 -4 | 30.9 |
| 53 -1 | Vault | 63 -1 | 35.3 | 73 -1 | 31.6 | 83 -1 | 51.5 |
| 53 -2 | **16.4** | 63 -2 | 34.6 | 73 -2 | 42.1 | 83 -2 | 56.9 |
| 53 -3 | 28.1 | 63 -3 | 46.6 | 73 -3 | 35.1 | 83 -3 | 57.8 |
| 53 -4 | 31.4 | 63 -4 | 41.1 | 73 -4 | 41.4 | 83 -4 | 52.1 |

cpm = Counts per minute

Indicates that data point was in soil covered planter.

Reading in **BOLD** depicts the lowest reading observed on East Ontario Street.

Table 4 (Page 3 of 3)

**Thorium Walkover Survey - East Ontario Street**

Ludlum 2241 with 44-9 Probe

McClurg Court Center

333 East Ontario Street

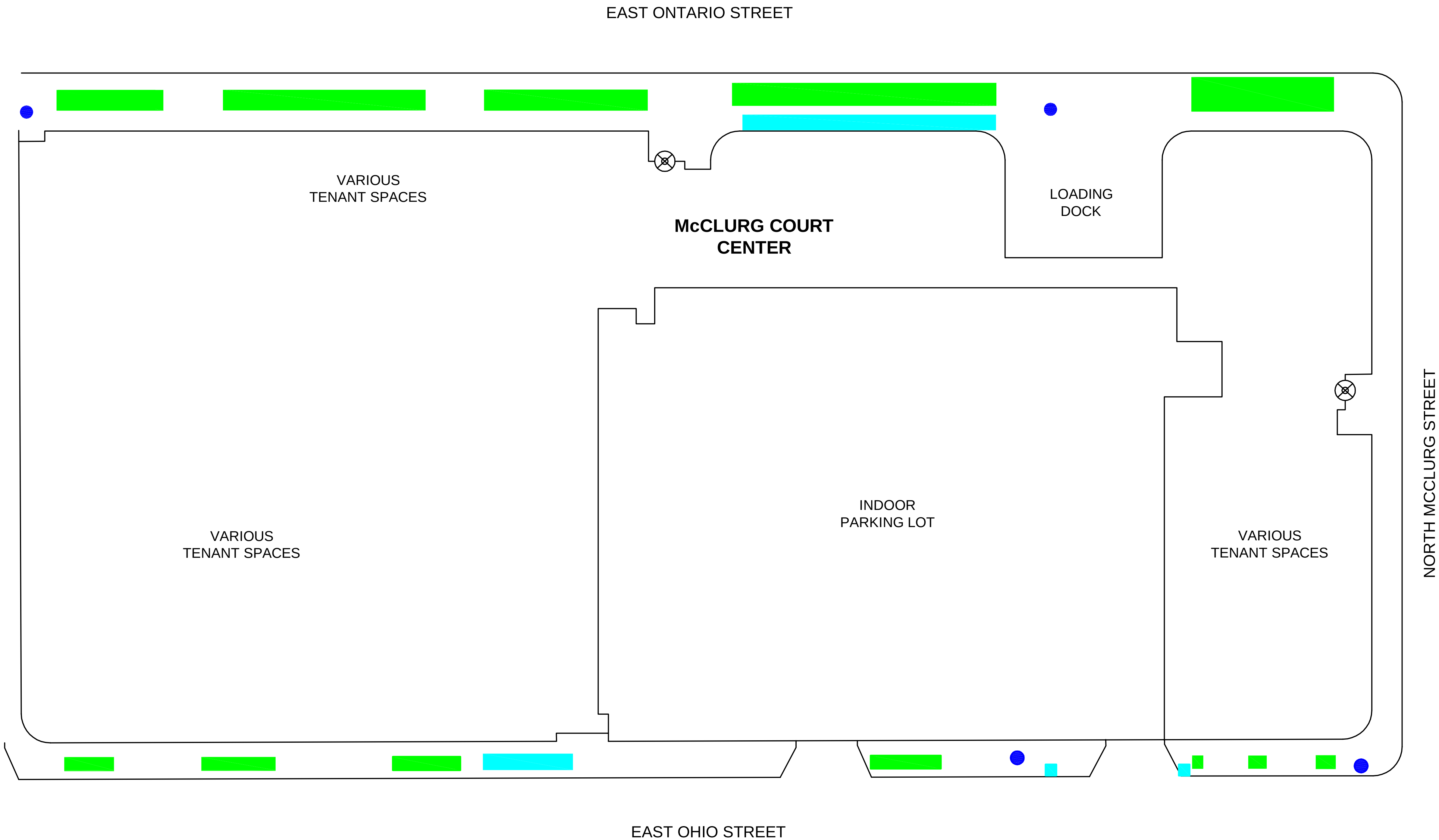
Chicago, IL

| **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** | **Location** | **Radiation Count (cpm)** |
|---|---|---|---|---|---|---|---|
| 84 -1 | 33.9 | 94 -1 | 33.7 | 104 -1 | 42.1 | 114 -1 | 37 |
| 84 -2 | 43.8 | 94 -2 | 47.5 | 104 -2 | 55 | 114 -2 | 43.5 |
| 84 -3 | 27.4 | 94 -3 | 26.9 | 104 -3 | 61.1 | 114 -3 | 49.4 |
| 84 -4 | 36.7 | 94 -4 | 26.4 | 104 -4 | 42.6 | 114 -4 | 33 |
| 85 -1 | 43.3 | 95 -1 | 42.8 | 105 -1 | 28.1 | 115 -1 | 35.8 |
| 85 -2 | 46.6 | 95 -2 | 41.2 | 105 -2 | 39.3 | 115 -2 | 41.4 |
| 85 -3 | 44.5 | 95 -3 | 48.5 | 105 -3 | 45.6 | 115 -3 | 34.8 |
| 85 -4 | 40.5 | 95 -4 | 38.9 | 105 -4 | 50.8 | 115 -4 | 39.3 |
| 86 -1 | 36.5 | 96 -1 | 22.2 | 106 -1 | 34.9 | 116 -1 | 42.1 |
| 86 -2 | 41.2 | 96 -2 | 37.9 | 106 -2 | 34.4 | 116 -2 | 35.1 |
| 86 -3 | 34.6 | 96 -3 | 38.1 | 106 -3 | 51.5 | 116 -3 | 40.5 |
| 86 -4 | 43.3 | 96 -4 | 39.1 | 106 -4 | 36.5 | 116 -4 | 38.4 |
| 87 -1 | 38.4 | 97 -1 | 44.7 | 107 -1 | 29.5 | 117 -1 | 34.4 |
| 87 -2 | 44.5 | 97 -2 | 27.4 | 107 -2 | 31.8 | 117 -2 | 46.6 |
| 87 -3 | 42.4 | 97 -3 | 35.1 | 107 -3 | 38.4 | 117 -3 | 34.4 |
| 87 -4 | 24.1 | 97 -4 | 44.2 | 107 -4 | 38.9 | 117 -4 | 45.9 |
| 88 -1 | 39.1 | 98 -1 | 28.3 | 108 -1 | 39.8 | 118 -1 | 34.2 |
| 88 -2 | 38.4 | 98 -2 | 51 | 108 -2 | 35.1 | 118 -2 | 35.8 |
| 88 -3 | 41.9 | 98 -3 | 41.7 | 108 -3 | 26.4 | 118 -3 | 60.6 |
| 88 -4 | 36.7 | 98 -4 | 31.6 | 108 -4 | 38.1 | 118 -4 | 56.9 |
| 89 -1 | 41 | 99 -1 | 40.5 | 109 -1 | 52.9 | 119 -1 | 34.9 |
| 89 -2 | 46.1 | 99 -2 | 42.6 | 109 -2 | 35.8 | 119 -2 | 42.8 |
| 89 -3 | 26.2 | 99 -3 | 42.1 | 109 -3 | 28.8 | 119 -3 | 33.8 |
| 89 -4 | 27.6 | 99 -4 | 37.7 | 109 -4 | 29.6 | 119 -4 | 41.2 |
| 90 -1 | 40.3 | 100 -1 | 45.9 | 110 -1 | 39.8 | 120 -1 | 52.7 |
| 90 -2 | 38.9 | 100 -2 | 40 | 110 -2 | 45.2 | 120 -2 | Manhole |
| 90 -3 | 31.8 | 100 -3 | 33.7 | 110 -3 | 41 | 120 -3 | 35.1 |
| 90 -4 | 31.4 | 100 -4 | 40.7 | 110 -4 | 32.1 | 120 -4 | 52.7 |
| 91 -1 | 26.7 | 101 -1 | 55.3 | 111 -1 | 58.3 | | |
| 91 -2 | 44 | 101 -2 | 41.4 | 111 -2 | 44.7 | | |
| 91 -3 | 40.3 | 101 -3 | 44.5 | 111 -3 | 42.6 | | |
| 91 -4 | 29.5 | 101 -4 | 44.2 | 111 -4 | 43.3 | | |
| 92 -1 | 41.2 | 102 -1 | 54.3 | 112 -1 | 21.7 | | |
| 92 -2 | 32.5 | 102 -2 | 44.9 | 112 -2 | 40 | | |
| 92 -3 | 37.2 | 102 -3 | 41.4 | 112 -3 | 31.6 | | |
| 92 -4 | 26.4 | 102 -4 | 44.5 | 112 -4 | 34 | | |
| 93 -1 | 39.2 | 103 -1 | 43.3 | 113 -1 | 52.4 | | |
| 93 -2 | 22.7 | 103 -2 | 55.5 | 113 -2 | 50.6 | | |
| 93 -3 | 38.1 | 103 -3 | 52.7 | 113 -3 | 43.1 | | |
| 93 -4 | 41.4 | 103 -4 | 44.9 | 113 -4 | 37.2 | | |
| | | | | | | | |

cpm = Counts per minute

Indicates that data point was in soil covered planter.

**APPENDIX B**




SOIL PLANTERS (DEPICTED IF SURVEY INCLUDED PLANTER)
UNDERGROUND VAULTS
MANHOLES

N

0 20' 40'
SCALE IN FEET

# SITE PLAN

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

| REVISIONS | | |
|---|---|---|
| DATE: | BRIEF DESCRIPTION | APPROVED |
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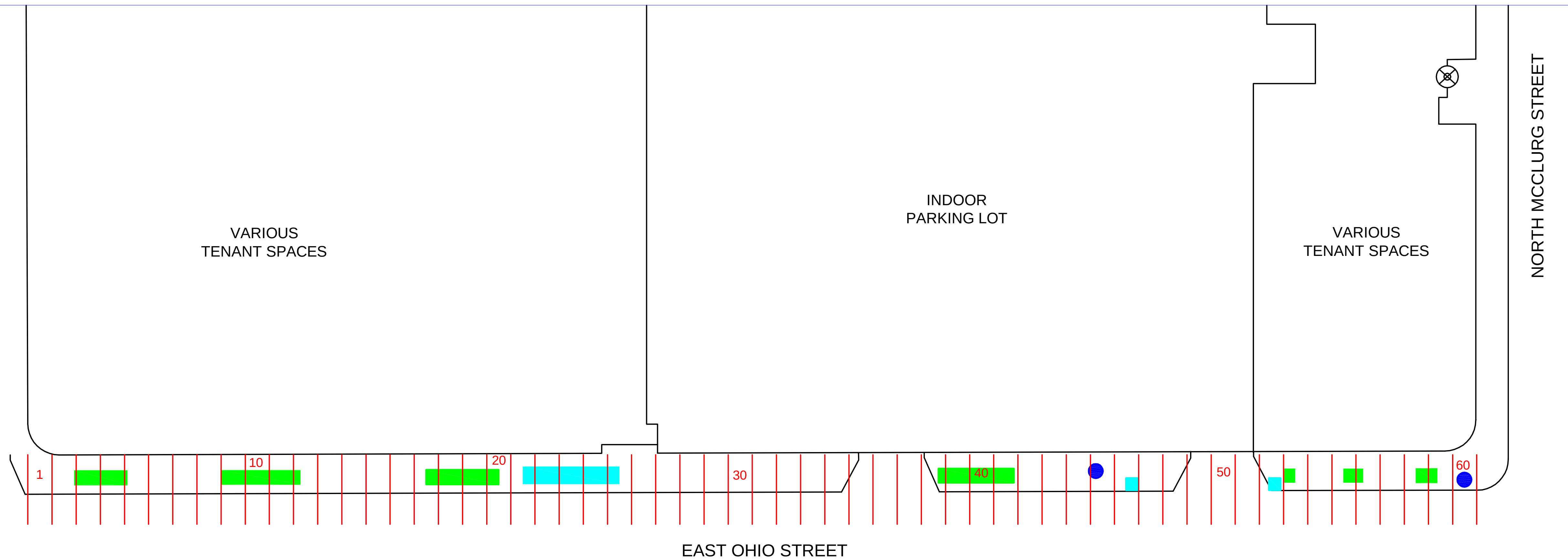
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 1 |

*ATC ASSOCIATES INC.*
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916-7272* Fox (630) 916-7013




SURVEY GRID SPACING (8–FEET WIDE AND FROM BUILDING FOOTPRINT TO SIDEWALK CURB

SOIL PLANTERS (DEPICTED IF SURVEY INCLUDED PLANTER)

UNDERGROUND VAULTS

MANHOLES

N

0 20' 40'
SCALE IN FEET

OHIO STREET
LUDLUM 2221 WITH 44–10 PROBE

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
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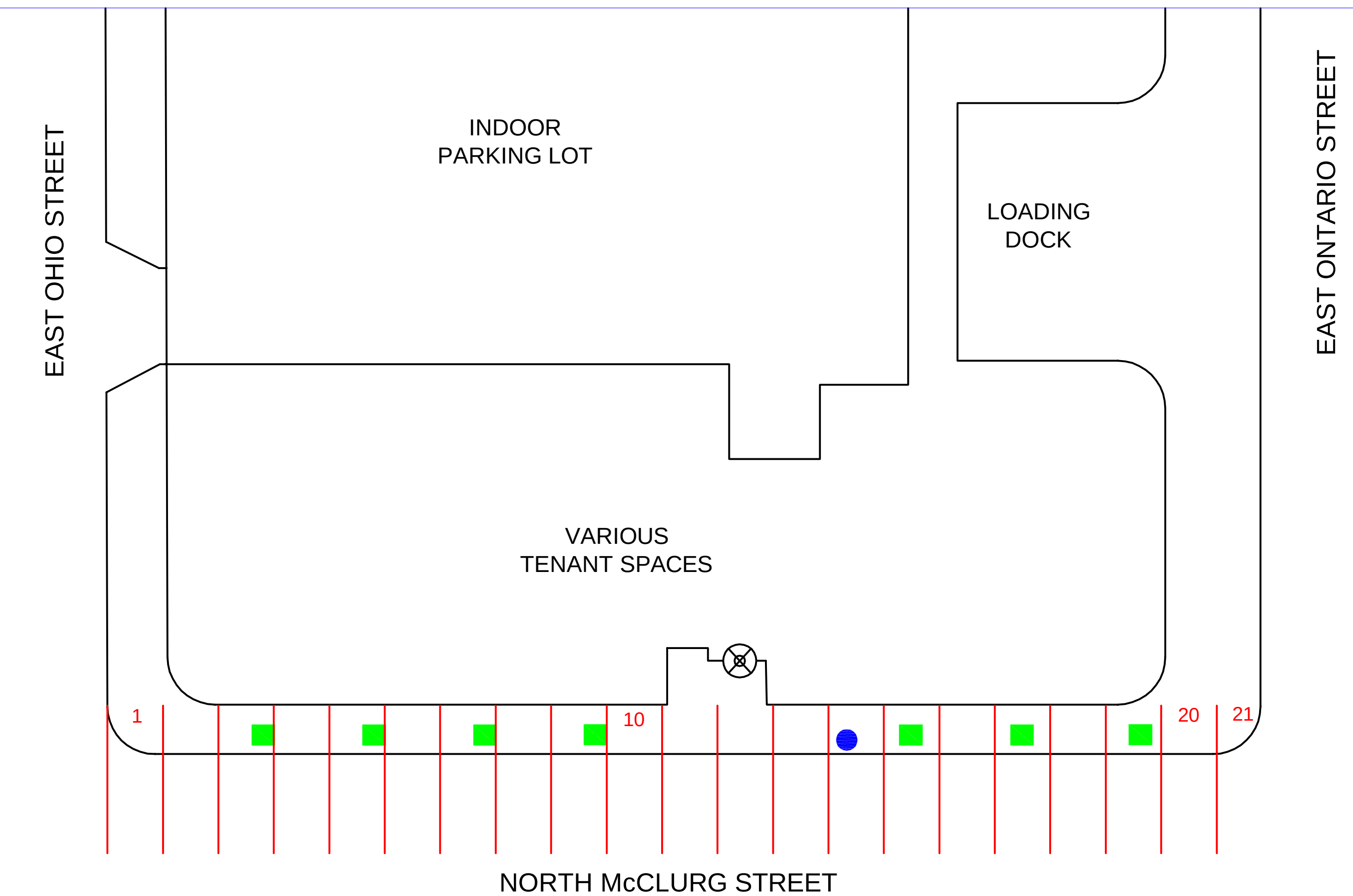
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 2 |

ATC ASSOCIATES INC.
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916–7272* Fax (630) 916–7013




SURVEY GRID SPACING (12-FEET WIDE AND FROM BUILDING FOOTPRINT TO SIDEWALK CURB

SOIL PLANTERS (DEPICTED IF SURVEY INCLUDED PLANTER)

UNDERGROUND VAULTS

MANHOLES

0 20' 40'
SCALE IN FEET

McCLURG STREET
LUDLUM 2221 WITH 44-10 PROBE

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
|---|---|---|
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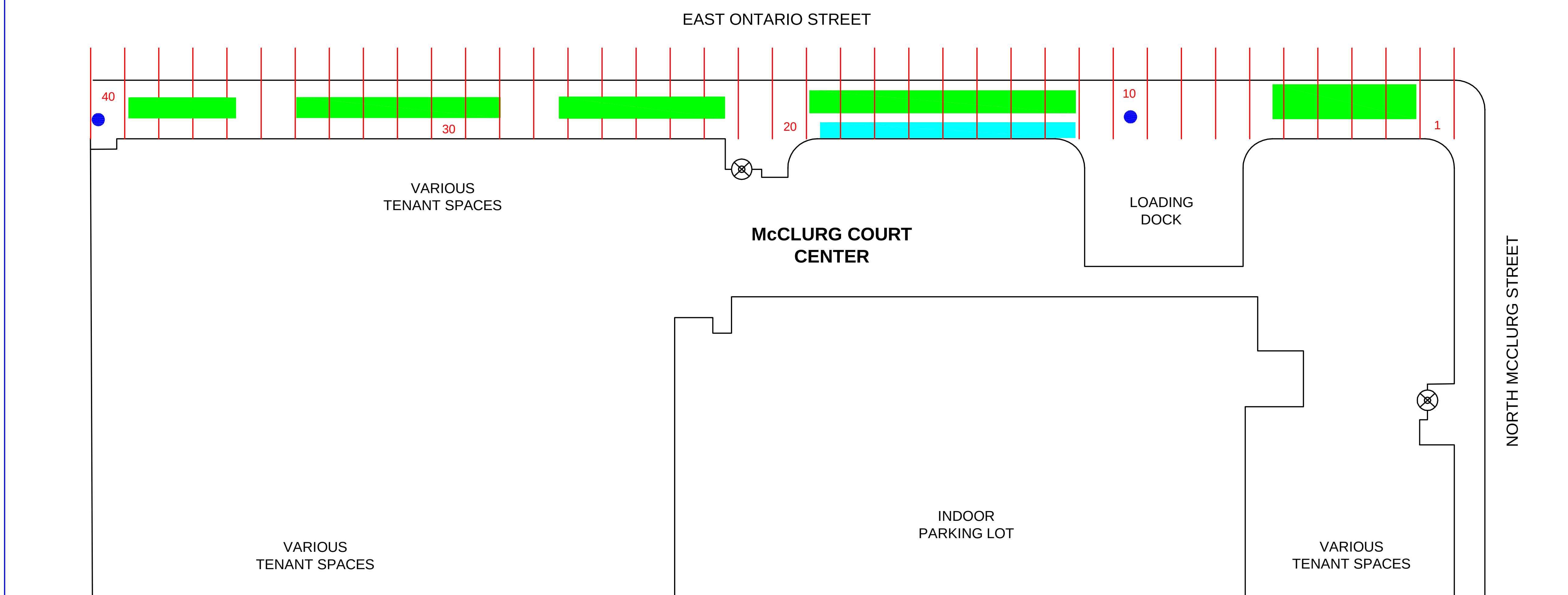
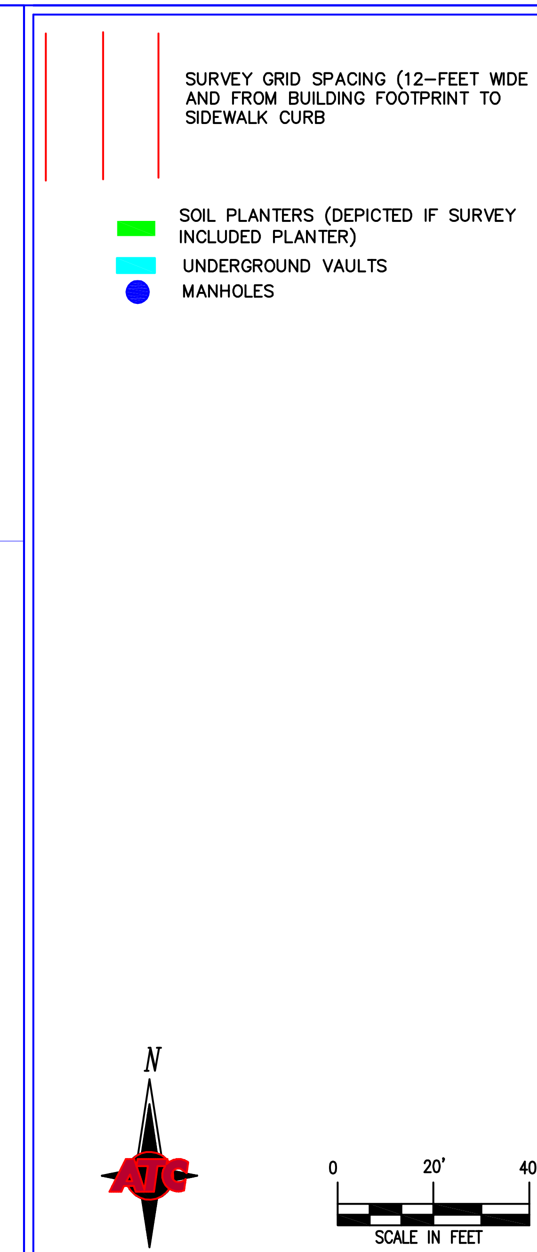
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 3 |

ATC ASSOCIATES INC.
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916-7272* Fax (630) 916-7013




ONTARIO STREET
LUDLUM 2221 WITH 44–10
PROBE

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
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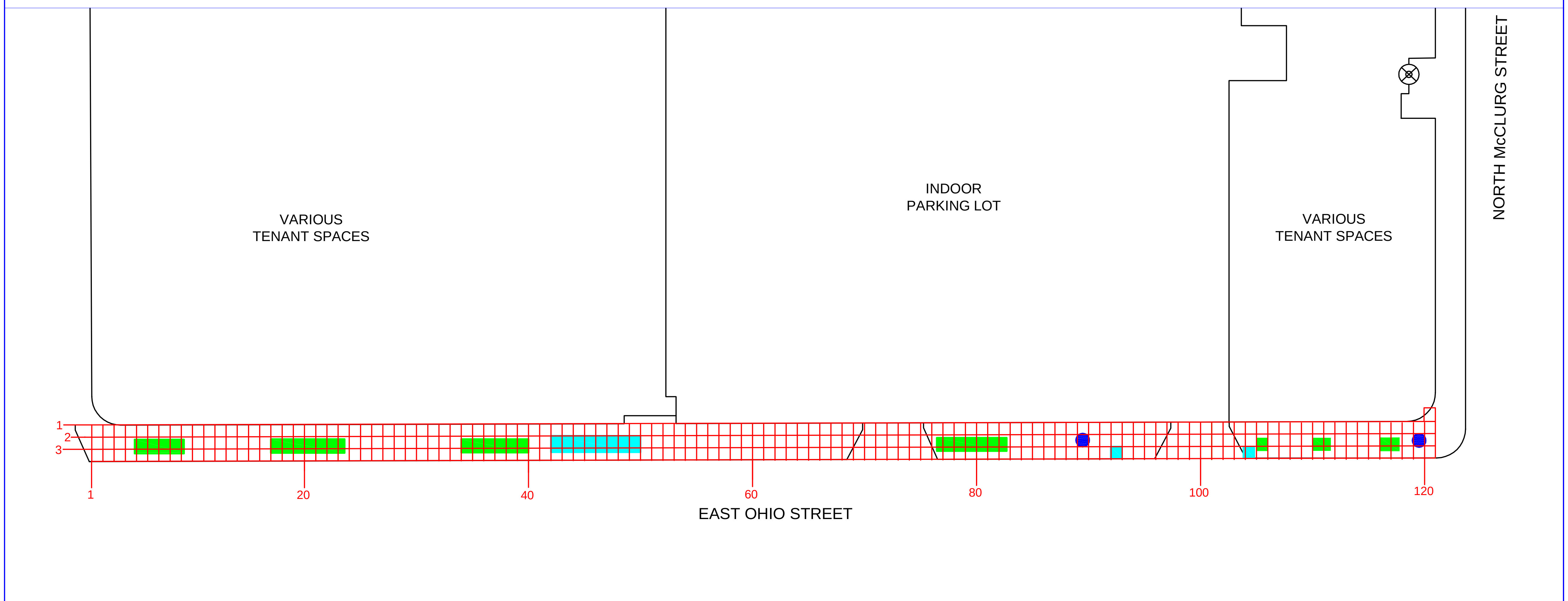
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 4 |

ATC ASSOCIATES INC.
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916–7272* Fax (630) 916–7013




SURVEY GRID SPACING (4-FOOT BY 4-FOOT) FROM BUILDING FOOTPRINT TO SIDEWALK CURB

SOIL PLANTERS (DEPICTED IF DATA POINT COLLECTED FROM PLANTER)

UNDERGROUND VAULTS

MANHOLES

N

0 20' 40'

SCALE IN FEET

OHIO STREET
LUDLUM 2241 WITH 44-9 PROBE

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
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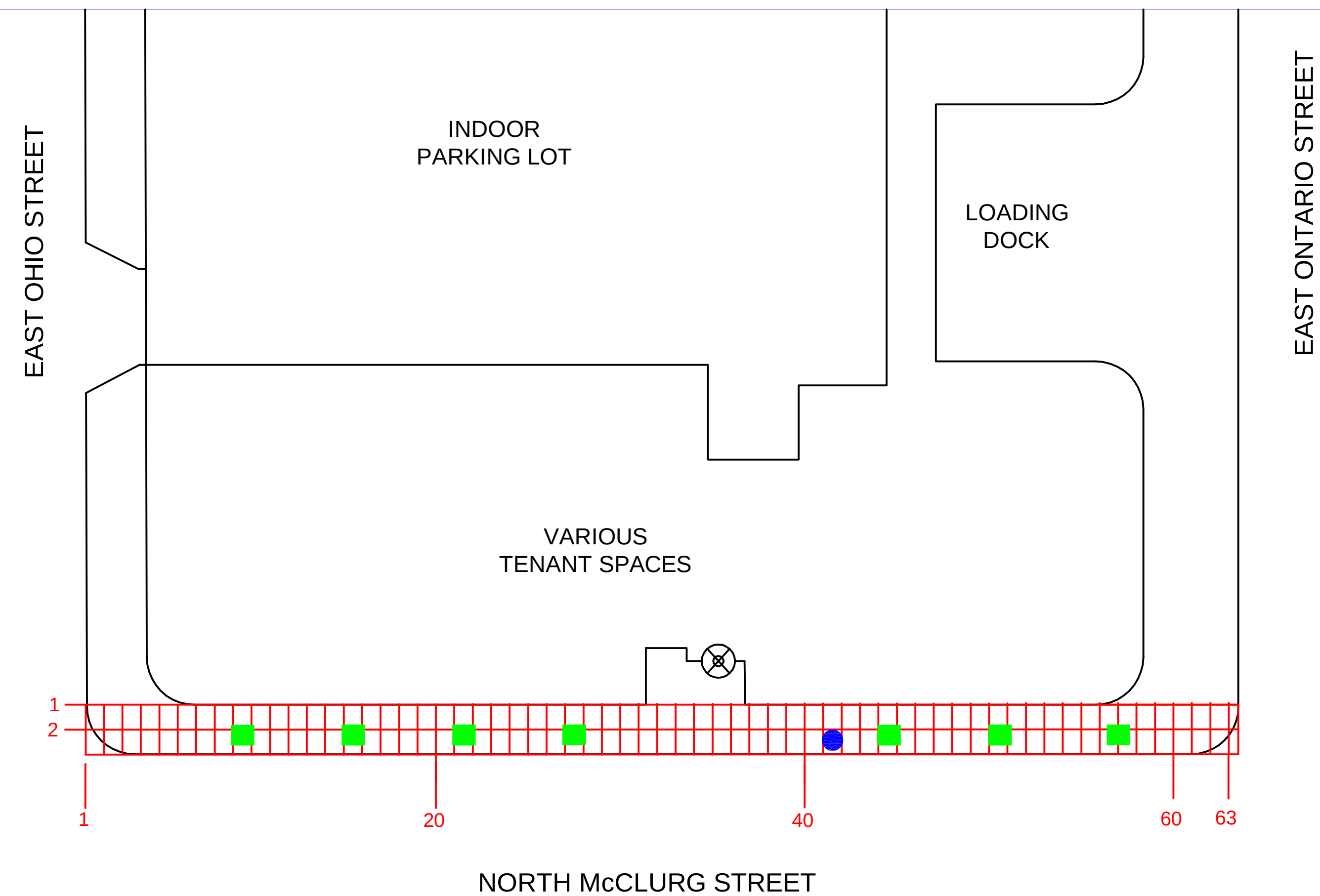
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 5 |

ATC ASSOCIATES INC.
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916-7272* Fax (630) 916-7013




SURVEY GRID SPACING (4-FOOT BY 5-FOOT) FROM BUILDING FOOTPRINT TO SIDEWALK CURB

SOIL PLANTERS (DEPICTED IF DATA POINT COLLECTED FROM PLANTER)

MANHOLE

N

0 20' 40'
SCALE IN FEET

McCLURG STREET
LUDLUM 2241 WITH 44-9 PROBE

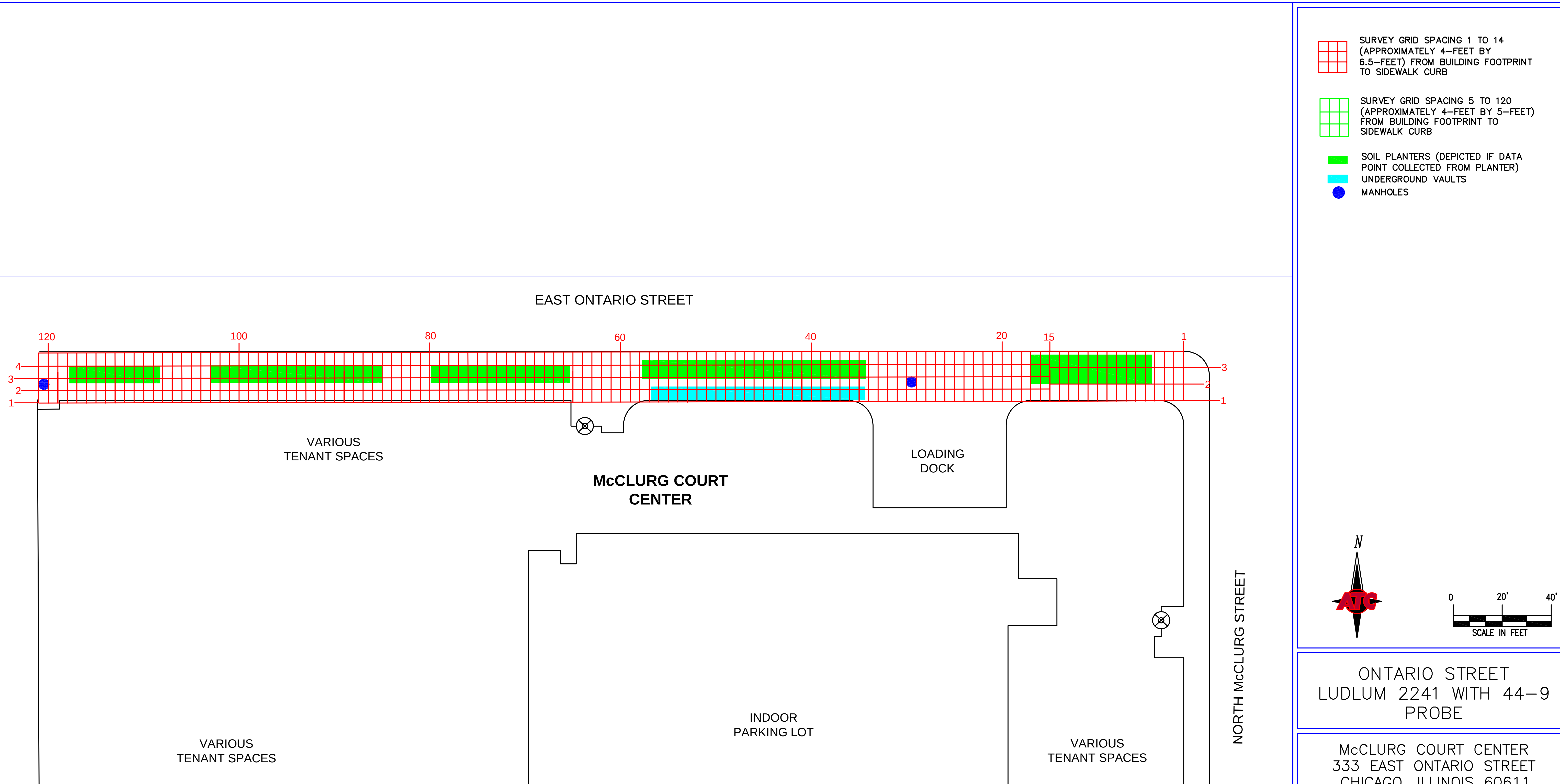
McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| | |
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 6 |


*ATC ASSOCIATES INC.*
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916-7272* Fax (630) 916-7013




ONTARIO STREET
LUDLUM 2241 WITH 44-9 PROBE

McCLURG COURT CENTER
333 EAST ONTARIO STREET
CHICAGO, ILLINOIS 60611

REVISIONS

| DATE: | BRIEF DESCRIPTION | APPROVED |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| | |
|---|---|
| SCALE: 1"=40' | CADFILE: 0007_SITEMASTER |
| DRAWN BY: LJH | CHECKED BY: JG |
| PROJECT NUMBER: 11.28570.0007 | FIGURE: 7 |

*ATC ASSOCIATES INC.*
419 EISENHOWER LANE SOUTH
LOMBARD, ILLINOIS 60148
(630) 916-7272* Fax (630) 916-7013

## APPENDIX C

Thorium Walkover Survey Field Logs

**WALKOVER SURVEY**

ATC Associates Inc. — Engineering Individual Solutions

Project: McClurg Court Center | Date: 10/12/2011

Location: Ohio Street (Grid = 8 X 12')

Project Number: 17.28570.0007 (11002) | Instrument: Ludlum 2221 with 44-10 Probe

| Location | Reading Low | Reading High | Location | Reading Low | Reading High | Location | Reading Low | Reading High |
|---|---|---|---|---|---|---|---|---|
| 1 | 6890 | 8065 | 25 | 5404 | 5844 | 49 | 7378 | 7778 |
| 2 | 8520 | 10007 | 26 | 5900 | 5983 | 50 | 7264 | 8368 |
| 3 | 9510 | 9636 | 27 | 7438 | 7832 | 51 | 7909 | 9340 |
| 4 | 7695 | 9666 | 28 | 6707 | 7401 | 52 | 8464 | 9934 |
| 5 | 8800 | 10442 | 29 | 7661 | 7832 | 53 | 6707 | 7253 |
| 6 | 6894 | 7362 | 30 | 5982 | 6404 | 54 | 7918 | 8266 |
| 7 | 7061 | 7424 | 31 | 6518 | 7245 | 55 | 7268 | 8444 |
| 8 | 7138 | 7652 | 32 | 7184 | 7909 | 56 | 7386 | 7594 |
| 9 | 8892 | 9536 | 33 | 5724 | 5705 | 57 | 8181 | 8415 |
| 10 | 9037 | 9513 | 34 | 5484 | 6458 | 58 | 7284 | 7415 |
| 11 | 9018 | 9533 | 35 | 6608 | 7075 | 59 | 6821 | 7249 |
| 12 | 8556 | 8636 | 36 | 6861 | 7731 | 60 | 6564 | 7399 |
| 13 | 8282 | 9060 | 37 | 7608 | 7977 | | | |
| 14 | 7833 | 8264 | 38 | 8796 | 9261 | | | |
| 15 | 6678 | 8124 | 39 | 7384 | 8876 | | | |
| 16 | 5871 | 7324 | 40 | 8292 | 8312 | | | |
| 17 | 7085 | 8205 | 41 | 8067 | 9035 | | | |
| 18 | 8006 | 8451 | 42 | 6904 | 7632 | | | |
| 19 | 7961 | 8680 | 43 | 6148 | 6444 | | | |
| 20 | 6974 | 8582 | 44 | 6280 | 7011 | | | |
| 21 | 6727 | 8357 | 45 | 6720 | 7441 | | | |
| 22 | 5271 | 6426 | 46 | 6902 | 8531 | | | |
| 23 | 5601 | 6349 | 47 | 7701 | 8671 | | | |
| 24 | 5996 | 7134 | 48 | 7834 | 7932 | | | |

Comments: 9, 10, 11, 12, 18 = Highs Are In Planters
20, 25 = Around Vaults
52 = East of Resident Parking Entrance In Planter
55, 57 = Building Footprint

ATC Associates Inc. Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/12/2011
Location: Mclurg (12' x 9' Grid)
Project Number: 17.28570.0007 (11002)
Instrument: Ludium 2221 with 44-10 Probe

| Location | Reading Low | Reading High | Location | Reading Low | Reading High | Location | Reading Low | Reading High |
|---|---|---|---|---|---|---|---|---|
| 1 | 6205 | 8415 | | | | | | |
| 2 | 7277 | 8943 | | | | | | |
| 3 | 8228 | 10282 | | | | | | |
| 4 | 8741 | 9012 | | | | | | |
| 5 | 7605 | 8256 | | | | | | |
| 6 | 6101 | 8824 | | | | | | |
| 7 | 7337 | 8324 | | | | | | |
| 8 | 8494 | 10455 | | | | | | |
| 9 | 7567 | 8594 | | | | | | |
| 10 | 6519 | 8244 | | | | | | |
| 11 | 7328 | 7445 | | | | | | |
| 12 | 6985 | 7344 | | | | | | |
| 13 | 7158 | 8142 | | | | | | |
| 14 | 9225 | 8492 | | | | | | |
| 15 | 7581 | 8359 | | | | | | |
| 16 | 7972 | 8475 | | | | | | |
| 17 | 7464 | 7925 | | | | | | |
| 18 | 7338 | 10421 | | | | | | |
| 19 | 7116 | 7326 | | | | | | |
| 20 | 6704 | 7408 | | | | | | |
| 21 | 6960 | 7316 | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Comments: 3 = By Building
3 to 9 = Heavy Traffic
10 to 12 = No Traffic
14 = High Reading In Planter
18 = By Building Footprint (By 28-1 on 44-9 Survey)

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center

Date: 10/12/2011

Location: Ontario (12'x14 and 12'x19' Grid)

Project Number: 17.28570.0007 (11002)

Instrument: Ludium 2221 with 44-10 Probe

| Location | Reading Low | Reading High | Location | Reading Low | Reading High | Location | Reading Low | Reading High |
|---|---|---|---|---|---|---|---|---|
| 1 | 6316 | 7163 | 25 | 6510 | 8061 | | | |
| 2 | 6704 | 7304 | 26 | 6624 | 8432 | | | |
| 3 | 6214 | 7974 | 27 | 6411 | 7281 | | | |
| 4 | 6808 | 8414 | 28 | 6304 | 6818 | | | |
| 5 | 6388 | 8400 | 29 | 5904 | 6700 | | | |
| 6 | 6594 | 8391 | 30 | 5881 | 6641 | | | |
| 7 | 6515 | 7441 | 31 | 5748 | 6942 | | | |
| 8 | 6342 | 7011 | 32 | 5688 | 8200 | | | |
| 9 | 6116 | 7414 | 33 | 6338 | 6904 | | | |
| 10 | 6741 | 7121 | 34 | 7248 | 8349 | | | |
| 11 | 6793 | 7844 | 35 | 6181 | 8134 | | | |
| 12 | 6155 | 8334 | 36 | 6571 | 8236 | | | |
| 13 | 6344 | 8514 | 37 | 7708 | 8179 | | | |
| 14 | 6101 | 8111 | 38 | 7610 | 8455 | | | |
| 15 | 6687 | 7904 | 39 | 6904 | 7904 | | | |
| 16 | 6944 | 8621 | 40 | 7154 | 7745 | | | |
| 17 | 7214 | 8577 | | | | | | |
| 18 | 5963 | 6118 | | | | | | |
| 19 | 6177 | 7461 | | | | | | |
| 20 | 5784 | 6042 | | | | | | |
| 21 | 7315 | 7764 | | | | | | |
| 22 | 7104 | 7342 | | | | | | |
| 23 | 6527 | 7873 | | | | | | |
| 24 | 6236 | 6313 | | | | | | |

Comments: 12 to 18 = Readings N of Vaults

All High Readings Were In Planters (3-6, 12-18)

**ATC ASSOCIATES INC.** Engineering Individual Solutions

# WALKOVER SURVEY

| Project: McClurg Court Center | | | | Date: 10/3/2011 | |
|---|---|---|---|---|---|
| Location: East Ohio Street | | | | Ludium 2241 | |
| Project Number: 17.28570.0007 (2) | | | Instrument: | with 44-9 Probe | |

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 1-1 | 64.9 | 10-3 | 59.5 | P 20-2 | 38.4 |
| 1-2 | 45.4 | 11-1 | 43.1 | 20-3 | 46.3 |
| 1-3 | 50.1 | 11-2 | 37.1 | 21-1 | 54.6 |
| 2-1 | 40.5 | 11-3 | 45.4 | P 21-2 | 29.7 |
| 2-2 | 55.5 | 12-1 | 52.4 | 21-3 | 46.8 |
| 2-3 | 48.2 | 12-2 | 44.4 | 22-1 | 45.6 |
| 3-1 | 35.3 | 12-3 | 44.5 | P 22-2 | 63.5 |
| 3-2 | 46.8 | 13-1 | 43.4 | 22-3 | 31.6 |
| 3-3 | 37.1 | 13-2 | 56.7 | 23-1 | 52.0 |
| 4-1 | 38.6 | 13-3 | 44.3 | P 23-2 | 43.8 |
| 4-2 | 37.2 | 14-1 | 44 | 23-3 | 58.1 |
| 4-3 | 58.8 | 14-2 | 58.8 | 24-1 | 46.3 |
| 5-1 | 49.6 | 14-3 | 38.9 | 24-2 | 51.5 |
| P 5-2 | 19.2 | 15-1 | 38.4 | 24-3 | 41.4 |
| 5-3 | 37.2 | 15-2 | 50.8 | 25-1 | 41 |
| 6-1 | 45.4 | 15-3 | 44.4 | 25-2 | 56.2 |
| P 6-2 | 40.5 | 16-1 | 52.2 | 25-3 | 35.8 |
| 6-3 | 35.3 | 16-2 | 48.5 | 26-1 | 51.5 |
| 7-1 | 34.2 | 16-3 | 40.5 | 26-2 | 55.3 |
| P 7-2 | 41.2 | 17-1 | 49.4 | 26-3 | 54.3 |
| 7-3 | 38.4 | P 17-2 | 65.3 | 27-1 | 61.8 |
| 8-1 | 73.3 | 17-3 | 42.4 | 27-2 | 40.3 |
| P 8-2 | 53.4 | 18-1 | 49.9 | 27-3 | 36.5 |
| 8-3 | 48.4 | P 18-2 | 53.6 | 28-1 | 38.6 |
| 9-1 | 57.6 | 18-3 | 36.5 | 28-2 | 31.6 |
| P 9-2 | 43.3 | 19-1 | 37.2 | 28-3 | 57.4 |
| 9-3 | 63.7 | P 19-2 | 44.1 | 29-1 | 35.3 |
| 10-1 | 33.0 | 19-3 | 29.2 | 29-2 | 52.4 |
| 10-2 | 25.7 | 20-1 | 46.8 | 29-3 | 36.5 |

Comments:

P = PLANTERS

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/3/2011
Location: East Ohio Street
Project Number: 17.28570.0007 (2)
Instrument: Ludium 2241 with 44-9 Probe

| | Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|---|
| | 30-1 | 31.1 | 39-3 | 28.3 | 49-2 | Vault |
| | 30-2 | 43.8 | 40-1 | 47.5 | 49-3 | 36.5 |
| | 30-3 | 62.8 | 40-2 | 48.7 | 50-1 | 48.2 |
| | 31-1 | 50.1 | 40-3 | 45.4 | 50-2 | 45.6 |
| | 31-2 | 48.2 | 41-1 | 41.4 | 50-3 | 49.9 |
| | 31-3 | 47.4 | 41-2 | 29.7 | 51-1 | 31.1 |
| | 32-1 | 32.1 | 41-3 | 27.6 | 51-2 | 42.6 |
| | 32-2 | 37.0 | 42-1 | 41.2 | 51-3 | 52.2 |
| | 32-3 | 51.3 | 42-2 | Vault | 52-1 | 50.6 |
| | 33-1 | 46.6 | 42-3 | 34.4 | 52-2 | 57.4 |
| | 33-2 | 52.1 | 43-1 | 41.2 | 52-3 | 59 |
| | 33-3 | 54.3 | 43-2 | Vault | 53-1 | 52.0 |
| | 34-1 | 34.4 | 43-3 | 25.7 | 53-2 | 39.3 |
| P | 34-2 | 37.4 | 44-1 | 42.6 | 53-3 | 27.8 |
| | 34-3 | 45.2 | 44-2 | Vault | 54-1 | 61.1 |
| | 35-1 | 43.3 | 44-3 | 31.1 | 54-2 | 60.2 |
| P | 35-2 | 43.5 | 45-1 | 39.6 | 54-3 | 43.5 |
| | 35-3 | 53.6 | 45-2 | Vault | 55-1 | 53.1 |
| | 36-1 | 37.7 | 45-3 | 45.2 | 55-2 | 54.6 |
| P | 36-2 | 50.8 | 46-1 | 42.6 | 55-3 | 35.6 |
| | 36-3 | 52.9 | 46-2 | Vault | 56-1 | 56.4 |
| | 37-1 | 53.8 | 46-3 | 57.8 | 56-2 | 32.8 |
| P | 37-2 | 32.3 | 47-1 | 56.0 | 56-3 | 56.7 |
| | 37-3 | 57.2 | 47-2 | Vault | 57-1 | 35.3 |
| | 38-1 | 34.4 | 47-3 | 52.4 | 57-2 | 34.2 |
| P | 38-2 | 52.4 | 48-1 | 31.1 | 57-3 | 43.8 |
| | 38-3 | 46.6 | 48-2 | Vault | 58-1 | 40.7 |
| | 39-1 | 55.3 | 48-3 | 27.1 | 58-2 | 54.3 |
| P | 39-2 | 39.1 | 49-1 | 52.2 | 58-3 | 30.4 |

Comments: P = PLANTINGS

VAULTS SKIPPED

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center | Date: 10/3/2011
Location: East Ohio Street
Project Number: 17.28570.0007 (2) | Instrument: Ludium 2241 With 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 59-1 | 46.3 | 68-3 | 40.3 | P 78-2 | 33.5 |
| 59-2 | 21.7 | 69-1 | 43.8 | 78-3 | 53.6 |
| 59-3 | 38.4 | 69-2 | 37.7 | 79-1 | 51.3 |
| 60-1 | 36.3 | 69-3 | 42.8 | P 79-2 | 51.2 |
| 60-2 | 50.6 | 70-1 | 26.9 | 79-3 | 66.3 |
| 60-3 | 41.1 | 70-2 | 23.9 | 80-1 | 58.6 |
| 61-1 | 38.1 | 70-3 | 38.6 | P 80-2 | 44.9 |
| 61-2 | 28.5 | 71-1 | 38.9 | 80-3 | 58.8 |
| 61-3 | 35.8 | 71-2 | 35.8 | 81-1 | 47.8 |
| 62-1 | 39.3 | 71-3 | 42.4 | P 81-2 | 46.3 |
| 62-2 | 42.6 | 72-1 | 30.2 | 81-3 | 25.3 |
| 62-3 | 47.8 | 72-2 | 33.7 | P 82-1 | 53.6 |
| 63-1 | 33.5 | 72-3 | 42.4 | 82-2 | 34.2 |
| 63-2 | 41.7 | 73-1 | 22.1 | 82-3 | 50.3 |
| 63-3 | 47.5 | 73-2 | 43.1 | 83-1 | 50.6 |
| 64-1 | 39.3 | 73-3 | 32.5 | 83-2 | 52.2 |
| 64-2 | 41.2 | 74-1 | 33.0 | 83-3 | 30.6 |
| 64-3 | 23.6 | 74-2 | 41.4 | 84-1 | 44.2 |
| 65-1 | 40.3 | 74-3 | 33.2 | 84-2 | 47.8 |
| 65-2 | 32.5 | 75-1 | 28.3 | 84-3 | 37.9 |
| 65-3 | 37.0 | 75-2 | 26.0 | 85-1 | 43.1 |
| 66-1 | 52.2 | 75-3 | 36.5 | 85-2 | 49.1 |
| 66-2 | 46.8 | 76-1 | 39.8 | 85-3 | 48.9 |
| 66-3 | 57.4 | P 76-2 | 52.4 | 86-1 | 22.1 |
| 67-1 | 53.4 | 76-3 | 59.1 | 86-2 | 35.8 |
| 67-2 | 31.4 | 77-1 | 44.5 | 86-3 | 59.5 |
| 67-3 | 30.2 | P 77-2 | 33.1 | 87-1 | 50.1 |
| 68-1 | 37.4 | 77-3 | 31.6 | 87-2 | 45.4 |
| 68-2 | 48.2 | 78-1 | 50.8 | 87-3 | 44.4 |

Comments: P = PLANTERS

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center — Date: 10/3/2011

Location: East Ohio Street

Project Number: 11.28570.0007.(2) — Instrument: Ludium 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 88-1 | 34.6 | 97-3 | 57.6 | 107-2 | 52.7 |
| 88-2 | 45.6 | 98-1 | 36.3 | 107-3 | 37.7 |
| 88-3 | 33 | 98-2 | 32.1 | 108-1 | 42.6 |
| 89-1 | 41.2 | 98-3 | 31.8 | 108-2 | 40.6 |
| 89-2 | 38.7 | 99-1 | 47.8 | 108-3 | 36.0 |
| 89-3 | 34.9 | 99-2 | 45.6 | 109-1 | 59 |
| 90-1 | 53.8 | 99-3 | 24.1 | 109-2 | 45.2 |
| 90-2 | MH | 100-1 | 43.5 | 109-3 | 41.9 |
| 90-3 | 48.2 | 100-2 | 50.6 | 110-1 | 40.7 |
| 91-1 | 54.3 | 100-3 | 42.4 | P 110-2 | 41.2 |
| 91-2 | 42.7 | 101-1 | 44.2 | 110-3 | 44.7 |
| 91-3 | 35.4 | 101-2 | 58.5 | 111-1 | 38.1 |
| 92-1 | 41.1 | 101-3 | 40.1 | P 111-2 | 48.9 |
| 92-2 | 41.7 | 102-1 | 39.6 | 111-3 | 38.6 |
| 92-3 | 44.7 | 102-2 | 23.1 | 112-1 | 37.0 |
| 93-1 | 34.6 | 102-3 | 58.2 | 112-2 | 36.0 |
| 93-2 | 26.0 | 103-1 | 23.4 | 112-3 | 56.9 |
| 93-3 | Vault | 103-2 | 45.6 | 113-1 | 39.6 |
| 94-1 | 46.3 | 103-3 | Vault | 113-2 | 37.2 |
| 94-2 | 47.3 | 104-1 | 43.8 | 113-3 | 38.6 |
| 94-3 | 39.9 | 104-2 | 49.6 | 114-1 | 32.8 |
| 95-1 | 56.9 | 104-3 | 49.9 | 114-2 | 45.6 |
| 95-2 | 36.3 | 105-1 | 32.3 | 114-3 | 39.8 |
| 95-3 | 32.3 | P 105-2 | 37.0 | 115-1 | 32.8 |
| 96-1 | 54.6 | 105-3 | 60.2 | 115-2 | 52.7 |
| 96-2 | 42.4 | 106-1 | 45.9 | 115-3 | 46.3 |
| 96-3 | 36.7 | 106-2 | 48.9 | 116-1 | 39.3 |
| 97-1 | 45.2 | 106-3 | 39.8 | P 116-2 | 53.4 |
| 97-2 | 64.4 | 107-1 | 51.3 | 116-3 | 45.9 |

Comments:
MH = MANHOLE COVER (POINT SKIPPED)
VAULTS SKIPPED
P = PLANTER

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: M^c Clurg Court Center | Date: 10/3/2011
Location: East Ohio Street
Project Number: 17.28570.0007 (2) | Instrument: Ludium 2241 With 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 117-1 | 31.1 | | | | |
| P 117-2 | 45.2 | | | | |
| 117-3 | 53.1 | | | | |
| 118-1 | 51.7 | | | | |
| 118-2 | 24.3 | | | | |
| 118-3 | 44.0 | | | | |
| 119-1 | 37.7 | | | | |
| 119-2 | MH | | | | |
| 119-3 | 30.4 | | | | |
| 120-1 | 31.4 | | | | |
| 120-2 | 50.1 | | | | |
| 120-3 | 43.3 | | | | |
| 120-4 | 39.1 | | | | |

Comments:
P = PLANTERS
M = MANHOLE COVERS SKIPPED

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

| | | | |
|---|---|---|---|
| Project: Mc Clurg Court Center | | Date: 10/3/2011 | |
| Location: North McClurg Street | | Instrument: | Ludium 2241 with 44-9 Probe |
| Project Number: 17.28570.0007 (2) | | | |

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 1-1 | MAT | P15-2 | 59.2 | 30-1 | 35.3 |
| 1-2 | MAT | 16-1 | 38.6 | 30-2 | 50.3 |
| 2-1 | 18.5 | 16-2 | 66.5 | 31-1 | 45.4 |
| 2-2 | 22.0 | 17-1 | 43.3 | 31-2 | 43.8 |
| 3-1 | 37.7 | 17-2 | 46.3 | 32-1 | 25.3 |
| 3-2 | 29.9 | 18-1 | 41.0 | 32-2 | 33.2 |
| 4-1 | 36.5 | 18-2 | 39.8 | 33-1 | 56.2 |
| 4-2 | 46.8 | 19-1 | 37.2 | 33-2 | 45.2 |
| 5-1 | 34.4 | 19-2 | 38.4 | 34-1 | 38.6 |
| 5-2 | 31.6 | 20-1 | 27.4 | 34-2 | 31.4 |
| 6-1 | 37.7 | 20-2 | 53.1 | 35-1 | 23.1 |
| 6-2 | 24.1 | 21-1 | 71.4 | 35-2 | 37.4 |
| 7-1 | 54.3 | P 21-2 | 43.3 | 36-1 | 41.0 |
| 7-2 | 42.6 | 22-1 | 27.8 | 36-2 | 31.4 |
| 8-1 | 40.0 | 22-2 | 37.9 | 37-1 | 38.9 |
| 8-2 | 36.7 | 23-1 | 55.5 | 37-2 | 25.5 |
| 9-1 | 49.4 | 23-2 | 42.1 | 38-1 | 51.3 |
| 9-2 | 43.8 | 24-1 | 41.2 | 38-2 | 56 |
| 10-1 | 51 | 24-2 | 50.3 | 39-1 | 49.2 |
| 10-2 | 48.2 | 25-1 | 34.9 | 39-2 | 51.3 |
| 11-1 | 44.2 | 25-2 | 38.6 | 40-1 | 38.6 |
| 11-2 | 43.3 | 26-1 | 43.3 | 40-2 | 53.8 |
| 12-1 | 39.6 | 26-2 | 58.8 | 41-1 | 44 |
| 12-2 | 62.5 | 27-1 | 56.7 | 41-2 | Manhole |
| 13-1 | 42.1 | P 27-2 | 60.9 | 42-1 | 44.7 |
| 13-2 | 29.5 | 28-1 | 41.2 | 42-2 | 42.6 |
| 14-1 | 42.1 | 28-2 | 33 | 43-1 | 31.1 |
| 14-2 | 29.0 | 29-1 | 53.6 | 43-2 | 41.1 |
| 15-1 | 35.8 | 29-2 | 54.8 | 44-1 | 52.2 |

Comments: MAT = CORNER HANDICAP MATS SKIPPED
P = PLANTERS
MANHOLES SKIPPED

ATC ASSOCIATES INC. Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center | Date: 10/3/2011

Location: North McClurg Street | Instrument: Ludium 2241 with 44-9 Probe

Project Number: 17.28570.0007 (2)

| | Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|---|
| P | 44-2 | 53.4 | 59-1 | 44.9 | | |
| | 45-1 | 34.9 | 59-2 | 44.2 | | |
| | 45-2 | 50.3 | 60-1 | NOT ACCESSIBLE | | |
| | 46-1 | 51.7 | 60-2 | 35.6 | | |
| | 46-2 | 40.0 | 61-1 | 22.2 | | |
| | 47-1 | 47.1 | 61-2 | 13.5 | | |
| | 47-2 | 49.4 | 62-1 | 49.3 | | |
| | 48-1 | 53.4 | 62-2 | off Curb | | |
| | 48-2 | 50.1 | 63-1 | 46.6 | | |
| | 49-1 | 48.5 | | | | |
| | 49-2 | 42.8 | | | | |
| | 50-1 | 43.1 | | | | |
| P | 50-2 | 46.8 | | | | |
| | 51-1 | 40.3 | | | | |
| | 51-2 | 55.3 | | | | |
| | 52-1 | 43.3 | | | | |
| | 52-2 | 57.8 | | | | |
| | 53-1 | 27.8 | | | | |
| | 53-2 | 46.6 | | | | |
| | 54-1 | 44.7 | | | | |
| | 54-2 | 44.2 | | | | |
| | 55-1 | 54.1 | | | | |
| | 55-2 | 46.6 | | | | |
| | 56-1 | 48.5 | | | | |
| | P 56-2 | 44.2 | | | | |
| | 57-1 | 42.4 | | | | |
| | P 57-2 | 44.5 | | | | |
| | 58-1 | 27.4 | | | | |
| | 58-2 | 29.2 | | | | |

Comments: P = PLANTER

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: Mc Clurg Court Center | Date: 10/3/2011

Location: East Ontario Street

Project Number: 17.28570.0007 (2) | Instrument: Ludium 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 1-1 | 32.5 | 10-3 P | 29.0 | 19-1 | 46.6 |
| 1-2 | 45.6 | 11-1 | 25.3 | 19-2 | 39.6 |
| 1-3 | 51.0 | 11-2 P | 41.2 | 19-3 | 22.0 |
| 2-1 | 45.6 | 11-3 P | 38.6 | 19-4 | 39.1 |
| 2-2 | 53.8 | 12-1 | 47.5 | 20-1 | 51.5 |
| 2-3 | 36.5 | 12-2 P | 50.1 | 20-2 | 43.5 |
| 3-1 | 55.3 | 12-3 P | 30.2 | 20-3 | 53.4 |
| 3-2 | 48.5 | 13-1 | 38.6 | 20-4 | 54.8 |
| 3-3 | 52.7 | 13-2 P | 37.2 | 21-1 | 46.8 |
| 4-1 | 66.3 | 13-3 P | 33.2 | 21-2 | 40.7 |
| 4-2 P | 43.5 | 14-1 | 26.2 | 21-3 | 27.6 |
| 4-3 P | 78.1 | 14-2 P | 53.6 | 21-4 | 37.1 |
| 5-1 | 52.1 | 14-3 P | 42.6 | 22-1 | 52.9 |
| 5-2 P | 23.4 | 15-1 | 39.1 | 22-2 | 39.1 |
| 5-3 P | 25.0 | 15-2 P | 40.5 | 22-3 | 38.1 |
| 6-1 | 39.3 | 15-3 P | 25.5 | 22-4 | 35.6 |
| 6-2 P | 23.9 | 15-4 P | 38.6 | 23-1 | 27.1 |
| 6-3 P | 49.6 | 16-1 | 42.6 | 23-2 | 27.8 |
| 7-1 | 37.0 | 16-2 P | 36.5 | 23-3 | 27.6 |
| 7-2 P | 41.4 | 16-3 P | 39.6 | 23-4 | 29.0 |
| 7-3 P | 30.9 | 16-3 P | 40.7 | 24-1 | 22.4 |
| 8-1 | 44.5 | 17-1 | 27.4 | 24-2 | 23.9 |
| 8-2 P | 41.9 | 17-2 P | 45.9 | 24-3 | 27.1 |
| 8-3 P | 24.8 | 17-3 P | 35.6 | 24-4 | 22.9 |
| 9-1 | 41.9 | 17-4 P | 51.5 | 25-1 | 29.2 |
| 9-2 P | 22.9 | 18-1 | 47.3 | 25-2 | 34.9 |
| 9-3 P | 34.2 | 18-2 | 32.3 | 25-3 | 19.9 |
| 10-1 | 44.2 | 18-3 | 31.1 | 25-4 | 32.3 |
| 10-2 P | 42.8 | 18-4 | 43.1 | 26-1 | 33.5 |

Comments:

P = PLANTER

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/3/2011
Location: East Ontario Street
Project Number: 17.28570.0007 (2)
Instrument: Ludrum 2241 with 44-9- Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 26-2 | 28.3 | 33.3 | 33.9 | 40-4 | 36.3 |
| 26-3 | 39.8 | 33.4 | 39.8 | 41-1 | V |
| 26-4 | 44.0 | 34-1 | V | 41-2 | 26.9 |
| 27-1 | Car | 34-2 | 24.1 | 41-3 P | 35.1 |
| 27-2 | 24.6 | 34-3 P | 52.0 | 41-4 | 54.6 |
| 27-3 | 31.1 | 34-4 | 45.9 | 42-1 | V |
| 27-4 | 37.7 | 35-1 | V | 42-2 | 29.9 |
| 28-1 | Car | 35-2 | 37.7 | 42-3 P | 30.6 |
| 28-2 | 29.2 | 35-3 P | 36.0 | 42-4 | 43.3 |
| 28-3 | 47.3 | 35-4 | 42.8 | 43-1 | V |
| 28-4 | 40.0 | 36-1 | V | 43-2 | 50.6 |
| 29-1 | 37.2 | 36-2 | 43.8 | 43-3 P | 51.3 |
| 29-2 | Manhole | 36-3 P | 39.6 | 43-4 | 39.1 |
| 29-3 | 22.9 | 36-4 | 44.9 | 44-1 | V |
| 29-4 | 34.2 | 37-1 | V | 44-2 | 36.3 |
| 30-1 | 33.7 | 37-2 | 49.4 | 44-3 P | 22.9 |
| 30-2 | 28.5 | 37-3 P | 37.9 | 44-4 | 46.8 |
| 30-3 | 44.2 | 37-4 | 65.1 | 45-1 | V |
| 30-4 | 37.2 | 38-1 | V | 45-2 | 35.6 |
| 31-1 | 39.1 | 38-2 | 50.8 | 45-3 P | 52.2 |
| 31-2 | 46.3 | 38-3 P | 38.4 | 45-4 | 36.5 |
| 31-3 | 40.0 | 38-4 | 22.2 | 46-1 | V |
| 31-4 | 37.4 | 39-1 | V | 46-2 | 40.5 |
| 32-1 | 26.9 | 39-2 | 35.1 | 46-3 P | 51.3 |
| 32-2 | 35.8 | 39-3 P | 27.1 | 46-4 | 34.4 |
| 32-3 | 26.7 | 39-4 | 56.2 | 47-1 | V |
| 32-4 | 28.8 | 40-1 | V | 47-2 | 38.9 |
| 33-1 | 45.4 | 40-2 | 38.6 | 47-3 P | 29.5 |
| 33-2 | 38.4 | 40-3 P | 37.2 | 47-4 | 54.8 |

Comments: 27-1 & 28-1 CAR (LOADING AREA) BLOCKING DATA AREA
P = PLANTERS
MAN HOLE SKIPPED
V = VAULTS (SKIPPED)

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/3/2011
Location: East Ontario Street
Project Number: 17.28570.0007 (2)
Instrument: Ludium 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 48-1 | V | 55-2 | 34.6 | | |
| 48-2 | 37.7 | 55-3 P | 28.8 | | |
| 48-3 P | 60.2 | 55-4 | 38.4 | | |
| 48-4 | 27.6 | 56-1 | V | | |
| 49-1 | V | 56-2 | 44.2 | | |
| 49-2 | 54.8 | 56-3 P | 47.3 | | |
| 49-3 P | 38.6 | 56-4 | 38.6 | | |
| 49-4 | 26.4 | 57-1 | 36.7 | | |
| 50-1 | V | 57-2 | 42.8 | | |
| 50-2 | 22.0 | 57-3 P | 30.2 | | |
| 50-3 P | 50.6 | 57-4 | 37.9 | | |
| 50-4 | 44.7 | | | | |
| 51-1 | V | | | | |
| 51-2 | 41.4 | | | | |
| 51-3 P | 36.5 | | | | |
| 51-4 | 52.9 | | | | |
| 52-1 | V | | | | |
| 52-2 | 23.6 | | | | |
| 52-3 P | 29.2 | | | | |
| 52-4 | 33.0 | | | | |
| 53-1 | V | | | | |
| 53-2 | 16.4 | | | | |
| 53-3 P | 28.1 | | | | |
| 53-4 | 31.4 | | | | |
| 54-1 | V | | | | |
| 54-2 | 48.9 | | | | |
| 54-3 P | 37.0 | | | | |
| 54-4 | 30.4 | | | | |
| 55-1 | V | | | | |

Comments:
V = VAULTS (SKIPPED)
P = PLANTERS

ATC Associates Inc.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/4/2011
Location: East Ontario Street
Project Number: 17.28570.0007 (2)
Instrument: Ludlum 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 58-1 | 43.8 | 65-2 | 47.8 | 72-3 P | 39.6 |
| 58-2 | 42.6 | 65-3 | 45.9 | 72-4 | 24.8 |
| 58-3 | 37.4 | 65-4 | 43.8 | 73-1 | 31.6 |
| 58-4 | 38.9 | 66-1 | 40.0 | 73-2 P | 42.1 |
| 59-1 | 36.3 | 66-2 | 35.3 | 73-3 P | 35.1 |
| 59-2 | 32.1 | 66-3 | 33.5 | 73-4 | 41.4 |
| 59-3 | 33.0 | 66-4 | 30.2 | 74-1 | 46.3 |
| 59-4 | 43.3 | 67-1 | 52.2 | 74-2 P | 36.0 |
| 60-1 | 35.1 | 67-2 | 55.4 | 74-3 P | 35.1 |
| 60-2 | 36.0 | 67-3 | 51.3 | 74-4 | 46.6 |
| 60-3 | 37.7 | 67-4 | 48.2 | 75-1 | 35.8 |
| 60-4 | 38.4 | 68-1 | 63.0 | 75-2 P | 43.3 |
| 61-1 | 41.4 | 68-2 | 29.4 | 75-3 P | 43.5 |
| 61-2 | 35.8 | 68-3 | 25.3 | 75-4 | 37.2 |
| 61-3 | 33.4 | 68-4 | 58.8 | 76-1 | 51.0 |
| 61-4 | 27.6 | 69-1 | 38.4 | 76-2 P | 38.9 |
| 62-1 | 35.1 | 69-2 P | 39.8 | 76-3 P | 39.1 |
| 62-2 | 37.2 | 69-3 P | 43.8 | 76-4 | 47.5 |
| 62-3 | 34.6 | 69-4 | 40.3 | 77-1 | 53.1 |
| 62-4 | 25.0 | 70-1 | 55.3 | 77-2 P | 41.4 |
| 63-1 | 35.3 | 70-2 P | 37.0 | 77-3 P | 36.3 |
| 63-2 | 34.6 | 70-3 P | 38.4 | 77-4 | 43.1 |
| 63-3 | 46.6 | 70-4 | 26.7 | 78-1 | 48.0 |
| 63-4 | 41.1 | 71-1 | 35.8 | 78-2 P | 40.3 |
| 64-1 | 46.8 | 71-2 P | 43.5 | 78-3 P | 35.5 |
| 64-2 | 38.4 | 71-3 P | 40.5 | 78-4 | 29.5 |
| 64-3 | 30.2 | 71-4 | 34.4 | 79-1 | 45.6 |
| 64-4 | 44.2 | 72-1 | 40.3 | 79-2 P | 36.5 |
| 65-1 | 35.1 | 72-2 P | 42.1 | 79-3 P | 39.8 |

Comments: P = PLANTERS

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: McClurg Court Center
Date: 10/4/2011
Location: East Ontario Street
Project Number: 17.28570.0007 (2)
Instrument: Ludium 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 79-4 | 33.9 | 87-1 | 38.4 | 94-2 P | 47.5 |
| 80-1 | 39.8 | 87-2 P | 44.5 | 94-3 P | 26.9 |
| 80-2 | 36.7 | 87-3 P | 42.4 | 94-4 | 26.4 |
| 80-3 | 41.2 | 87-4 | 24.1 | 95-1 | 42.8 |
| 80-4 | 44.9 | 88-1 | 39.1 | 95-2 P | 41.2 |
| 81-1 | 59.2 | 88-2 P | 38.4 | 95-3 P | 48.5 |
| 81-2 | 43.8 | 88-3 P | 41.9 | 95-4 | 38.9 |
| 81-3 | 34.4 | 88-4 | 36.7 | 96-1 | 22.2 |
| 81-4 | 39.6 | 89-1 | 41.0 | 96-2 P | 37.9 |
| 82-1 | 32.8 | 89-2 P | 46.1 | 96-3 P | 38.1 |
| 82-2 | 22.0 | 89-3 P | 26.2 | 96-4 | 39.1 |
| 82-3 | 26.0 | 89-4 | 27.6 | 97-1 | 44.7 |
| 82-4 | 30.9 | 90-1 | 40.3 | 97-2 P | 27.4 |
| 83-1 | 51.5 | 90-2 P | 38.9 | 97-3 P | 35.1 |
| 83-2 | 56.9 | 90-3 P | 31.8 | 97-4 | 44.2 |
| 83-3 | 57.8 | 90-4 | 31.4 | 98-1 | 28.3 |
| 83-4 | 52.1 | 91-1 | 26.7 | 98-2 P | 57.0 |
| 84-1 | 33.9 | 91-2 P | 44.0 | 98-3 P | 41.7 |
| 84-2 | 43.8 | 91-3 P | 40.3 | 98-4 | 31.6 |
| 84-3 | 27.4 | 91-4 | 29.5 | 99-1 | 40.5 |
| 84-4 | 36.7 | 92-1 | 41.2 | 99-2 P | 42.6 |
| 85-1 | 43.3 | 92-2 P | 32.5 | 99-3 P | 42.1 |
| 85-2 P | 46.6 | 92-3 P | 37.2 | 99-4 | 37.7 |
| 85-3 P | 44.5 | 92-4 | 26.4 | 100-1 | 45.9 |
| 85-4 | 40.5 | 93-1 | 39.2 | 100-2 P | 40.0 |
| 86-1 | 36.5 | 93-2 P | 22.7 | 100-3 P | 33.7 |
| 86-2 P | 41.2 | 93-3 P | 38.1 | 100-4 | 40.7 |
| 86-3 P | 34.6 | 93-4 | 41.4 | 101-1 | 55.3 |
| 86-4 | 43.3 | 94-1 | 33.7 | 101-2 P | 41.4 |

Comments:
P: PLANTERS

ATC ASSOCIATES INC.
Engineering Individual Solutions

# WALKOVER SURVEY

Project: Mc Clurg Court Center
Date: 10/4/2011
Location: East Ontario Street
Project Number: 17.28570.0007 (2)
Instrument: Ludium 2241 with 44-9 Probe

| Location | Reading | Location | Reading | Location | Reading |
|---|---|---|---|---|---|
| 101-3 P | 44.5 | 108-4 | 38.1 | 116-1 | 42.1 |
| 101-4 | 44.2 | 109-1 | 52.9 | 116-2 P | 35.1 |
| 102-1 | 54.3 | 109-2 P | 35.8 | 116-3 P | 40.5 |
| 102-2 P | 44.9 | 109-3 P | 28.8 | 116-4 | 38.4 |
| 102-3 P | 41.4 | 109-4 | 29.6 | 117-1 | 34.4 |
| 102-4 | 44.5 | 110-1 | 39.8 | 117-2 P | 46.6 |
| 103-1 | 43.3 | 110-2 P | 45.2 | 117-3 P | 34.4 |
| 103-2 | 55.5 | 110-3 P | 41.0 | 117-4 | 45.9 |
| 103-3 | 52.7 | 110-4 | 32.1 | 118-1 | 34.2 |
| 103-4 | 44.9 | 111-1 | 58.3 | 118-2 | 35.8 |
| 104-1 | 42.1 | 111-2 P | 44.7 | 118-3 | 60.6 |
| 104-2 | 55.0 | 111-3 P | 42.6 | 118-4 | 56.9 |
| 104-3 | 61.1 | 111-4 | 43.3 | 119-1 | 34.9 |
| 104-4 | 42.6 | 112-1 | 21.7 | 119-2 | 42.8 |
| 105-1 | 28.1 | 112-2 P | 40.0 | 119-3 | 33.8 |
| 105-2 | 39.3 | 112-3 P | 31.6 | 119-4 | 42.2 |
| 105-3 | 45.6 | 112-4 | 34.0 | 120-1 | 52.7 |
| 105-4 | 50.8 | 113-1 | 52.4 | 120-2 | MH |
| 106-1 | 34.9 | 113-2 P | 50.6 | 120-3 | 35.1 |
| 106-2 | 34.4 | 113-3 P | 43.1 | 120-4 | 52.7 |
| 106-3 | 51.5 | 113-4 | 37.2 | | |
| 106-4 | 36.5 | 114-1 | 37.0 | | |
| 107-1 | 29.5 | 114-2 P | 43.5 | | |
| 107-2 | 31.8 | 114-3 P | 49.4 | | |
| 107-3 | 38.4 | 114-4 | 33.0 | | |
| 107-4 | 38.9 | 115-1 | 35.8 | | |
| 108-1 | 39.8 | 115-2 P | 41.4 | | |
| 108-2 P | 35.1 | 115-3 P | 34.8 | | |
| 108-3 P | 26.4 | 115-4 | 39.3 | | |

Comments:

P = PLANTER

MH = MANHOLE (SKIPPED)

**APPENDIX D**

Instrument Specification Manuals and Certificates of Calibration

ERG

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
(505) 298-4224
www.ERGoffice.com

# Certificate of Calibration

## Calibration and Voltage Plateau

| | | | | | | |
|---|---|---|---|---|---|---|
| Meter: | Manufacturer: Ludlum | Model Number: 2221r | Serial Number: 108853 |
| Detector: | Manufacturer: Ludlum | Model Number: 44-10 | Serial Number: PR119805 |

☑ Mechanical Check ☑ Geotropism ☑ THR/WIN Operation ☑ Audio Check ☑ Battery Check (Min 4.4 VDC)

☑ F/S Response Check ☑ Meter Zeroed ☑ Reset Check HV Check (+/- 2.5%): ☑ 500 V ☑ 1000 V ☑ 1500 V

Source Distance: ☐ Contact ☑ 6 inches ☐ Other: ____ Cable Length: ☐ 39-inch ☐ 72-inch ☑ Other: 60"

Source Geometry: ☑ Side ☐ Below ☐ Other: ____ Temperature: 72 °F Relative Humidity 20 %

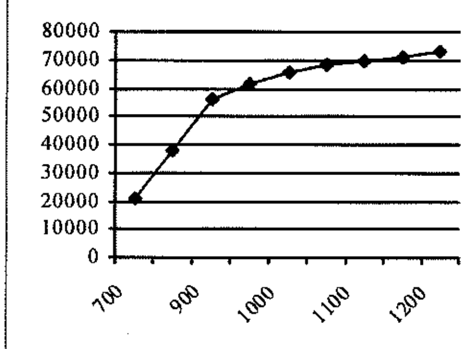
Threshold: 10 mV Window: ____ Barometric Pressure: 24.54 inches Hg

Instrument found within tolerance: ☑ Yes ☐ No

| Range/Multiplier | Reference Setting | "As Found Reading" | Meter Reading | Integrated 1-Min. Count | Log Scale Count |
|---|---|---|---|---|---|
| x 1000 | 400 | 400 | 400 | 399939 | 400 |
| x 1000 | 100 | 100 | 100 | | 100 |
| x 100 | 40 | 400 | 400 | 39996 | 400 |
| x 100 | 10 | 100 | 100 | | 100 |
| x 10 | 4 | 400 | 400 | 4000 | 400 |
| x 10 | 1 | 100 | 100 | | 100 |
| x 1 | 400 | 400 | 400 | 400 | 400 |
| x 1 | 100 | 100 | 100 | | 100 |

| High Voltage | Source Counts | Background |
|---|---|---|
| 700 | 21185 | |
| 800 | 37933 | |
| 900 | 55969 | |
| 950 | 61545 | |
| 1000 | 65676 | |
| 1050 | 68191 | |
| 1100 | 69936 | |
| 1150 | 71132 | 10868 |
| 1200 | 73258 | |

Voltage Plateau




Comments: HV Plateau Scaler Count Time = 1-min. Recommended HV =1150

**Reference Instruments and/or Sources:**

Ludlum pulser serial number: ☐ 97743 ☑ 201932 Fluke multimeter serial number: ☐ 8749012

☐ Alpha Source: Th-230 @ 13,000 dpm (1/13/10) sn: 4098-03 ☑ Gamma Source Cs-137 @ 5.37 uCi (1/13/10) sn: 4097-03

☐ Beta Source: Tc-99 @ 17,700 dpm (1/13/10) sn: 4099-03 ☐ Other Source: ____

Calibrated By: [signature] Calibration Date: 10-11-11 Calibration Due: 10-11-12

Reviewed By: [signature] Review Date: 10/11/11

This calibration conforms to the requirements and acceptable calibration conditions of ANSI N323A - 1997.
NMRCB Registration No. 921-3 * Calibration of Radiation Detection Instrument Devices

# LUDLUM MODEL 44-10
# GAMMA SCINTILLATOR

**July 2009**
**Serial Number PR107232 and Succeeding Serial Numbers**

# LUDLUM MODEL 44-10
# GAMMA SCINTILLATOR

**July 2009**
**Serial Number PR107232 and Succeeding Serial Numbers**

**LUDLUM MEASUREMENTS, INC.**
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

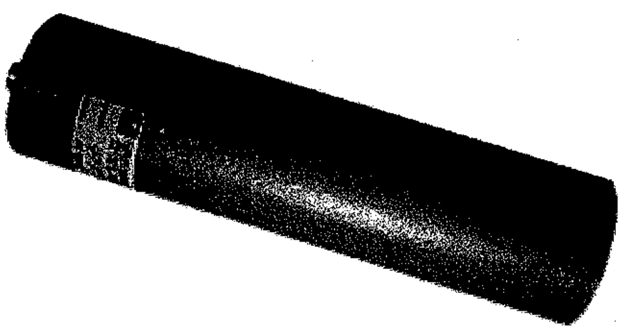
# Table of Contents

# Introduction

The Model 44-10 sodium iodide (NaI) gamma scintillator is primarily used for detecting high energy gamma radiation in the range of 60 keV - 2 MeV. It consists of a 2"(5.1cm) diameter X 2"(5.1cm) thick NaI crystal coupled to a photomultiplier tube and is housed in a 0.062" thick aluminum housing. The detector is energy dependent, over responding by a factor of five in the 100 keV range and underresponding by a factor of 0.5 above 1 MeV when normalized to $^{137}Cs$.

The Model 44-10 will operate with any Ludlum instrument or equivalent instrument that provides 500 - 1200 volts. The recommended instrument input sensitivity is approximately 10 mV or higher.

Some common applications for this detector include background radiation monitoring, high-sensitivity surveying, and spectrum analysis when used in conjunction with a single or multi channel analyzer.



*Model 44-10*

**Note:**

The detector does not contain any consumable materials.

**Note:**

If the detector is used in a manner not intended by the manufacturer, the detector may not function properly.

# Unpacking and Repacking

Remove the calibration certificate or detector functional check certificate and place it in a secure location. Remove the detector and accessories (cable, etc.) and ensure that all of the items listed on the packing list are in the carton. If more than one detector is in the carton, refer to the calibration certificate(s) for serial number(S/N) match. The Model 44-10 S/N is located on the side of the detector near the connector.

To return the instrument or detector for repair or calibration, provide sufficient packing material to prevent damage during shipment and appropriate warning labels to ensure careful handling. The following items and information should also be included to insure a quick turnaround time on your repair/calibration:

- instrument(s) and related cable(s)
- brief description as to the reason for return
- description of service requested
- return shipping address
- customer name and telephone number

# Specifications

**SCINTILLATOR:** 2" (5.1 cm) diameter X 2" (5.1 cm) thick NaI (Tl) crystal

**SENSITIVITY:** Typically 900 cpm/μR/hr (*$^{137}$Cs gamma*)

**ENERGY RESPONSE:** Energy dependent

**COMPATIBLE INSTRUMENTS:** General purpose survey meters, ratemeters, and scalers

**TUBE:** 2" (5.1 cm) diameter magnetically shielded photomultiplier

**OPERATING VOLTAGE:** 500 - 1200 volts

**DYNODE STRING RESISTANCE:** 60 megohm

**CONNECTOR:** Series "C" (*others available*)

**CONSTRUCTION:** Aluminum housing with beige polyurethane enamel paint

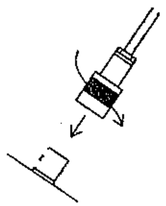
**TEMPERATURE RANGE:** -4°F(-20°C) to 122°F(50°C) May be certified to operate from -40°F(-40°C) to 150°F(65°C)

**SIZE:** 2.6" (6.6 cm) diameter X 11" (27.94 cm) L

**WEIGHT:** 2.3 lb (1.04kg)

# Operating Procedures

## CONNECTING TO AN INSTRUMENT



Connect one end of the cable provided to the detector by firmly pushing the connector together while twisting clockwise ¼ turn until latched. Repeat the process in the same manner with the other end of the cable and the instrument.

## TESTING THE DETECTOR

1. Insure that the instrument high voltage (HV) is at the proper setting for the detector (900 volts).
2. Connect the detector to the instrument and check for a proper background reading (typically 4,000- 10,000 cpm at 8-15 μR/hr).
3. Expose the detector to a check source and verify that the instrument indicates within 20% of the check source reading from the last calibration. Alternatively, expose the detector to a source of known value and verify that the detector detects greater than or equal to the efficiency listed in the specification section of this manual.
4. Instruments and detectors which meet these criteria are ready for use. Failure to meet these criteria may indicate a malfunction in the detector.

# Safety Considerations

## Environmental Conditions for Normal Use

1. Indoor or outdoor use (in a dry environment)
2. No maximum altitude
3. Temperature range of – 20°C to 50°C (5°F to 122°F); May be certified for operation from – 40°F to 150°F).
4. Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664)

## Cleaning Instructions and Precautions

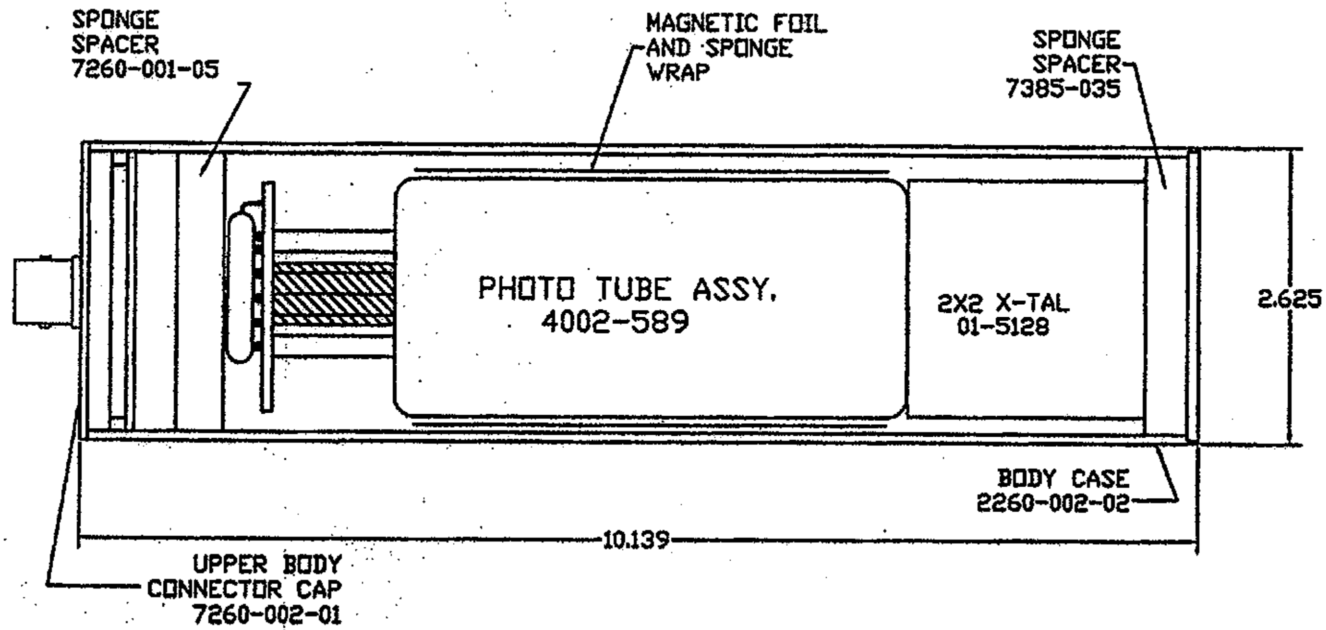
The detector may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument electronics OFF.
2. Allow the instrument to sit for 1 minute.
3. Disconnect the detector cable before cleaning the detector.

# Parts List, Drawings and Diagrams

**Model 44-10 Gamma Scintillator**

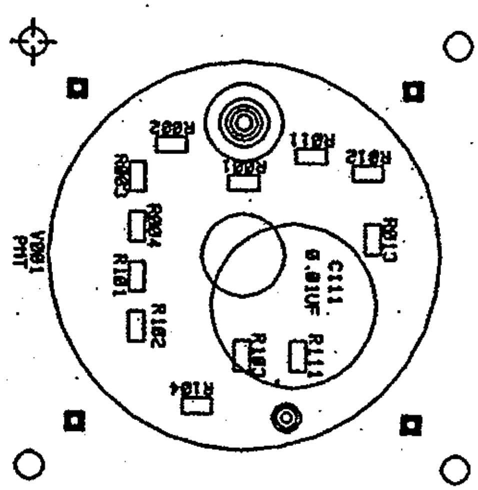
| Reference | Description | Part Number |
|---|---|---|
| UNIT | Completely Assembled Model 44-10 Gamma Scintillator | 47-1540 |
| 1 EA | BODY CASE W/ CAP | 2260-002-02 |
| 1 EA | CONNECTOR CAP | 7260-002-01 |
| 1 EA | 2" x 2" NaI CRYSTAL | 01-5128 |
| 1 EA | 2" PHOTO TUBE ASSY | 4002-589 |
| 1 EA | 2" PM TUBE | 01-5640 |
| 1 EA | CONNECTOR, UG706/U | 4478-011 |
| 1 EA | O-RING | 16-8289 |
| 8 EA | SPONGE SPACER | 7260-001-05 |
| 1 EA | END SPONGE SPACER | 7385-035 |
| * | MAGNETIC FOIL | 01-5019/5026 |
| 1 EA | SPONGE WRAP | 21-9267 |


SPONGE SPACER 7260-001-05
MAGNETIC FOIL AND SPONGE WRAP
SPONGE SPACER 7385-035
PHOTO TUBE ASSY. 4002-589
2X2 X-TAL 01-5128
2.625
BODY CASE 2260-002-02
10.139
UPPER BODY CONNECTOR CAP 7260-002-01

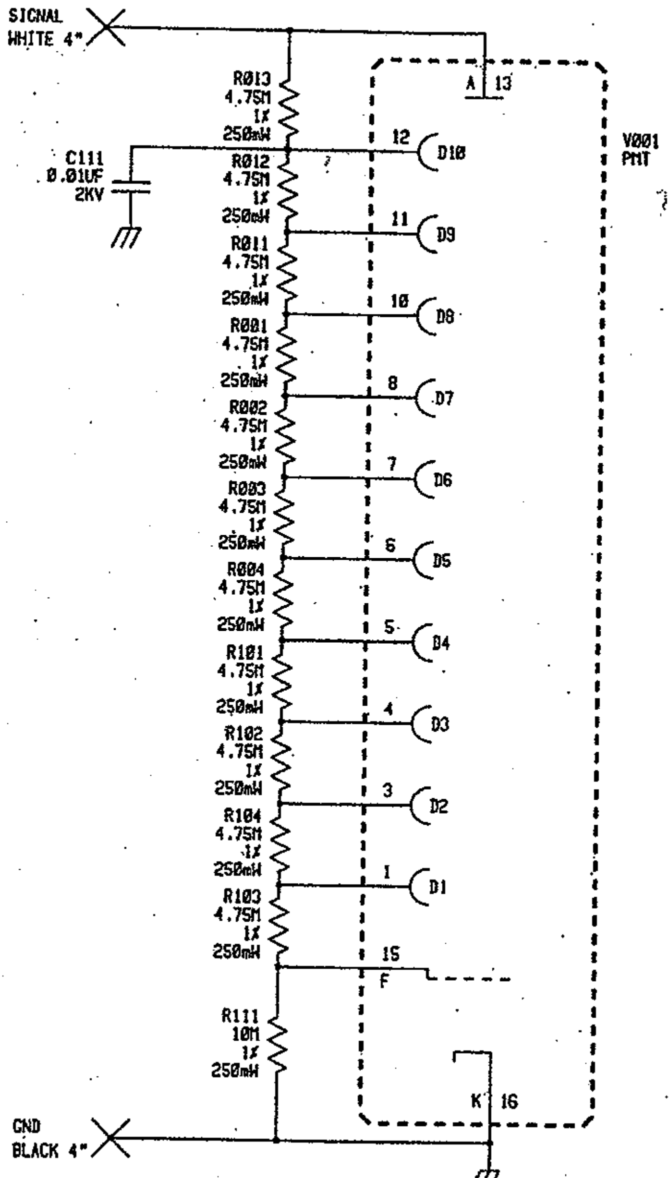
| Reference | Description | Part Number |
|---|---|---|

**2" Voltage Divider Board**

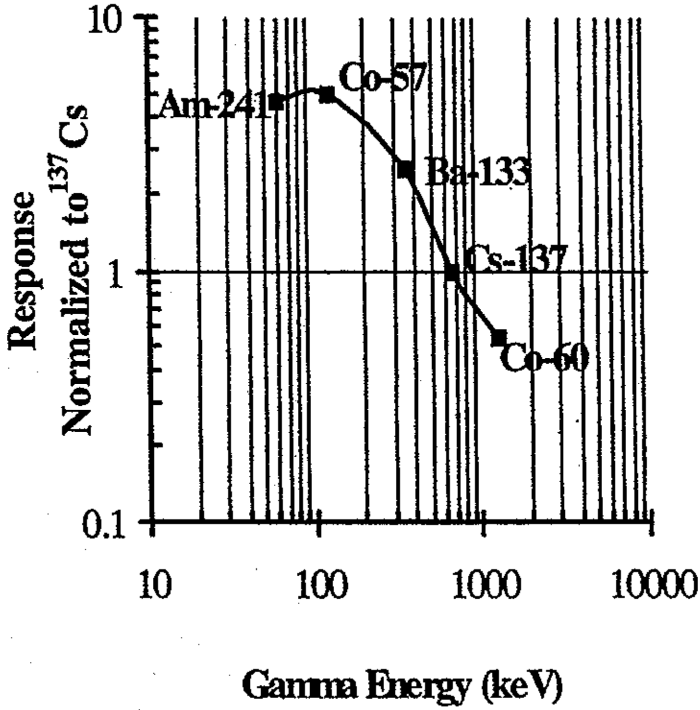
| | | |
|---|---|---|
| 1EA | VOLTAGE DIVIDER | 2002-357 |
| 1EA | CAP 0.01 μF 2kv | 04-5525 |
| 11 EA | RES 4.75 meg 1/8 W, 1% | 12-7995 |
| 1 EA | RES 10 meg 1/8 W, 1% | 12-7996 |



## 2" Voltage Divider Board - Schematic



# Energy Response for Ludlum Model 44-10



# LUDLUM MODEL 2221
# PORTABLE SCALER RATEMETER

**Revised November 2010**

**Serial Number 161568 and Succeeding Serial Numbers**

# LUDLUM MODEL 2221
# PORTABLE SCALER RATEMETER

**Revised November 2010**

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**LUDLUM MEASUREMENTS, INC.**
**501 OAK ST., P.O. BOX 810**
**SWEETWATER, TX 79556**
**325/235-5494 FAX: 325/235-4672**

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## 1. GENERAL

The Ludlum Model 2221 Portable Scaler Ratemeter is a self-contained counting instrument designed for operation with scintillation, proportional or GM detectors. Power is derived from four flashlight batteries.

The unit is complete with a voltage-sensitive preamplifier, linear amplifier, electronic timer, detector high-voltage power supply and detector overload detection circuitry. A single channel analyzer is also featured in this unit for use in gamma spectrum analysis. The analyzer may be switched on or off, allowing gross or window counting.

The unit has a combination four-decade linear and log ratemeter and a six-digit LCD readout for the scaler and digital ratemeter. Potentiometers are supplied for threshold, window and high-voltage controls.

## 2. SPECIFICATIONS

- **HIGH VOLTAGE**: 200 to 2400 volts with digital readout
- **BATTERY COMPLEMENT**: four each "D" cell batteries
- **BATTERY LIFE**: approximately 250 hours.
- **CALIBRATION STABILITY**: less than 3% variance to battery endpoint
- **SENSITIVITY**: voltage-sensitive and adjustable from 1.5 mV to 100 mV; typically factory-calibrated to 10 mV = 100 on the THR display
- **INPUT IMPEDANCE**: 22k ohm
- **READOUT**: 6 digit liquid crystal display, 1.3cm(0.5 inch) characters with backlight selection
- **METER**: 6.35 cm(2.5 inch) scale, 1 mA, pivot and jewel suspension
- **SCALES/RANGE**: four decade log ratemeter ranging from 50 to 500 kcpm; four decade linear ratemeter - 0-500 CPM meter dial with range multipliers of X1K, X100, X10, X1 producing an overall range of 0- 500k CPM
- **OPERATING TEMPERATURE**: -20° to 50°C (-4° to -122°F)
- **LINEARITY**: ±10% of the true value for the analog and digital ratemeter; ±2% of the true value for the digital Scaler, HV, THR, and WIN digital voltmeter readings; ±4% of the true value for the BAT voltmeter reading
- **RESPONSE**: 2 positions - **F**ast response = 4 ±1 second, **S**low response = 22 ± 2 second; all response times are measured from 10-90% of final reading
- **CALIBRATION CONTROLS**: recessed screwdriver adjustments with calibration cover
- **AUDIO**: built-in unimorph speaker with click-per-event and switch selectable divide by 1, 10, and 100.
- **CONNECTOR**: Series "C"

- **SIZE**: 10.8 x 25.4 x 22.9 cm( 4.25 x 10 x 9 inch) (W x L x H) including handle

- **WEIGHT**: 2.5kg(5.51 lbs) including 4 each "D" cell batteries

- **FINISH**: computer beige polyurethane enamel with silk-screened nomenclature

## 3. DESCRIPTION OF CONTROLS AND FUNCTIONS

- **POWER**: Two-position ON-OFF switch

- **DETECTOR**: series "C" connector for detector

  Input Impedance: 22kΩ

  Ballast Resistor: 1M

**RATEMETER**:

- **F-S RESP Switch**: Two-position switch for selecting ratemeter response: F position 4 ±1 second; S position 22 ±2 seconds.

- **ZERO**: when pressed, resets the ratemeter

- **RANGE SELECTOR**: Five-position switch labeled LOG, X1K, X100, X10, X1 used to select the analog ratemeter range. The LOG position selects the upper meter scale to provide a four decade logarithmic reading from 50-500k CPM. The X1, X10, X100, and X1K range multipliers used with the lower 0-500 CPM meter scale, providing an overall measuring range from 0-500k CPM. Multiply the meter reading by the respective range position.

**DIGITAL CONTROL**:

- **COUNT Pushbutton**: When pressed, resets and starts the counter. While the counter is counting, two sets of colons are displayed.

- **HOLD Pushbutton**: When pressed, stops the counter and leaves the count in the display.

- **SCALER/DIG RATE Toggle Switch**: Two-position toggle switch for selecting scaler or digital ratemeter

SCALER Position: The display shows the counter contents.

DIG. RATE Position: The display shows the ratemeter count rate.

√ Note: The scaler and digital ratemeter are active even when not selected. This allows the user to start a timed count, switch to the Digital Ratemeter and then switch back to Scaler without having to restart the counter.

**MINUTES Selector Switch**: Eight-position switch used for selecting the count times for the Scaler:

| POSITION | COUNT TIME IN MINUTES |
|---|---|
| 0.1 | 0.1 |
| 0.2 | 0.2 |
| 0.5 | 0.5 |
| 1 | 1 |
| 2 | 2 |
| 5 | 5 |
| 10 | 10 |
| CONT | |

COUNTER COUNTS UNTIL HOLD IS PRESSED

**CALIBRATION CONTROLS**:

- **WIN**: 20-turn potentiometer used to adjust window width when the window toggle switch, WIN, is in the "IN" position

- **THR**: 20-turn potentiometer used to adjust the threshold

- **HV**: 20-turn potentiometer used to adjust detector voltage

- **O.L.**: 20-turn potentiometer used to adjust detector overload current

**TEST**:

- **BAT Pushbutton Switch**: When pressed, displays the battery voltage in the digital display.

- **HV Pushbutton Switch**: When pressed, displays the detector high voltage in the digital display.

- **THR Pushbutton Switch**: When pressed, displays the threshold setting in the digital display.

- **WIN Pushbutton Switch**: When pressed, displays the window setting in the digital display.

- **LAMP Toggle Switch**: Two-position switch to turn on the display lights.

- **WIN Toggle Switch**: Two- position switch for switching the window IN or OUT

IN position: The SCA (Single Channel Analyzer) is set up as a window counter. Detector pulses to be counted, must be above the threshold but below the window.

OUT position: The SCA is set up as a gross counter: all detector pulses above the threshold are counted.

**AUDIO**:

- **VOL Control**: One-turn potentiometer used to adjust the volume of the speaker or headset.

- **AUDIO DIVIDE**:

“1” Position: provides 1 click per event
“10” Position: provides 1 click per 10 events
“100” Position: provides 1 click per 100 events

- **1/8 inch HEAD PHONE JACK**: Used for headset. When headset is plugged in, the unimorph speaker on the can is disabled.

- **LIQUID CRYSTAL DISPLAY**: 16.51 cm (6.5 inch) high digits, displaying counter contents or digital count rate

**STATUS INDICATORS:**

Counter Overflow: When in SCALER mode, the left digit alternates between the correct digit and an "H".

Detector Overload: The display flashes all dashes. (“------“).

Battery: When the battery voltage is 4.4 volts or less, all decimal points are turned on. This indicates that the batteries should be changed immediately.

Scaler Counting: The two colons are turned on when MINUTES selector switch is in CONT position.

# 4. OPERATING PROCEDURES

## 4.1 Initial Preparation

- Unscrew battery door latch.

- Install 4 "D" size batteries in the battery holder. The correct position of the batteries is indicated on the bottom of the battery door.

- Switch the POWER ON/OFF switch to the ON position. A random number will first be observed in the display, then 8.8:8.8:8.8. The third displayed number will be the program version. (At the time of this printing, program version is #261010.)

- Press COUNT pushbutton. The display should zero. Two sets colons should appear on the display.

- Press HOLD pushbutton. The colons should disappear.

- Switch LAMP toggle switch to the ON position. LCD display backlighting and two lamps at the bottom of the analog meter should be illuminated.

√ NOTE: If the Lamp switch is left in the ON position for extended periods of time, battery life will decrease rapidly.

- Check TEST pushbutton functions for proper operation.

## 4.2 Operating Point

Instrument and detector operating point is established by setting the probe voltage (HV) and instrument sensitivity (THR). For a given detector system, efficiency, background and noise are fixed by the physical makeup of the detector and rarely vary from unit to unit. However, the selection of the operating point makes a marked difference in the apparent contribution of these three sources of count.

In the singular case of the GM detector, a minimum operating voltage is required to establish the GM operating region. (At lower voltages, the detector operates as a very insensitive proportional counter.) This detector is not capable of energy discrimination (pulse-height discrimination). The threshold (THR) is typically adjusted to 550, with a THR reading of 100 = 10 mV input pulse, for GM detectors.

For gain sensitive detectors (proportional or scintillation), the most straightforward method of selecting the operating point is to develop a graph, relating count rate to system gain. This relationship is commonly referred to as a plateau or instrument plateau curve. System gain may be changed by adjusting detector high voltage or THR control. The threshold is typically adjusted for 100 = 10 mV for scintillation detectors and 50 (5mV equivalent) on the THR readout for proportional detectors.

## 4.3 Limitation of Controls

HV Control provides a linear adjustment of the detector voltage supply. The range is approximately 200 to 2400 volts. Changing the detector voltage will cause the detector gain to change. It should be remembered that a linear change in voltage will cause an exponential change in detector gain. THR Control sets the basic pulse discrimination point of the scaler.

WIN Control is calibrated with the THR control so that the reading of the WIN control is equivalent to the reading of the THR control. As an example, 100 on the THR is equal to 100 on the WIN.

## 5. DETERMINING INSTRUMENT PLATEAU AND SELECTING OPERATING POINT

- Set WIN ON/OFF to OFF.
- Set MINUTES switch to 0.1 minutes.
- Set THR control at 100.
- With detector shielded from source, turn up high voltage control and take a plot of HV versus background count rate until the detector maximum voltage rating is reached. (Maximum voltage on most scintillation detectors is 1500-1600 Vdc; maximum voltage on proportional detectors is reached at the continuous discharge point. Return HV control to minimum.
- Expose the detector to a source and again make a plot of voltage versus count.
- Plot both sets of data and select the operating point to correspond with maximum source count and minimum background count. Avoid areas of very fast count rate changes with small changes in detector voltage. The optimum operating point for low background detectors is just above the inflection point (or break-over point or knee)) of the plateau curve. If background count is irrelevant, shift operating point to the plateau center for greater stability.

## 6. WINDOW OPERATION AND ENERGY CALIBRATION PROCEDURES

- The following procedure calibrates threshold directly in keV.
- Place RATEMETER multiplier switch to LOG position.
- Unscrew and remove CAL cover.
- Press HV pushbutton. The HV should read out on the display directly in volts. While depressing the HV pushbutton, turn HV potentiometer maximum counterclockwise. The HV should be less than 50 volts.
- Depress the THR pushbutton. Turn the THR potentiometer clockwise until 652 displays.
- With WIN IN/OUT switch IN, depress the WIN pushbutton. Turn the WIN potentiometer until 20 appears on the display.
- Switch WIN IN/OUT to OUT.
- Connect the probe and expose to Cs137 source (a source of approximately 10μCi placed 3-4 inches away is recommended).
- Increase HV (if HV potentiometer is at minimum, it will take approximately 3 turns before any change is indicated). While increasing the HV, observe the log scale of the ratemeter. Increase HV until ratemeter indication occurs.
- Switch WIN IN/OUT switch to IN.
- Turn the HV control until maximum reading occurs on the log scale. Increase HV until reading starts to drop off, then decrease the HV for maximum reading.
- Turn RATEMETER selector switch to the X1K position.
- Press ZERO pushbutton and release. If meter does not read, switch to a lower range until a reading occurs.

● Carefully adjust HV potentiometer until maximum reading is achieved on the range scale. The instrument is now peaked for Cs137 on both the LOG and Linear scales.

√ NOTE: When the THR control is adjusted, the effective window width remains constant. As an example, if the THR is set at 612, the WIN at 100, a 662 keV peak 612 + (100 divided by 2) will be centered in the window. Then the threshold point is equivalent to 612 keV with a 100 keV window and calibrated for 100 keV per turn. Now, if the threshold is reduced to 250, the threshold is equivalent to 250 keV, but the window (100) is still equal to 100 keV. Proportionally, this represents a broader window.

## 7. OVERLOAD DETECTION CALIBRATION

● Detector Count Saturation is detected in this instrument and is indicated by the LCD display flashing all dashes and the analog ratemeter deflecting full scale. The count saturation or "overload" point is calibrated by the O.L. front panel control.

● Adjust the O.L. control to fully clockwise position.

● Connect detector and set HV for correct detector operating voltage.

● Expose detector to radiation field and while observing ratemeter, increase field intensity until a decrease in count rate is noticed. For alpha scintillators, the detector photomultiplier tube (PMT) should be exposed to a small light leak through the probe face to establish the detector saturation point.

● With the detector in the count saturation field, adjust the O.L. control counterclockwise until the overload alarm point is reached (flashing dashes in LCD display).

● Position detector in a lower field intensity just below the saturation point and confirm overload is defeated.

Example: Ludlum Model 44-9 GM pancake detector saturates at approximately 500 mR/hr (5mS/h).

● Full scale instrument analog meter reading=200 mR/hr (2 mS/h). Set the Model 2221 to overload at 500 mR/hr (5 mS/h) field, then position detector in a 300 mR/hr (3 mS/h) field and confirm that overload alarm is defeated. The O.L. control will have to be "fine adjusted" to perform the above procedure.

## 8. CALIBRATION

● Refer to schematic and component layout for the following calibration.

### 8.1 Ratemeter Calibration

● Connect Frequency counter to pin 18 of U22 (80C51FA) on Processor board, #5261-073. Confirm crystal frequency is 6 MHz ±0.1% (6,006 khz-5,994 kHz).

● Set THR control to 100 and Window IN/OUT switch to the OUT position.

● Connect Ludlum Model 500 Pulser or equivalent and adjust count rate for 40,000 CPM.

- Switch Ratemeter Multiplier switch to the X100 position and the Response switch to "F."

- Adjust pulse amplitude above threshold until a steady count rate is observed on ratemeter.

- Adjust R40 Meter Cal (labeled MCAL) on Processor board, for 40,000 CPM on meter.

- Switch SCALER/DIG RATE switch to the SCALER position.

- Confirm counter time operation by taking 0.1 minute count. Colons should be observed during count cycle.

**8.2 TEST Pushbutton/Display Calibration**

- Adjust THR control to fully clockwise position.

- Connect positive voltmeter lead to pin 7 of U3 (TLC27M7IP) on the Amplifier/ Power Supply board. Connect negative lead to ground near U3.

- Press the THR test pushbutton and adjust R171 Volt Cal (labeled "V"), so that the front panel display reading corresponds to the voltmeter reading at pin 7 of U3.

**8.3 High Voltage Calibration**

- Connect HV meter (1000 Megohm input impedance or greater) to the junction of R32 (4.7 Meg) and R33 (1 Meg) on Amplifier /Power Supply. board.

- While pressing the HV Test pushbutton, adjust the HV front panel control until the display reads 1500.

- Adjust R175 HV Cal on Amplifier/ Power Supply board for 1500 ±5 volts on external HV meter.

- Confirm HV will adjust from 200 to 2400-2500 volts. Insure HV displayed reading tracks within 2% of HV output.

**8.4 Threshold/Gain Calibration**

- Set pulser pulse amplitude to 10mV.

- With THR set at 100, on display, fine adjust R174 Gain control (on Power Supply board) until ratemeter reads 30,000 CPM with 40,000 CPM from pulser.

- Adjust THR control for readings of 200, 300, 400, and 500 to insure the pulser input is 20, 30, 40 and 50mV respectively. Use the 3/4 CPM input setting to discriminate turn on points as in procedure above.

- Adjust THR control back to 100.

- Switch Window IN/OUT switch to the IN position. Adjust WIN control for 100, 200, 300, 400 and 500 to confirm 20, 30, 40 and 50mV window cut off points.

- Set WIN back to 100 and OUT position.

- Check the rest of the front panel functions for proper operation.

## 9. OVERHAUL PROCEDURE

 The checkout below can be performed with boards in instrument. An extender board (part no. 5261-098) is available if better access to board components is necessary.

### 9.1 Amplifier/Power Supply Board

- Connect low voltage power supply, capable of supplying 4.0-5.0 Vdc, to the Model 2221 and plug in Amplifier/Power Supply board. (component side to back of instrument).

- Adjust the WIN, THR and O.L. front panel controls to maximum clockwise position. Turn HV control to maximum counterclockwise position. Switch the lamp switch to the OFF position. Window IN/ OUT switch to the OUT position.

- Adjust input voltage for approximately +4 Vdc and turn instrument to the ON position. Battery current should be approximately 30 mA or less.

- Confirm pin 8 of U7 (CA3290A) is equal to or greater than +6.4 Vdc.

- Increase supply voltage to approximately +5 Vdc and pin 8 of U7 should increase to +9 ±1 Vdc.

- Check for +5 ±0.15 Vdc at pin 8 of any of the TLC27M7IP's (such as U3 or U4).

- Check for -6.5 ± 0.5 Vdc at pin 4 of any of the same TLC27M7IP's.

- Connect subminax wire from detector input to Amplifier/Power Supply board.

- Connect HV meter to detector input and adjust front panel HV control to fully clockwise position.

- Adjust the HV front panel control to the fully clockwise position. Then adjust R175 HV CAL for approximately 2400-2450 Vdc. Decrease front panel HV control to the fully counterclockwise position and confirm that HV output is 50 volts or less. Then set HV for approximately 1000 Vdc.

- Connect voltmeter to pin 1 of U3 (TLC27M7IP).

- With HV output set at approximately 1000 volts adjust R176 Current Cal (labeled "O") for approximately 0.1 Vdc at pin 1 of U3.

- Connect Overrange Simulator (needs to have a 1000 meg resistor) to detector input and confirm pin 1 of U3 increases to approximately 0.15 ±0.01 Vdc.

- Connect voltmeter to pin 1 of U2 (LM358) and with Overrange Simulator connected, adjust O.L. control on the front panel counterclockwise until the voltmeter reads approx +0.5 Vdc. Disconnect Simulator and confirm pin 1 of U2 goes above +3 volts.

- Turn O.L. control to its maximum clockwise position.

- Connect positive voltmeter lead to pin 7 of U3 (TLC27M7IP) and connect negative lead to ground close to U3.

- Press the WIN test pushbutton and confirm pin 7 of U3 is approximately 2.7 to 3.8 volts.

- Press THR test and confirm pin 7 is 1.23 ±0.02 Vdc.

- Press BAT test pushbutton and confirm pin 7 is approximately 0.5 with supply voltage at +5 Vdc.

- With the HV still set at 1000 Vdc, pin 7 of U3 should be approximately 1 ±0.1 Vdc while pressing the HV test pushbutton.

- Connect oscilloscope to pin 3 of U5 (LM331) and adjust R171 Volt Cal (labeled "V") for approximately 2 kHz (0.5 millisecond period) with the HV pushbutton pressed.

- Connect voltmeter to pin 7 of U3 and while pressing the THR test pushbutton, adjust THR control for approximately +0.1 Vdc.

- Switch the Window IN/OUT switch to the IN position. While pressing the WIN test pushbutton, adjust the WIN control for approximately +0.1 Vdc at pin 7 of U3 also. Then switch the Window to the OUT position.

- Connect oscilloscope to pin 2 of U8 (CA3096).

- Connect pulser and set pulse amplitude for approximately 10 millivolts. Set CPM to 40,000.

- Adjust R174 Gain (labeled "G") to maximum clockwise position and confirm positive pulses at pin 2 of U8 are approximately 1 ± 0.1 volt in amplitude.

- Connect oscilloscope to pin 10 of U105 (CD4098).

- Adjust R174 Gain until pulses just start to appear at pin 10 of U105. Then adjust pulser amplitude until pulses are clearly visible.

- Adjust R173 T Pulse (labeled "T") for a 2.5 microsecond positive pulse width at pin 10 of U105.

- Connect oscilloscope to pin 7 of U105 and adjust R172 Width (labeled "W") for a 3 microsecond negative pulse width.

- Switch the Window IN/OUT switch to the IN position and verify that the pulses are present at pin 7 of U105 from 10 to 20 mV input pulse amplitude and off above approximately above 20 mV.

- Switch Window IN/OUT switch to the OUT position and verify the pulses appear above the window limit as in the above step.

- Battery current should be less than 30 mA with +5 Vdc supply input.

### 9.2 Processor Board Checkout

- The procedure below is to be used without the Amplifier/Power Supply board. If the Amplifier/Power Supply board is used, delete the steps containing the signal generator use. Use the pulser for the standard count rate inputs. Window, Threshold, HV and Bat test will display the control setting.

- Plug in Amplifier/Power Supply Simulator board and connect Signal Generator to jumper wires (black= probe ground).

- Plug in Processor board, component side toward back of instrument. Connect display ribbon cable.

- Set Signal Generator to square wave function.

Range= 10k and all other switches to the OUT position.

- Adjust the Freq. Symmetry, Amplitude and D.C. Offset controls to achieve a 5 volt negative pulse with a pulse width of approximately 50 microseconds and a period of approximately 1.2 milliseconds.

- With supply voltage set at +5 ± 0.15 Vdc, turn instrument ON and observe display= 8.8:8.8:8.8 for approximately 2 seconds, then 261010 indicating the program number.

- Connect Frequency Counter to pin 18 of U22 (80C51FA) and confirm crystal frequency is 6 Mhz ±0.1% (6,006 khz-5,994 khz).

- Switch the Scaler/Dig. Rate Switch to the Dig Rate position.

- Counts should start accumulating every 2 seconds until approximately 50,000 CPM is observed. (The symmetry control can be fine adjusted until 50,000 CPM is achieved). At this displayed count rate, the low BAT Test indication should be observed, indicated by 5 decimal points across the bottom of the display.

- Press BAT Test and display should be 4.1 ± 0.2.

- Press HV and WINDOW= 410 ±20. Threshold pushbutton has no effect without Amp/P.S. plugged in.

- Switch Ratemeter Response time to F.

- Switch Ratemeter multiply to X100.

- Adjust R40 Meter Cal, (labeled MCAL), until Ratemeter matches displayed accumulated count (approximately 50,000 CPM).

- Change the Multiplier range on the Signal Generator to correspond to each decade on Rate Multiplier to confirm range switch operation.

- Connect Voltmeter to recorder output and confirm R41 RCDR CAL, (labeled RCAL), will adjust from 0 to approximately 3.7 Vdc, with full scale CPM on display and ratemeter. Then set for 1 Vdc to equal full scale meter deflection.

- Connect Oscilloscope to pin 9 of U10 (ICM7556) and decade Sweep Generator down to the 1k range.

- Switch the Audio Divide switch between the 1, 10, and 100 positions to confirm Audio frequency divides or multiplies by 10, between each position.

- Connect Headset or turn on unimorph and confirm volume control operation.

- With full scale meter deflection (500), check F/S response time (90% full scale) for 4.5 ± 0.5 seconds and 22 ± 2 seconds respectively.

- Check Count, Hold, and Zero pushbutton functions.

- Switch Scaler/Dig. Rate switch to the Scaler position and check the 0.1, 0.2 and 2 minute time multipliers for correct time operation.

- With +5 volts supply input, battery current should be less than approximately 15 mA, with full scale meter deflection.

## 9.3 Functional/Chassis Checkout

- This procedure requires a checked-out Amp/P.S. board and Processor board.

- Connect one lead of an ohmmeter to chassis ground.

- Connect other lead of ohmmeter to the Processor board cinch connector pins below to check count time switch operation. Boards are not plugged in yet.

1= open
0= shorted

| COUNT TIME POSITION | PROCESSOR BOARD CINCH CONNECTOR PIN 8 | 30 | 31 |
|---|---|---|---|
| 0.1 | 0 | 0 | 0 |
| 0.2 | 0 | 0 | 1 |
| 0.5 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 2 | 0 | 1 | 0 |
| 5 | 0 | 1 | 1 |
| 10 | 1 | 1 | 0 |
| CONT | 1 | 1 | 1 |

- Connect external power supply and set input voltage for approximately +5 Vdc.

- Turn Lamp switch to the OFF position. THR and O.L. controls to maximum clockwise position and HV to maximum counterclockwise position.

- Plug in Processor and Amp/P.S. boards and related cable connections.

- Turn instrument ON. Current draw should be less than 45 mA.

- Confirm display reads 8.8:8.8:8.8 for approximately 2 seconds, then 261010 indicating the program version.

- Connect positive voltmeter lead to pin 7 of U3 (TLC27M7IP) on the Amp./P.S. board. Connect negative lead to ground near U3.

- With the THR control full clockwise, press the THR test pushbutton and adjust R171 Volt Cal (labeled "V"), so that the front panel display reading corresponds to the voltmeter reading at pin 7 of U3.

- Connect HV meter (2500 Megohm input impedance or greater) to the junction of R32 (4.7 Meg) and R33 (1 Meg) on P.S. board.

- While pressing the HV Test pushbutton, adjust HV control until the display reads 1500. R176 Current Cal may have to be adjusted counterclockwise to defeat the Overrange function.

- Adjust R175 HV Cal on Amp/P.S. board for 1500 ±5 on external HV meter.

- Confirm HV will adjust from 50 to 2400-2500 volts. Insure HV displayed reading tracks within 2% of HV output.

- Adjust HV for approximately 1000 volts.

- Adjust R176 Current Cal (labeled "0") for approximately 0.1 volt at pin 1 of U3 (TLC27M7IP) on Amp/P.S. board.

- Connect Overrange Simulator (1000 megohm) to the detector input.

- Adjust the O.L. control counterclockwise until hyphens start flashing across display every other count interval. Disconnect Overrange Simulator and confirm overrange function is defeated. Then adjust to fully clockwise position.

- Set THR control to 100 and Window IN/OUT switch to the OUT position.

- Connect pulser and adjust count rate for 40,000 CPM.

- Switch Ratemeter Multiplier switch to the X100 position and the Response switch to “F.”
- Adjust pulse amplitude above threshold until a steady count rate is observed on ratemeter.

- Adjust R40 Meter Cal (labeled MCAL) on Processor board, for 400 CPM on meter.

- Adjust pulser for 10,000 CPM and check meter for ±10% linearity of reading. Adjust pulser and rate Multiplier switch to confirm linear readings on all ranges.

- Switch SCALER/DIG. RATE switch to the SCALER position.

- Confirm count time switch operation by taking a 0.1 minute and 0.5 minute count. Colons should be observed during count cycle.

- Check HOLD and ZERO pushbutton functions.

- Switch SCALER/DIG. RATE switch to the DIG. RATE position and confirm update count display operation approximately every 2 seconds.

- Connect unimorph and headset to the audio outputs and confirm audio divide and volume control functions. NOTE: Unimorph should shut off when headset is connected.

- With the THR control adjusted for 100, adjust R174 Gain (labeled G) for 1.5 millivolt input sensitivity. Insure instrument functions at low input sensitivity without "noise".

- Instrument may have to be placed in can to permit "noise free" operation.

- Set pulser pulse amplitude to 10mV.

- With THR still set at 100, fine adjust R174 Gain control until ratemeter reads 30,000 CPM with 40,000 CPM from pulser.

- Adjust THR control for readings of 200, 300, 400, and 500 to insure the pulser input is 20, 30, 40 and 50mV respectively. Use the 3/4 CPM input setting to discriminate turn on points as in procedure above.

- Adjust THR control back to 100.

- Switch Window IN/OUT switch to the IN position. Adjust WIN control for 100, 200, 300, 400 and 500 to confirm 20, 30, 40 and 50mV window cut off points.

- Set WIN back to 100 and OUT position for instrument shipment.

- Input a full-scale ratemeter count rate (500 CPM) and connect voltmeter to the recorder output. Adjust R41 (labeled RCAL) on Processor board for 1 volt.

- Check F/S ratemeter response time for 4.5 ±0.5 and 22 ±2 seconds at 90% of full scale.

- Decrease input supply voltage until periods are observed at bottom of display. Press BAT Test pushbutton and confirm low BAT Test is 4.4 ± 0.1 Vdc. Adjust supply voltage back to 5 volts and confirm BAT test and actual supply input is 5 ∀0.05 Vdc.

- Switch SCALER/DIG. RATE switch to the SCALER position. Count Time Multiplier to CONT. Press count pushbutton and start with low enough count rate to observe each digit number count sequence from Least significant digit to MSD. Decade pulser count rate to speed up digit segment display check.

- Increase count rate enough to overflow counter. An "H" should be observed in the MSD flashing every count interval.

- Turn Lamp switch to the ON position and confirm 2 lamps in the display and 2 lamps below the meter are illuminated.

- Current draw with lamps on should be 210 ±20 mA.

- Turn lamp OFF and current should be approximately 40 ±5 mA.

## 10. PARTS LIST

| Ref. No. | Description | Part No. |
|---|---|---|
| | **Model 2221 Portable Scaler Ratemeter** | |
| UNIT | Completely Assembled Model 2221 Portable Scaler Ratemeter | 48-2065 |
| | **Amplifier/Power Supply Board, Drawing 261 X 56** | |
| BOARD | Assembled Board | 5261-072 |
| | • **CAPACITORS** | |
| C107 | 1µF, 35V, DT | 04-5575 |
| C108 | 2.2µF, 25V, DT | 04-5559 |
| C109 | 4.7µF, 10V, DT | 04-5578 |
| C110 | 4.7µF, 10V, DT | 04-5578 |
| C111 | 100µF, 10V, DT | 04-5576 |
| C112 | 4.7µF, 10V, DT | 04-5578 |
| C114 | 10pF, 100V, C | 04-5573 |
| C115 | 0.1µF, 100V, C | 04-5521 |
| C116 | 0.1µF, 100V, C | 04-5521 |
| C117 | 0.1µF, 100V, C | 04-5521 |
| C118 | 0.1µF, 100V, C | 04-5521 |
| C120 | 0.0022µF, 100V, P | 04-5580 |
| C121 | 0.001µF, 100V, C | 04-5519 |
| C122 | 0.1µF, 100V, C | 04-5521 |
| C123 | 100pF, 100V, C | 04-5527 |
| C124 | 0.1µF, 100V, C | 04-5521 |
| C125 | 0.01µF, 100V, C | 04-5523 |
| C126 | 47pF, 100V, C | 04-5533 |
| C127 | 0.1µF, 100V, C | 04-5521 |
| C128 | 47pF, 100V, C | 04-5533 |
| C129 | 100pF, 100V, C | 04-5527 |
| C130 | 10pF, 100V, C | 04-5573 |
| C131 | 0.1µF, 100V, C | 04-5521 |
| C132 | 10pF, 100V, C | 04-5573 |
| C133 | 0.0015µF, 3kV, C | 04-5518 |
| C135 | 0.0015µF, 3kV, C | 04-5518 |
| C136 | 0.0015µF, 3kV, C | 04-5518 |
| C137 | 100pF, 3kV, C | 04-5532 |
| C138 | 100pF, 3kV, C | 04-5532 |
| C139 | 0.0056µF, 3kV, C | 04-5522 |
| C140 | 0.0056µF, 3kV, C | 04-5522 |
| C141 | 0.0056µF, 3kV, C | 04-5522 |
| C145 | 1µF, 35V, DT | 04-5575 |
| C146 | 100µF, 10V, DT | 04-5576 |
| C147 | 100µF, 10V, DT | 04-5576 |
| C148 | 10µF, 20V, DT | 04-5592 |

| | | |
|---|---|---|
| C154 | 0.0015µF, 3kV, C | 04-5518 |
| C164 | 0.1µF, 100V, C | 04-5521 |
| C165 | 0.1µF, 100V, C | 04-5521 |
| | • **TRANSISTORS** | |
| Q142 | 2N3904 | 05-5755 |
| Q143 | MPSU51 | 05-5765 |
| | • **INTEGRATED CIRCUITS** | |
| U1 | TLC27M7 | 06-6248 |
| U2 | LM358 | 06-6024 |
| U3 | TLC27M7 | 06-6248 |
| U4 | TLC27M7 | 06-6248 |
| U5 | LM331 | 06-6156 |
| U6 | LM2578 | 06-6223 |
| U7 | CA3290AE | 06-6140 |
| U8 | CA3096 | 06-6023 |
| U9 | CA3096 | 06-6023 |
| U105 | CD4098 | 06-6066 |
| U106 | CA3096 | 06-6023 |
| U144 | CD4052 | 06-6141 |
| | • **DIODES** | |
| CR10 | IN5819 | 07-6306 |
| CR12 | MR-250-2 | 07-6266 |
| CR13 | MR-250-2 | 07-6266 |
| CR14 | MR-250-2 | 07-6266 |
| CR15 | MR-250-2 | 07-6266 |
| CR16 | 1N4148 | 07-6272 |
| CR17 | 1N4148 | 07-6272 |
| CR18 | 1N4148 | 07-6272 |
| CR19 | 1N4148 | 07-6272 |
| CR20 | 1N4148 | 07-6272 |
| CR21 | 1N4148 | 07-6272 |
| CR22 | 1N4148 | 07-6272 |
| CR24 | 1N5819 | 07-6306 |
| CR25 | 1N5819 | 07-6306 |
| CR151 | MR-250-2 | 07-6266 |
| CR177 | 1N5252 | 07-6265 |
| | • **RESISTORS** | |
| R32 | 4.7M | 10-7030 |
| R33 | 1M | 10-7028 |
| R34 | 1M | 10-7028 |
| R35 | 1G | 12-7686 |
| R36 | 1G | 12-7686 |
| R37 | 0.1 OHM, 1% | 12-7647 |

**Ref. No.** **Description** **Part No.**

**Ref. No.** **Description** **Part No.**

| | | |
|---|---|---|
| R38 | 10k | 12-7748 |
| R39 | 1M, 1% | 12-7763 |
| R40 | 10k | 12-7748 |
| R41 | 10k | 12-7748 |
| R42 | 10k | 12-7748 |
| R43 | 10k | 12-7748 |
| R44 | 47k | 12-7758 |
| R45 | 4.7k | 12-7755 |
| R46 | 10k | 12-7748 |
| R47 | 10k | 12-7748 |
| R48 | 10k | 12-7748 |
| R49 | 1k | 12-7750 |
| R50 | 220 OHM | 12-7753 |
| R51 | 220 OHM | 12-7753 |
| R52 | 470k | 12-7757 |
| R53 | 47k | 12-7758 |
| R54 | 1k | 12-7750 |
| R55 | 10k | 12-7748 |
| R56 | 4.7k | 12-7755 |
| R57 | 10k | 12-7748 |
| R58 | 10k | 12-7748 |
| R59 | 10k | 12-7748 |
| R60 | 1k | 12-7750 |
| R61 | 178k, 1% | 12-7769 |
| R62 | 4.7k | 12-7755 |
| R63 | 100k | 12-7747 |
| R64 | 10k | 12-7748 |
| R65 | 10k, 1% | 12-7764 |
| R66 | 220 OHM | 12-7753 |
| R68 | 10k | 12-7748 |
| R69 | 1.5k | 12-7773 |
| R70 | 100k, 1% | 12-7747 |
| R71 | 200k | 12-7752 |
| R72 | 200k | 12-7752 |
| R73 | 100k | 12-7747 |
| R74 | 100k | 12-7747 |
| R78 | 22k | 12-7754 |
| R79 | 10k | 12-7748 |
| R80 | 10k | 12-7748 |
| R81 | 100k | 12-7557 |
| R82 | 200k | 12-7752 |
| R83 | 22k | 12-7754 |
| R84 | 10k | 12-7748 |
| R85 | 1M | 12-7763 |
| R86 | 4.42k | 12-7760 |
| R87 | 47 OHM | 12-7756 |
| R88 | 100k, 1% | 12-7747 |
| R89 | 17.8k | 12-7759 |
| R90 | 10k,1% | 12-7764 |
| R91 | 1M, 1% | 12-7763 |
| R92 | 1M, 1% | 12-7763 |
| R93 | 40.2k, 1% | 12-7761 |
| R94 | 100 OHM | 12-7746 |
| R95 | 10k | 12-7748 |
| **Ref. No.** | **Description** | **Part No.** |

| | | |
|---|---|---|
| R96 | 1M, 1% | 12-7763 |
| R97 | 10M | 12-7749 |
| R98 | 1M | 12-7751 |
| R99 | 470k | 12-7757 |
| R100 | 470k | 12-7757 |
| R101 | 100k | 12-7747 |
| R102 | 1M, 1% | 12-7763 |
| R171 | 10k TRIMMER | 09-6822 |
| R172 | 100k TRIMMER | 09-6823 |
| R173 | 100k TRIMMER | 09-6823 |
| R174 | 10k TRIMMER | 09-6822 |
| R175 | 1M TRIMMER | 09-6828 |
| R176 | 1M TRIMMER | 09-6828 |

- **TRANSFORMERS**

| | | |
|---|---|---|
| T103 | M2300 HVPS | 4275-037 |
| T104 | M2221 LVPS | 4275-094 |

- **MISCELLANEOUS**

| | | |
|---|---|---|
| 9 EA. | CLOVERLEAF RECEPTACLES | |
| | 011-6809-00 | 18-8771 |
| 3 EA. | SPACERS | 18-8933 |
| * | TRANSISTOR SPACER | 18-8992 |
| * | AMPLIFIER SHIELD | 7261-100 |

**Processor Board, Drawing 261 X 91**

| | | |
|---|---|---|
| BOARD | Assembled Board | 5261-136 |

- **CAPACITORS**

| | | |
|---|---|---|
| C1 | 47pF, 100V, C | 04-5533 |
| C2 | 0.047µF, 100V, C | 04-5565 |
| C3 | 0.001µF, 100V, C | 04-5519 |
| C4 | 27pF, 100V, C | 04-5614 |
| C5 | 27pF, 100V, C | 04-5614 |
| C6 | 22µF, 15V, DT | 04-5579 |
| C7 | 10µF, 20V, DT | 04-5592 |
| C8 | 100µF, 10V, DT | 04-5576 |
| C9 | 100µF, 10V, DT | 04-5576 |

- **TRANSISTOR**

| | | |
|---|---|---|
| Q36 | 2N3904 | 05-5755 |

- **INTEGRATED CIRCUITS**

| | | |
|---|---|---|
| U10 | ICM7556 | 06-6244 |
| U11 | CD74HCO8 | 06-6222 |
| U13 | CD4054 | 06-6245 |
| U14 | CD4056 | 06-6095 |
| U15 | CD4056 | 06-6095 |
| U16 | CD4056 | 06-6095 |
| **Ref. No.** | **Description** | **Part No.** |

| | | |
|---|---|---|
| U17 | CD4056 | 06-6095 |
| U18 | CD4056 | 06-6095 |
| U19 | CD4056 | 06-6095 |
| U20 | CD74HC573 | 06-6093 |
| U21 | 87C257 | 06-6278 |
| U22 | 80C51FA | 06-6236 |
| U25 | RDD104 | 06-6060 |
| U26 | LM358 | 06-6024 |
| U43 | CD74HC238 | 06-6246 |

- **DIODE**

| | | |
|---|---|---|
| CR45 | 1N4148 | 07-6272 |

- **RESISTORS**

| | | |
|---|---|---|
| R27 | 3.3k | 10-7013 |
| R28 | 220k | 10-7066 |
| R29 | 130k | 10-7067 |
| R30 | 470k | 10-7026 |
| R31 | 220k | 10-7066 |
| R32 | 1.2k | 10-7058 |
| R33 | 5.6k | 10-7042 |
| R40 | 1M TRIMMER | 09-6828 |
| R41 | 1M TRIMMER | 09-6828 |

- **RESISTOR NETWORKS**

| | | |
|---|---|---|
| R34-R35 | NETWORK-22k SIP 10 PIN | 12-7566 |

- **TRANSFORMER**

| | | |
|---|---|---|
| T37 | M300-9 | 4275-074 |

- **CRYSTAL**

| | | |
|---|---|---|
| Y39 | 6.000 MHZ | 01-5209 |

- **CONNECTOR**

| | | |
|---|---|---|
| P3/1-50 | RIBBON-1-102159-0 | 13-7834 |

- **MISCELLANEOUS**

| | | |
|---|---|---|
| * | 28P SOCKET | 06-6096 |
| 7 EA. | SPACER-816-045 16P | 18-8990 |
| * | SPACER-470-015 | 18-8991 |
| 2 EA. | RIBBON-102312-2 LATCH | 13-7805 |

## Calibration Board, Drawing 261 X 59

| | | |
|---|---|---|
| BOARD | Assembled Board | 5261-075 |

- **VOLTAGE REFERENCES**

| | | |
|---|---|---|
| U1 | LM385Z-1.2 | 05-5808 |
| U2 | LM385Z-1.2 | 05-5808 |
| U3 | LM385Z-1.2 | 05-5808 |

- **RESISTORS**

| | | |
|---|---|---|
| R4 | 22k | 12-7754 |
| R10 | 22k | 12-7754 |
| R11 | 100k TRIMMER | 09-6813 |
| R12 | 100k TRIMMER | 09-6813 |
| R13 | 100k TRIMMER | 09-6813 |
| R14 | 100k TRIMMER | 09-6813 |

- **CONNECTOR**

| | | |
|---|---|---|
| P6/1-7 | 640457-7 MTA100 | 13-8183 |

## LCD Display Board, Drawing 261 X 58

| | | |
|---|---|---|
| BOARD | Assembled Board | 5261-074 |

- **INTEGRATED CIRCUIT**

| | | |
|---|---|---|
| U7 | 3918 | 07-6252 |

- **RESISTORS**

| | | |
|---|---|---|
| R4 | 22 OHM | 10-7072 |
| R14 | 22 OHM | 10-7072 |

- **CONNECTORS**

| | | |
|---|---|---|
| P4 | RIBBON-RD67<br>50BRN EDGE 50P | 13-7816 |
| P5 | 640456-2 MTA100 | 13-8073 |

- **MISCELLANEOUS**

| | | |
|---|---|---|
| DS10-DS13 | BULB-#6833 | 22-9613 |

**Ref. No.** **Description** **Part No.**

## Backplane Board, Drawing 261 X 60

| Ref. No. | Description | Part No. |
|---|---|---|
| BOARD | Assembled Backplane Board | 5261-076 |
| | **DIODE** | |
| CR6 | 1N5819 | 07-6306 |
| | **CONNECTORS** | |
| J1-J2 | EZA22DRSN | 13-8181 |
| P7 | 640456-7 MTA100 | 13-8115 |
| P8 | 1-640456-4 MTA100 | 13-8141 |
| P9 | 640456-5 MTA100 | 13-8057 |
| P10 | 640456-2 MTA100 | 13-8073 |
| P11 | 1-640456-4 MTA100 | 13-8141 |

## Chassis Wiring Diagram, Drawing 261 X 61

| Ref. No. | Description | Part No. |
|---|---|---|
| | **AUDIO** | |
| DS1 | UNIMORPH 60690 | 21-9251 |
| | **CONNECTORS** | |
| J1 | CONN-640456-2 MTA100 | 13-8073 |
| J2 | UG706/U SERIES C | 13-7751 |
| J5 | PHONE JACK TINI #42A | 21-9333 |
| J6-J7 | (ON CAL HARNESS) | 8261-088 |
| J8 | (ON MAIN HARNESS) | 8261-087 |
| J9 | (ON BATTERY HARNESS) | 8261-089 |
| J10 | NOT USED | |
| J11 | (ON MAIN HARNESS) | 8261-087 |
| | **SWITCHES** | |
| S1-S7 | 30-1-PB GRAYHILL | 08-6517 |
| S8-S12 | 7101-SYZ-QE TOGGLE | 08-6511 |
| SW1 | 513381 | 08-6656 |
| SW2 | 513381 | 08-6656 |
| SW3 | MTA-206PA | 08-6657 |
| | **BATTERY** | |
| B1-B4 | 1.5 VOLT "D" DURACELL | 21-9313 |
| | **RESISTORS** | |
| R1 | 10k NON-LOCKING | 09-6753 |
| | **MISCELLANEOUS** | |
| M1 | M2221 METER ASSY. | 4261-091 |

| Ref. No. | Description | Part No. |
|---|---|---|
| **RS-232 Port Kit (optional)** | | **4261-148** |

**RS-232 Board, Drawing 261 X 179**

| | | |
|---|---|---|
| BOARD | Assembled RS-232 Board | 5261-179 |

- **CAPACITORS**

| | | |
|---|---|---|
| C1 | 4.7µF, 20V, SMT | 04-5653 |
| C2 | 10µF, 20V, SMT | 04-5655 |
| C3 | 4.7µF, 20V, SMT | 04-5653 |
| C4 | 10µF, 20V, SMT | 04-5655 |
| C5-C6 | 68µF, 10V, SMT | 04-5654 |

- **INTEGRATED CIRCUITS**

| | | |
|---|---|---|
| U001 | IC-MAX220CSE, SMT | 06-6329 |

## 11. RS-232 Port Addition (LMI Part No. 4261-148)

The Model 2221 RS-232 port addition allows the Model 2221 data to be read as output to a computer or serial printer, by dumping either the ratemeter or scaler reading, as desired. The desired reading is selected with a toggle switch located in the digital control section of the front panel, labeled with two positions: SCALER and DIG. RATE. The port addition kit (LMI Part No. 4261-148) includes the internal board and a cable that will connect directly to a 9-pin PC port.

The scaler reading dumps when the scaler has completed a count. The ratemeter is dumped every two seconds in one of three formats, depending on the firmware installed. The three available formats are 1 count per 2 seconds, 2 counts per 60 seconds (cpm) or 3 counts per second (cps). Data output is always in a six-digit format with a letter prefix, corresponding to the following:

Ratemeter: “R”

Scaler: According to the table below

| **Letter Prefix** | **Time of Count (min)** | **Time of Count (sec)** |
|---|---|---|
| | **Format 1 or 2** | **Format 3 (cps version)** |
| A | 0.1 | 1 |
| B | 0.2 | 2 |
| C | 0.5 | 5 |
| D | 1.0 | 10 |
| E | 2.0 | 30 |
| F | 5.0 | 60 |
| G | 10.0 | 120 |

A carriage return and then a linefeed character follows the sixth digit.

The communication protocol is 9600 baud, nor parity, 1 stop bit and 8 data bits. The RS-232 port is an output only with no handshaking available.

The Model 2221 will dump the data, no matter what, even if the attached computer or printer is not read. The cable provided is a coaxial cable, providing TXD and GND to a 9-pin D-connector, ready to plug into a standard PC serial port.

Windows Hyper Terminal may be used to display and/or log the readings.

The Model 2221 Processor Board utilizes an EPROM with one of the following firmware numbers, depending on the desired rate:

Rate Dump as counts per 2 seconds – #261-06-N03.

Rate Dump as counts per 60 seconds – #261-07-N02.

Rate Dump as counts per second with mateface 202-930 – #261-02-N02.

---

**261-06-N03** RS-232 output rate dump as counts per 2 seconds.

**261-07-N02** RS-232 output rate dump as counts per 60 seconds.

**261-02-N02** RS-232 output rate dump as counts per second (cps) with special meterface 202-930 (0-10 kcps).

**261-02-N04 NEW** RS-232 output every second, 0-10 kcps mf 202-930, 1,2,5,10,30,60,120 sec scaler.

**261-02-N07 NEW** RS-232 output every second, original meterface, cpm RS-232 output.

## DRAWINGS AND DIAGRAMS

Amplifier/Power Supply Board Schematic, Drawing 261 x 56
Amplifier/Power Supply Board Component Layout, Drawing BS261072

Processor Board Schematic, Drawing 261 x 91
Processor Board Component Layout, Drawing 261 x 103

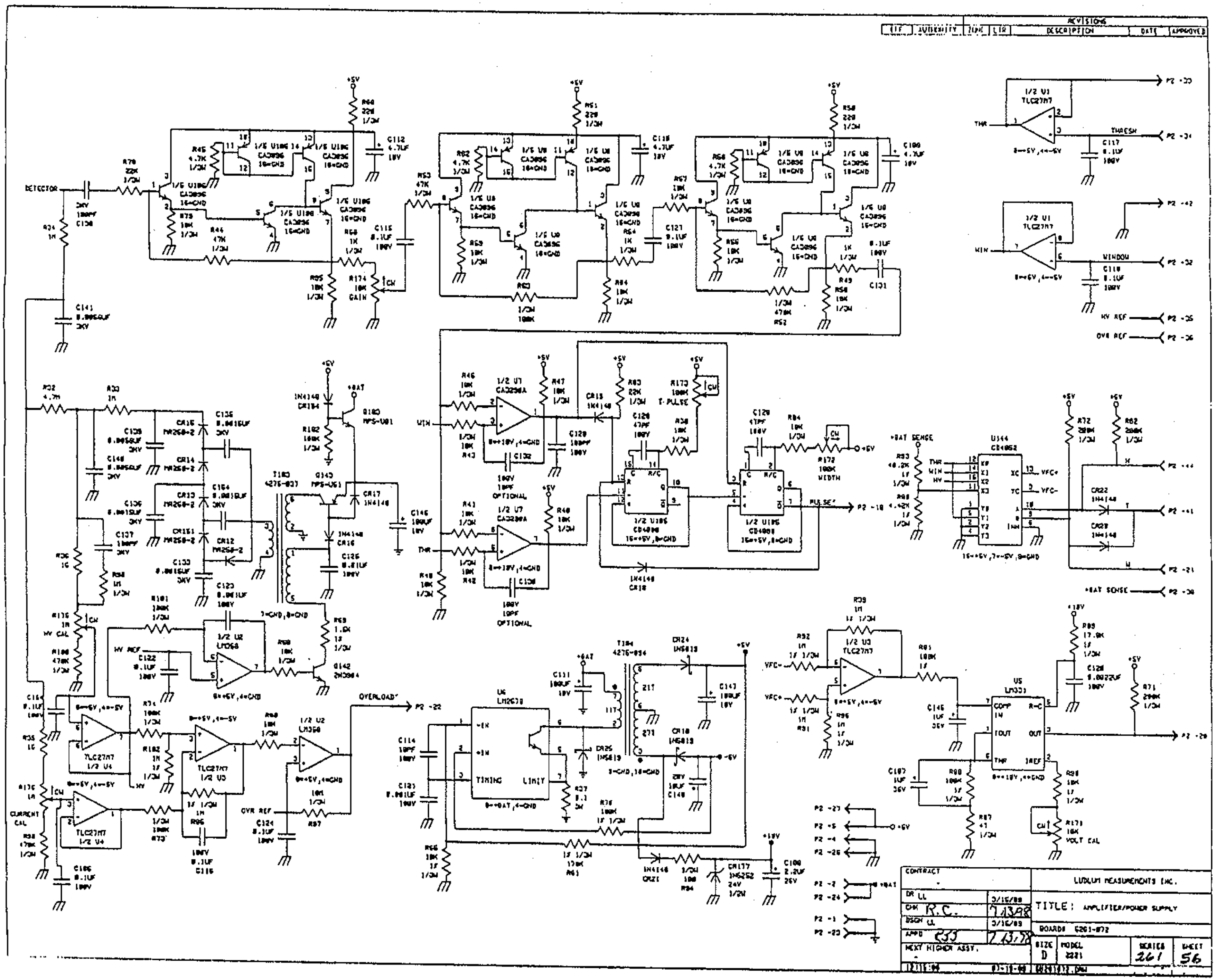
Calibration Board Schematic, Drawing 261 x 59
Calibration Board Component Layout, Drawing BS261075

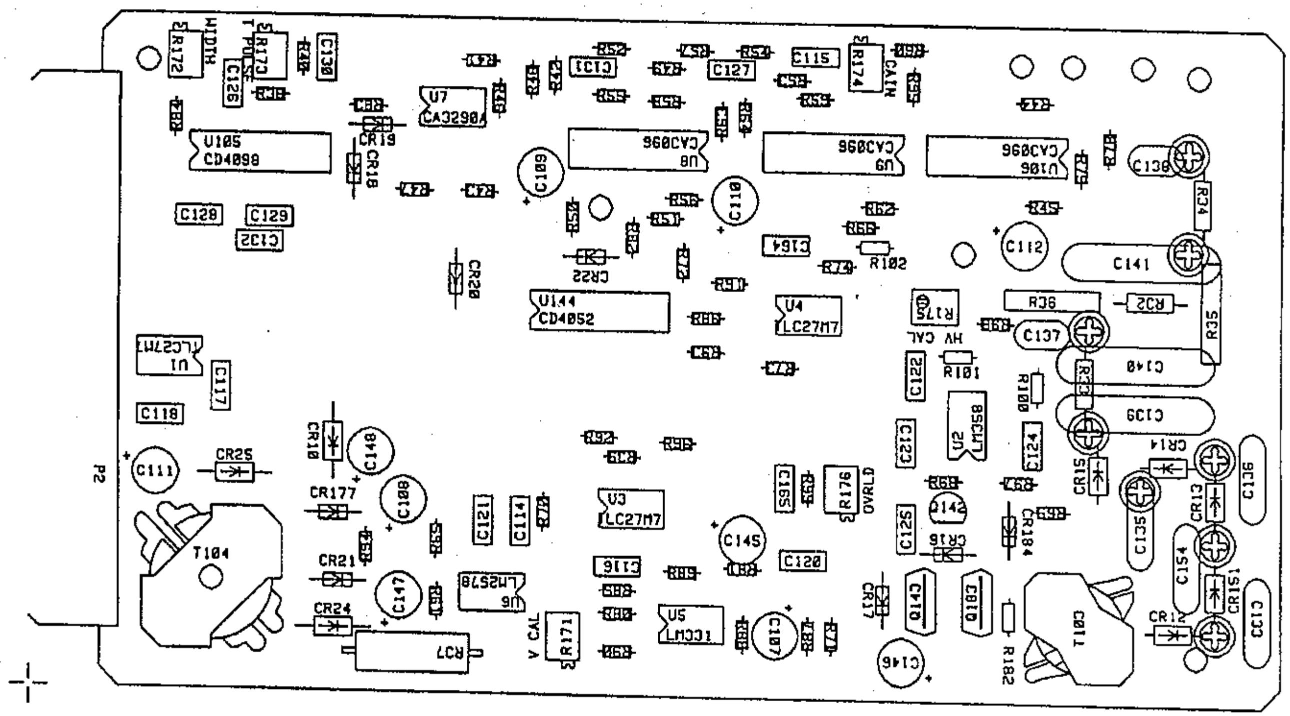
LED Display Board Schematic, Drawing 261 x 58
LED Display Board Component Layout, Drawing BS261074

Backplane Board Schematic, Drawing 261 x 60
Backplane Board Component Layout, Drawing BS261076

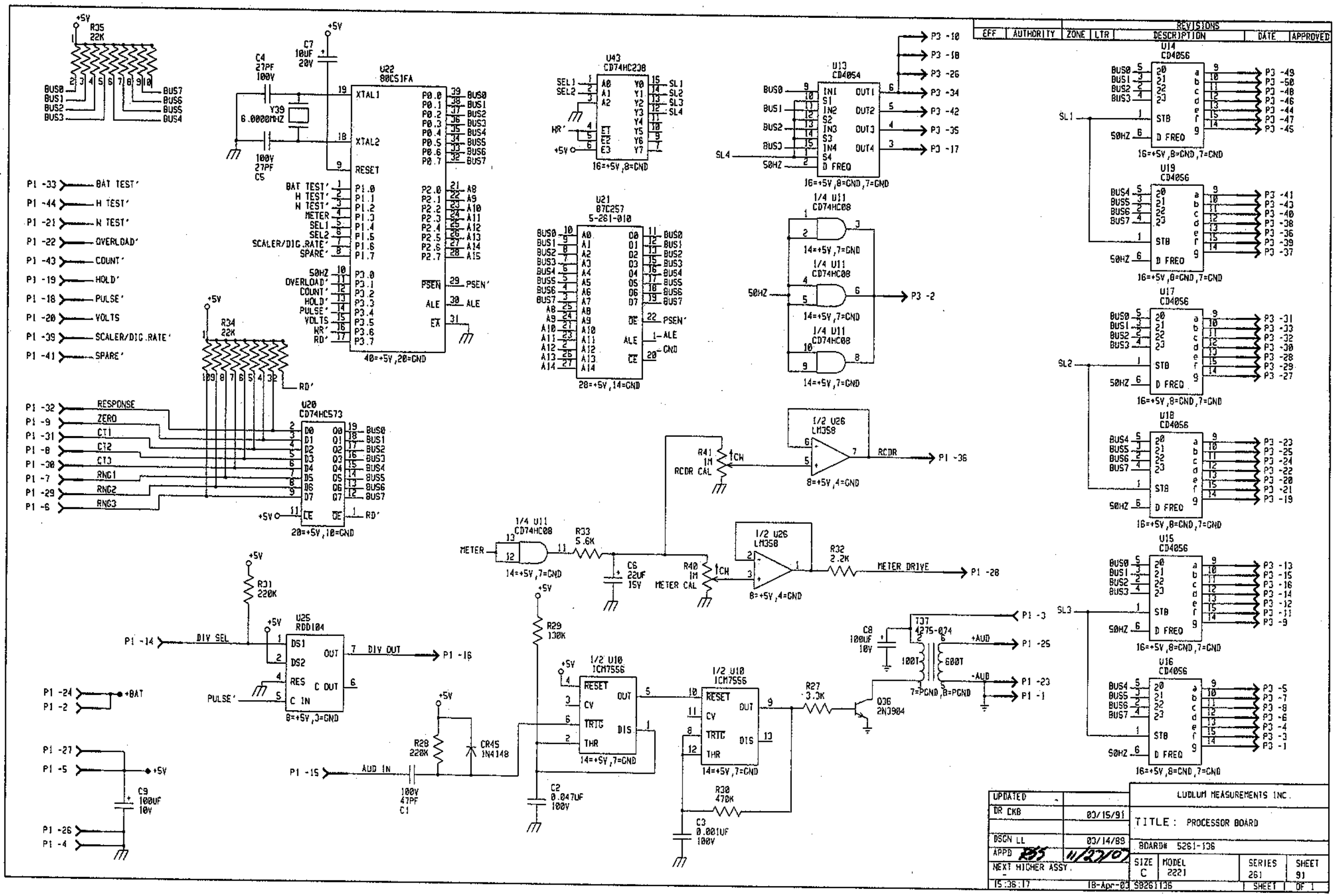
RS-232 Board Schematic, Drawing 261 x 179
RS-232 Board Component Layout, Drawing 261 x 180

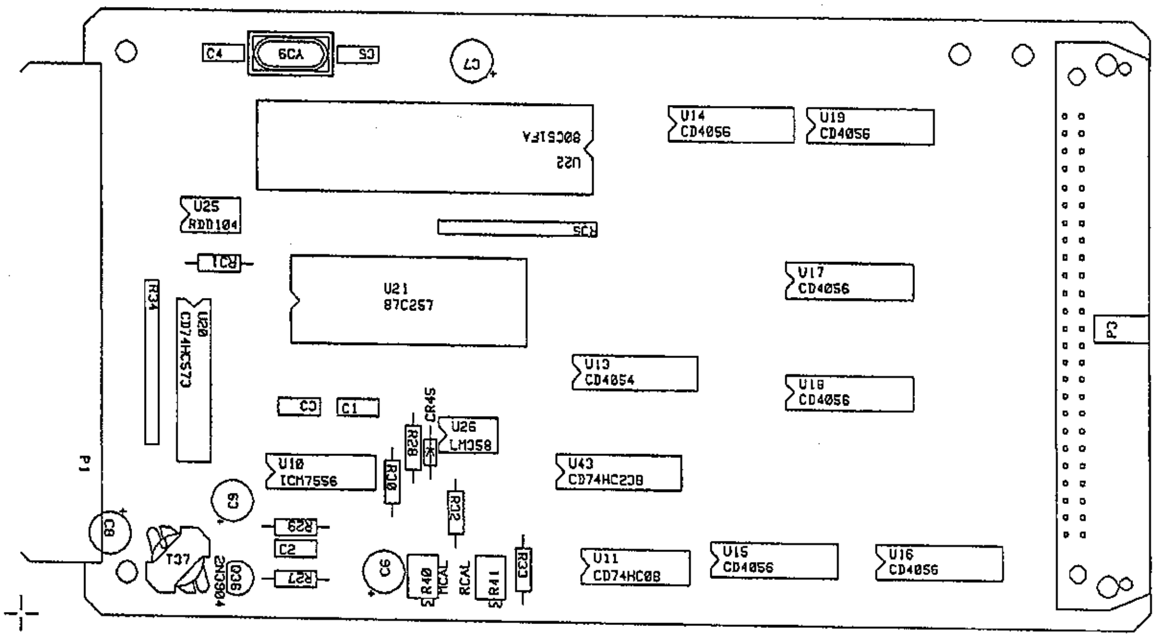
Wiring Diagram, Drawing 261 x 61


REVISIONS
DESCRIPTION
DATE
APPROVED
DETECTOR
GAIN
HV CAL
CURRENT CAL
VOLT CAL
T-PULSE
WIDTH
OPTIONAL
OVERLOAD*
PULSE*
THRESH
WINDOW
HV REF
OVR REF
+BAT SENSE
CONTRACT
LUDLUM MEASUREMENTS INC.
TITLE: AMPLIFIER/POWER SUPPLY
NEXT HIGHER ASSY.
SIZE D
MODEL 2221
SERIES 261
SHEET 56



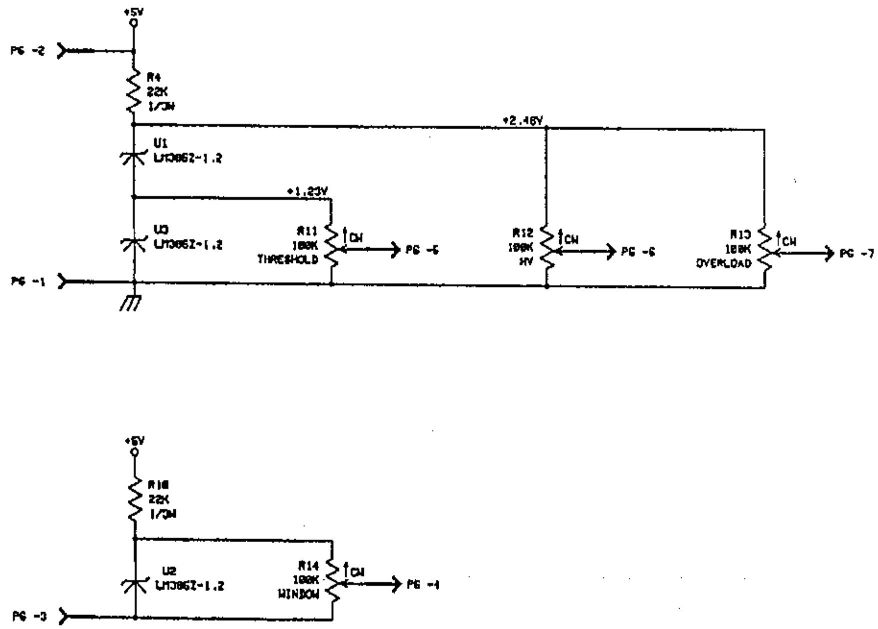
| | |
|---|---|
| BOARD# 5261-072 | |
| TITLE AMPLIFIER/POWER SUPPLY | |
| MODEL 2221 | |
| COMPONENT OUTLINES | |
| DR RDS | 4/7/89 |
| CHK R.C. | 7/13/98 |
| DSGN LL | 3/15/89 |
| APPD BS | 7/13/98 |
| B :BS261072.DRW | |
| 07-19-89 | 15:32:24 |


REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
R35 22K
BUS0 BUS1 BUS2 BUS3 BUS4 BUS5 BUS6 BUS7
C4 27PF 100V
C7 10UF 20V
Y39 6.0000MHZ
C5 27PF 100V
U22 80C51FA
XTAL1 XTAL2 RESET
P0.0 P0.1 P0.2 P0.3 P0.4 P0.5 P0.6 P0.7
P1.0 P1.1 P1.2 P1.3 P1.4 P1.5 P1.6 P1.7
P2.0 P2.1 P2.2 P2.3 P2.4 P2.5 P2.6 P2.7
P3.0 P3.1 P3.2 P3.3 P3.4 P3.5 P3.6 P3.7
BAT TEST' H TEST' N TEST' METER SEL1 SEL2 SCALER/DIG.RATE' SPARE'
50HZ OVERLOAD' COUNT' HOLD' PULSE' VOLTS WR' RD'
PSEN ALE EA
A8 A9 A10 A11 A12 A13 A14 A15
40=+5V,20=GND
U43 CD74HC238
SEL1 SEL2 SL1 SL2 SL3 SL4
16=+5V,8=GND
U21 87C257 5-261-010
28=+5V,14=GND
U13 CD4054
16=+5V,8=GND,7=GND
1/4 U11 CD74HC08
14=+5V,7=GND
P1 -33 BAT TEST'
P1 -44 H TEST'
P1 -21 N TEST'
P1 -22 OVERLOAD'
P1 -43 COUNT'
P1 -19 HOLD'
P1 -18 PULSE'
P1 -20 VOLTS
P1 -39 SCALER/DIG.RATE'
P1 -41 SPARE'
R34 22K
U20 CD74HC573
P1 -32 RESPONSE
P1 -9 ZERO
P1 -31 CT1
P1 -8 CT2
P1 -30 CT3
P1 -7 RNG1
P1 -29 RNG2
P1 -6 RNG3
20=+5V,10=GND
1/2 U26 LM358
R41 1M RCDR CAL
RCDR P1 -36
8=+5V,4=GND
R33 5.6K
C6 22UF 15V
R40 1M METER CAL
R32 2.2K
METER DRIVE P1 -28
R31 220K
U25 RDD104
P1 -14 DIV SEL
DIV OUT P1 -16
8=+5V,3=GND
P1 -24 +BAT
P1 -2
P1 -27
P1 -5 +5V
C9 100UF 10V
P1 -26
P1 -4
R29 130K
1/2 U10 ICM7556
14=+5V,7=GND
R28 220K
CR45 1N4148
P1 -15 AUD IN
C1 47PF 100V
C2 0.047UF 100V
R30 470K
C3 0.001UF 100V
R27 3.3K
Q36 2N3904
C8 100UF 10V
T37 4275-024
100T 600T
7=PGND,8=PGND
P1 -3 +AUD P1 -25 -AUD P1 -23 P1 -1
U14 CD4056 U19 CD4056 U17 CD4056 U18 CD4056 U15 CD4056 U16 CD4056
16=+5V,8=GND,7=GND
STB D FREQ
P3 -49 P3 -50 P3 -48 P3 -46 P3 -44 P3 -47 P3 -45
P3 -41 P3 -43 P3 -40 P3 -38 P3 -36 P3 -39 P3 -37
P3 -31 P3 -33 P3 -32 P3 -30 P3 -28 P3 -29 P3 -27
P3 -23 P3 -25 P3 -24 P3 -22 P3 -20 P3 -21 P3 -19
P3 -13 P3 -15 P3 -16 P3 -14 P3 -12 P3 -11 P3 -9
P3 -5 P3 -7 P3 -8 P3 -6 P3 -4 P3 -3 P3 -1
P3 -10 P3 -18 P3 -26 P3 -34 P3 -42 P3 -35 P3 -17 P3 -2
UPDATED
DR CKB 03/15/91
DSGN LL 03/14/89
APPD 11/22/07
NEXT HIGHER ASSY.
15:36:17 18-Apr-03 S9261136
LUDLUM MEASUREMENTS INC.
TITLE: PROCESSOR BOARD
BOARD# 5261-136
SIZE C MODEL 2221 SERIES 261 SHEET 91
SHEET 1 OF 1

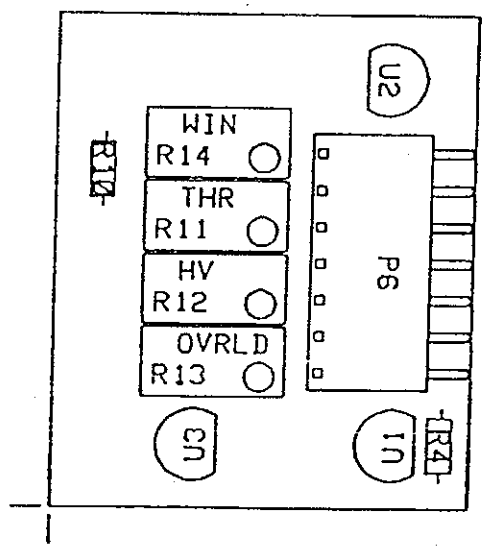



| | | | | |
|---|---|---|---|---|
| LUDLUM MEASUREMENTS INC. SWEETWATER, TX. | | | | |
| DR CKB | 03/15/91 | TITLE: PROCESSOR BOARD | | |
| CHK R.C. | 4-13-98 | BOARD# 5261-136 | | BS261136 |
| DSGN LL | 03/14/91 | MODEL 2221 | SERIES 261 | SHEET 103 |
| APP [illegible] | 7-13-98 | COMP ARTWORK ☐ | SLDR ARTWORK ☐ | |
| 09:19:04 | 29-Mar-94 | COMP OUTLINE ☒ | SLDR OUTLINE ☐ | |
| COMP PASTE ☐ | COMP MASK ☐ | SLDR PASTE ☐ | SLDR MASK ☐ | |

| REVISIONS | | | | | | |
|---|---|---|---|---|---|---|
| EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED |

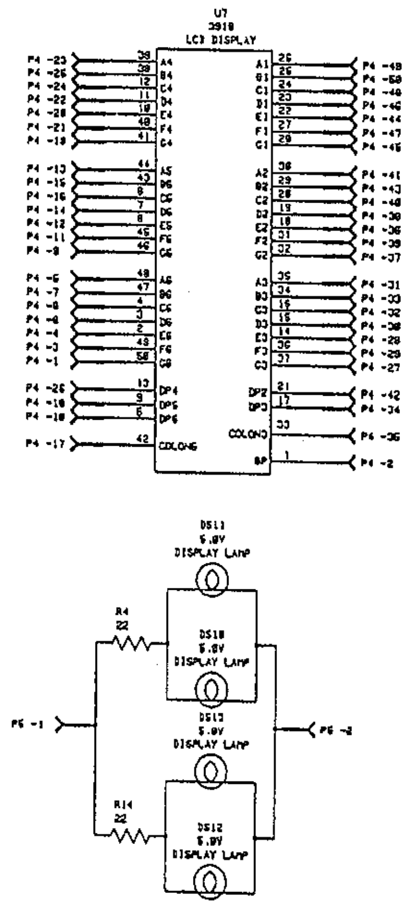



| | | | | | |
|---|---|---|---|---|---|
| CONTRACT - | | LUDLUM MEASUREMENTS INC | | | |
| DR LL | 3/16/89 | TITLE: CALIBRATION BOARD | | | |
| CHK R.C. | 4/13/98 | | | | |
| DSGN LL | 3/16/89 | BOARD# 5261-075 | | | |
| APPD BSS | 7/13/98 | SIZE D | MODEL 2221 | SERIES 261 | SHEET 59 |
| NEXT HIGHER ASSY. - | | | | | |
| 15:59:34 | 07-19-89 | 0:SB261075.DRW | | SHEET 1 OF 1 | |

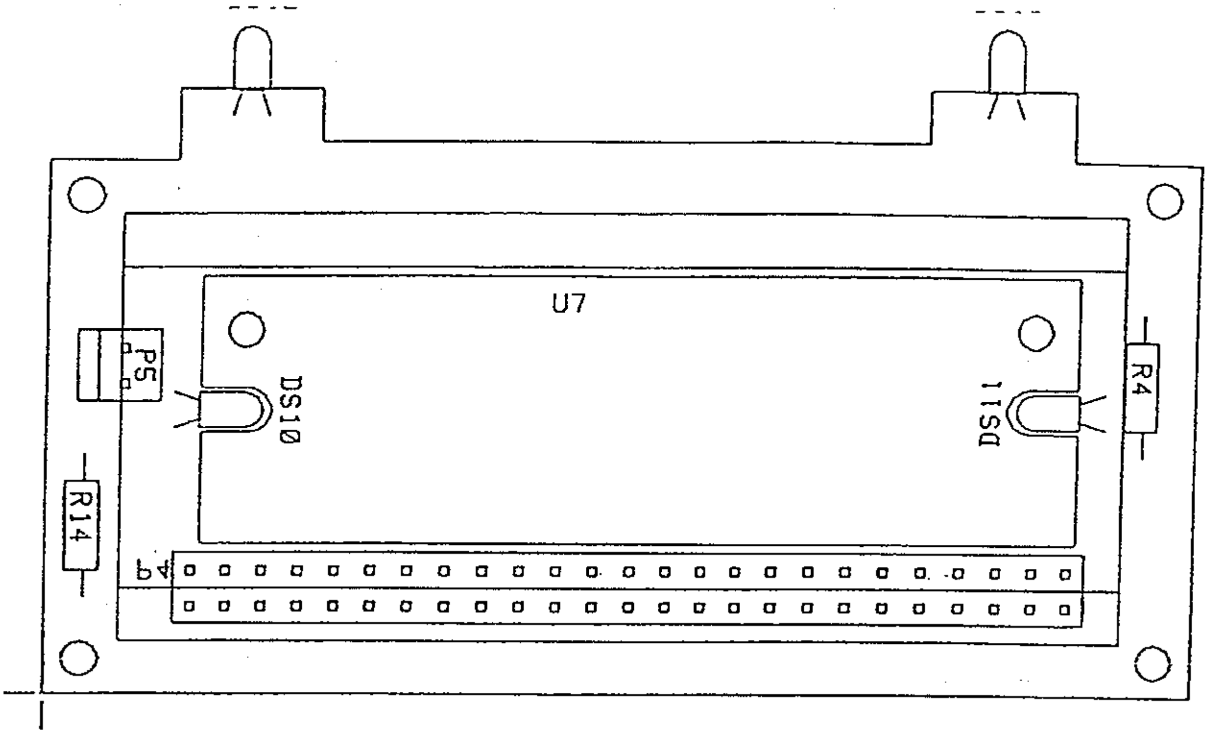



| | |
|---|---|
| BOARD# 5261-Ø75 | |
| TITLE CAL BOARD | |
| MODEL 2221 | |
| COMPONENT OUTLINES | |
| DR RDS | 3/28/89 |
| CHK R.C. | 7/13/98 |
| DSGN LL | 3/16/89 |
| APPD RSS | 7/13/98 |
| BS261Ø75.DRW | |
| Ø5-2Ø-89 | Ø7:38:12 |

| EFF | AUTHORITY | ZONE | LTR | REVISIONS DESCRIPTION | DATE | APPROVED |
|---|---|---|---|---|---|---|




| | |
|---|---|
| CONTRACT - | LUDLUM MEASUREMENTS INC. |
| DR LL 3/16/89 | |
| CHK R.C. 7/13/98 | TITLE: LCD DISPLAY |
| DSGN LL 3/16/89 | BOARD# 5201-074 |
| APPD BSS 7/13/98 | |
| NEXT HIGHER ASSY. - | SIZE D · MODEL 2221 · SERIES 261 · SHEET 58 |




| | |
|---|---|
| BOARD# 5261-Ø74 | |
| TITLE DISPLAY BOARD | |
| MODEL 2221 | |
| COMPONENT OUTLINES | |
| DR - | 3/27/89 |
| CHK R.C. | 7/13/98 |
| DSGN LL | 3/16/89 |
| APP.D RSS | 7/13/98 |
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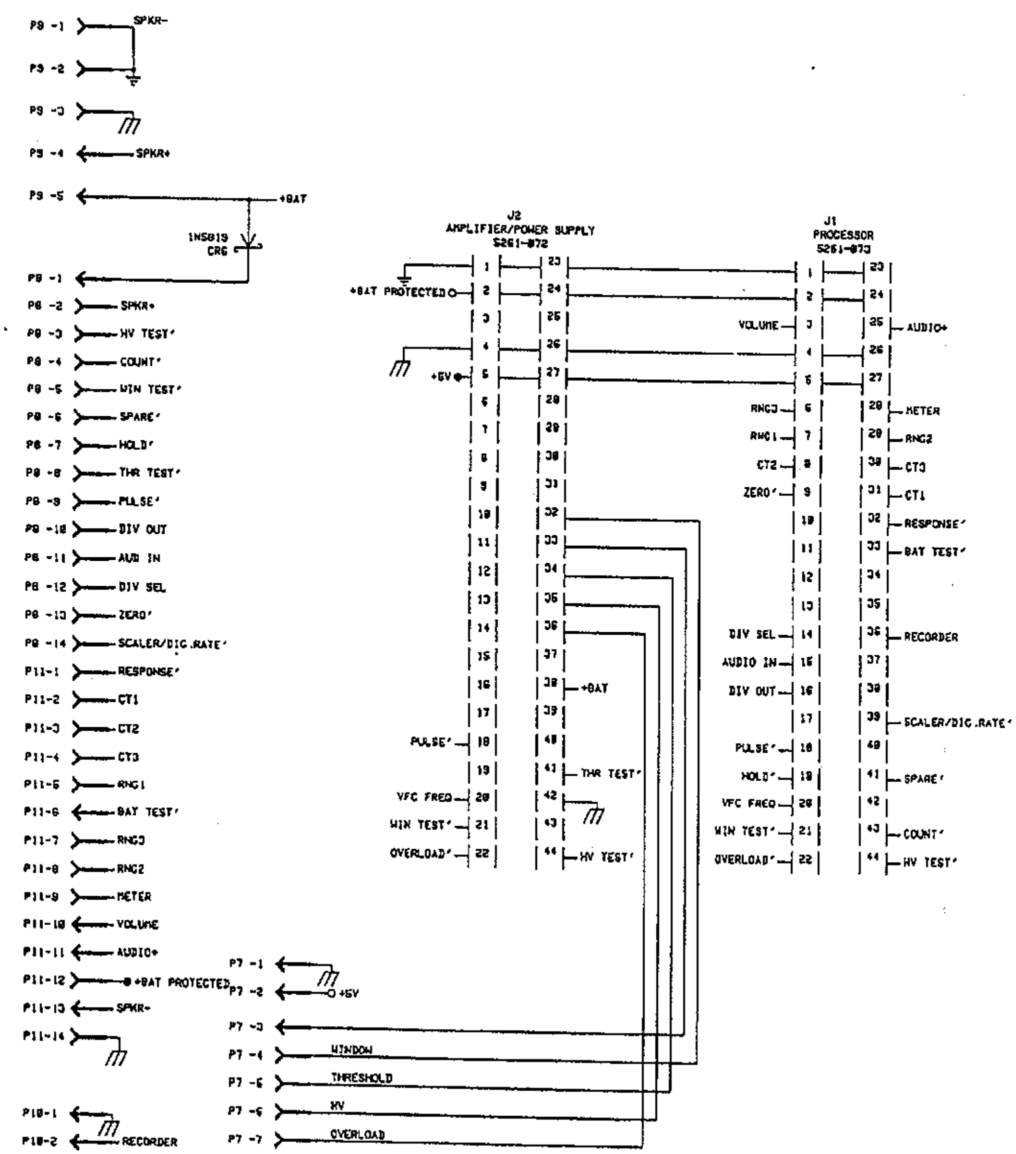
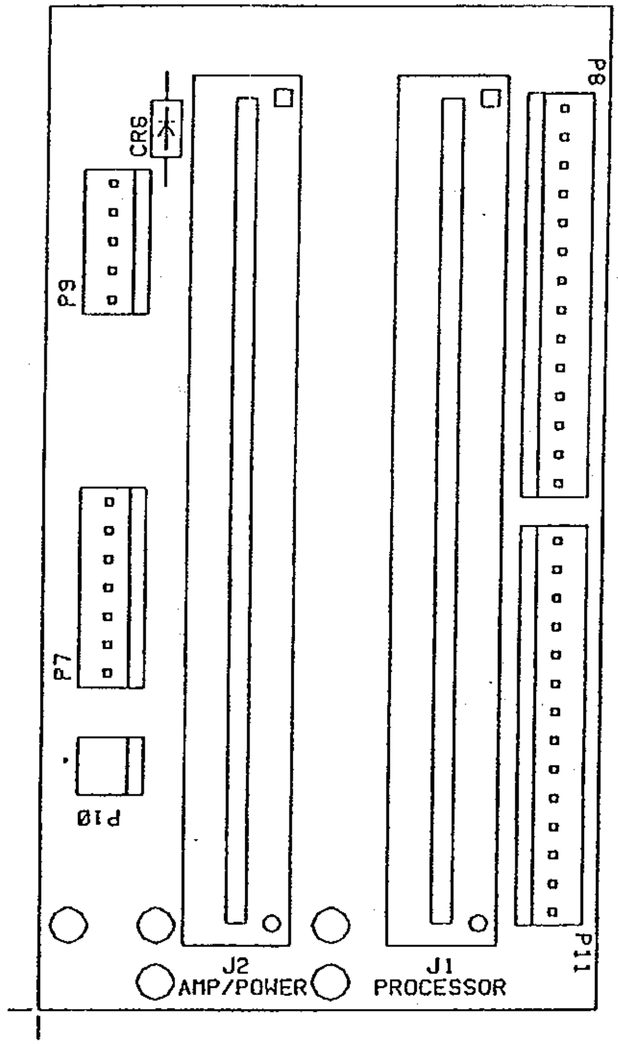



| REVISIONS | | | | | |
|---|---|---|---|---|---|
| EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED |

| | |
|---|---|
| CONTRACT | LUDLUM MEASUREMENTS INC. |
| DR LL 3/16/88 | TITLE: BACKPLANE |
| CHK R.C. 7/13/98 | |
| DSGN LL 3/16/89 | BOARD# 5261-076 |
| APPD BS 7/13/98 | SIZE D · MODEL 2221 · SERIES 261 · SHEET 60 |
| NEXT HIGHER ASSY. - | |
| 07:46:14 · 06-24-09 | S0261076.DRW · SHEET 1 OF 1 |




| | |
|---|---|
| BOARD# 5261-Ø76 | |
| TITLE BACKPLANE | |
| MODEL 2221 | |
| COMPONENT OUTLINES | |
| DR RDS | 3/28/89 |
| CHK R.C. | 7/13/98 |
| DSGN LL | 3/16/89 |
| APPD RSS | 7/13/98 |
| BS261Ø76.DRW | |
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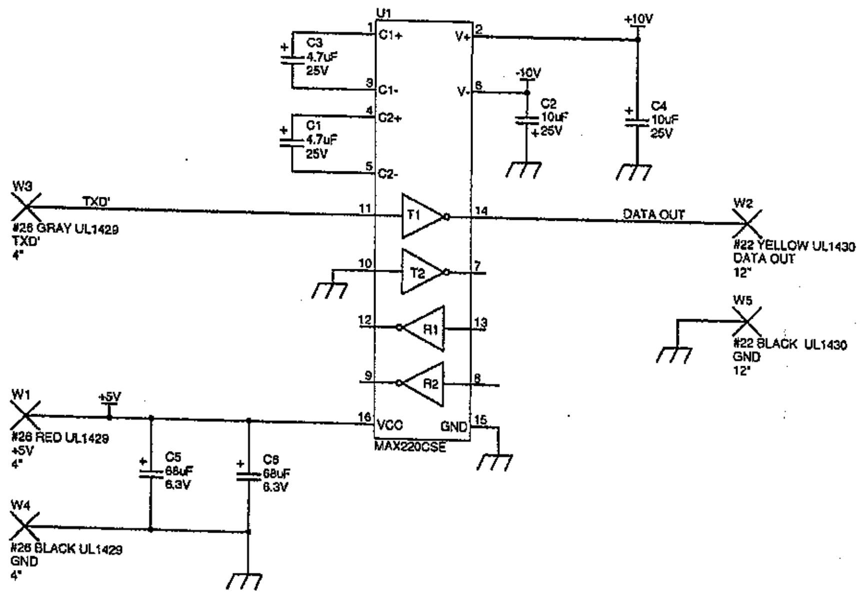
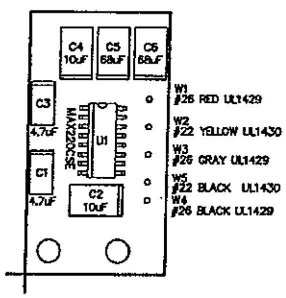



LUDLUM MEASUREMENTS, INC.

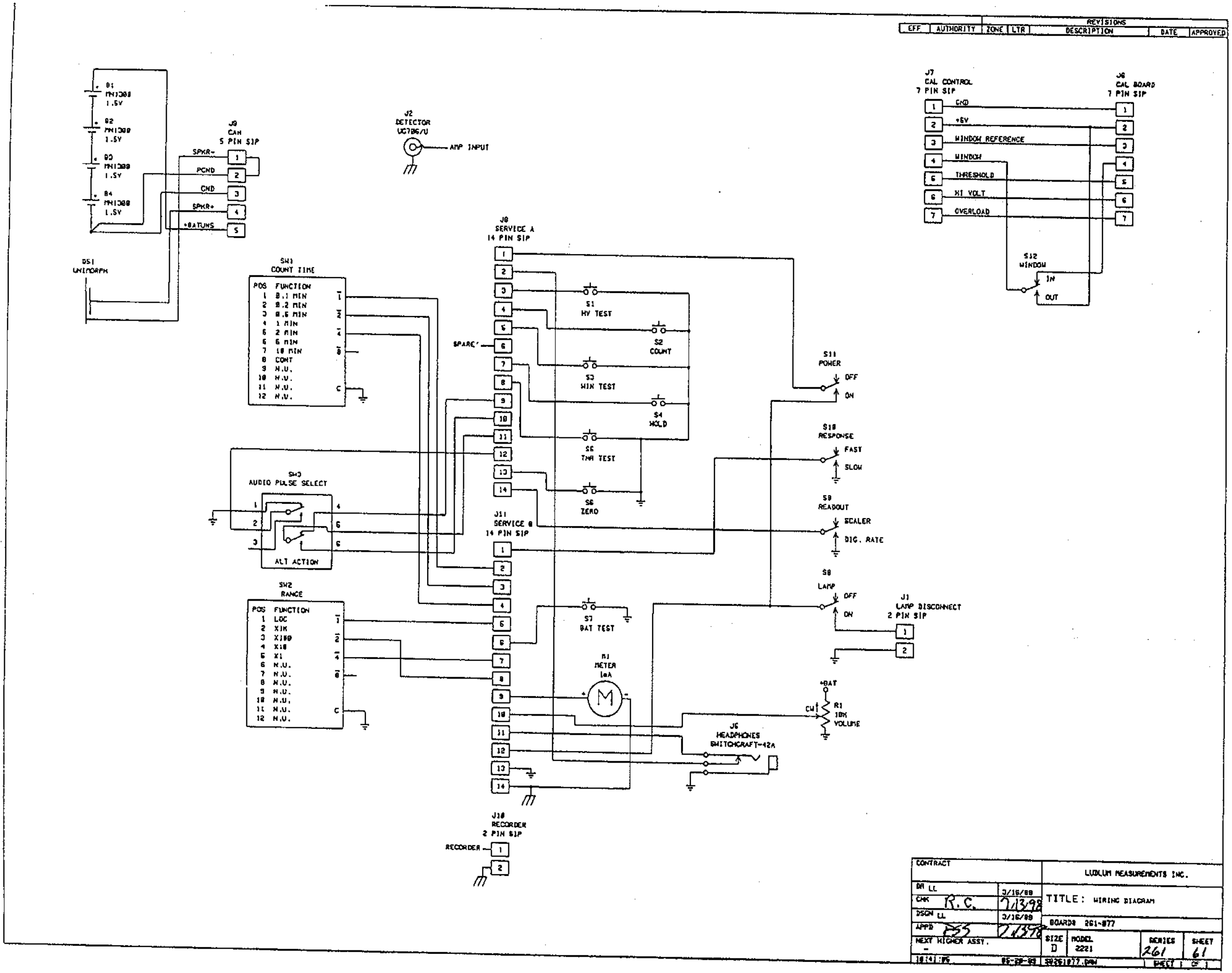
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

| | | |
|---|---|---|
| Drawn: CKB | 21-MAR-01 | Title: RS-232 BOARD |
| Design: RDS | 11-NOV-99 | Model: 2221 |
| Check: RC | Feb 4 02 | Board#: 5261-179 |
| Approve: | 4 Feb 02 | Sheet: 1 of 1 |
| 14:13:37 | 4-Feb-2002 | Rev: 1.0 |

Series 261 | Sheet 179




| | | | | | |
|---|---|---|---|---|---|
| Drawn: CKB | 21-MAR-01 | Title: RS-232 BOARD | | | |
| Design: RDS | 11-NOV-99 | | | | |
| Check: R.C. | Feb 4, 2002 | Model: 2221 | | | |
| Approve: RDS | 4Feb02 | Board#: 5261-179 | | | |
| Layer: Mech.1 Mech.2 Mech.3 Mech.4 | Top Overlay<br>MD:<br>14:02:28 4-Feb-2002 | Rev: 1.0 | | Series | Sheet |
| | | SCALE: 1.00 | | 261 | 180 |



REVISIONS
EFF
AUTHORITY
ZONE
LTR
DESCRIPTION
DATE
APPROVED
B1 MN1300 1.5V
B2 MN1300 1.5V
B3 MN1300 1.5V
B4 MN1300 1.5V
J9 CAN 5 PIN SIP
SPKR-
PGND
GND
SPKR+
+BATUNS
DS1 UNIMORPH
J2 DETECTOR UG706/U
AMP INPUT
J7 CAL CONTROL 7 PIN SIP
J6 CAL BOARD 7 PIN SIP
GND
+5V
WINDOW REFERENCE
WINDOW
THRESHOLD
HI VOLT
OVERLOAD
S12 WINDOW
IN
OUT
J8 SERVICE A 14 PIN SIP
SW1 COUNT TIME
POS FUNCTION
1 0.1 MIN
2 0.2 MIN
3 0.5 MIN
4 1 MIN
5 2 MIN
6 5 MIN
7 10 MIN
8 CONT
9 N.U.
10 N.U.
11 N.U.
12 N.U.
SPARE
S1 HV TEST
S2 COUNT
S3 WIN TEST
S4 HOLD
S5 THR TEST
S6 ZERO
S11 POWER
OFF
ON
S10 RESPONSE
FAST
SLOW
S9 READOUT
SCALER
DIG. RATE
SW3 AUDIO PULSE SELECT
ALT ACTION
J11 SERVICE B 14 PIN SIP
S8 LAMP
OFF
ON
J1 LAMP DISCONNECT 2 PIN SIP
SW2 RANGE
POS FUNCTION
1 LOC
2 X1K
3 X100
4 X10
5 X1
6 N.U.
7 N.U.
8 N.U.
9 N.U.
10 N.U.
11 N.U.
12 N.U.
S7 BAT TEST
M1 METER 1mA
+BAT
CW
R1 10K VOLUME
J5 HEADPHONES SWITCHCRAFT-42A
J10 RECORDER 2 PIN SIP
RECORDER
CONTRACT
LUDLUM MEASUREMENTS INC.
DR LL 3/16/89
CHK R.C. 7/13/98
DSGN LL 3/16/89
APPD 7/13/98
TITLE: WIRING DIAGRAM
BOARD# 261-077
NEXT HIGHER ASSY.
SIZE D
MODEL 2221
SERIES 261
SHEET 61
SHEET 1 OF 1
05-29-89
5W261077.DWG

# R-METRICS LTD.

389 DAVIS ROAD
OAKVILLE, ON. L6J 2X2
PHONE (905-338-1857)
FAX (905-315-8251)


R4375

**CALIBRATOR**
C.N.S.C. LICENCE No.: 07533-1-11.3

CERT. No.: 6772

## GAMMA RADIATION SURVEY METER CALIBRATION CERTIFICATE

**LICENSEE**

Procedure:RM-SM-01 Rev.1

| | | | |
|---|---|---|---|
| NAME: | Ashtead Technology Rentals | | |
| PHONE: | 905-607-9639 | C.N.S.C. LICENCE No.: | 13939-2-11.1 |

**SURVEY METER**

| | |
|---|---|
| MAKE: Ludlum | MODEL: 2241 |
| SERIAL No.:175617 | TYPE OF DETECTOR: PGM -Probe |
| METHOD OF CALIBRATION: | Attenuation Method |

**CALIBRATION SYSTEM IDENTIFICATION**

| | |
|---|---|
| MAKE: Amersham (Amertest) | MODEL: #773 |
| SERIAL No.: S-915 | ISOTOPE: Cs-137 |
| ACTIVITY OR EXPOSURE RATE: 157 mCi | DATE: (Year Month Day) 96/04/08 |

**PRE-CALIBRATION CHECKS**

| | | |
|---|---|---|
| BATTERY: OK | ZERO: OK | OPERATING VOLTAGE 930volts |
| ALARM: OK | OTHERS: 44-9 probe S/N PR 180199 | |
| TEMPERATURE: 70°F | PRESSURE: 99.9 kpa | HUMIDITY: 37% |

**CALIBRATION**

| TEST POINTS | RANGE | PRE-CALIBRATION | POST CALIBRATION |
|---|---|---|---|
| 100 µR/HR | Auto | 98 µR/HR | 98 µR/HR |
| 400 µR/HR | Auto | 399 µR/HR | 399 µR/HR |
| 1 mR/HR | Auto | 1.06 mR/HR | 1.06 mR/HR |
| 4 mR/HR | Auto | 4.2 mR/HR | 4.2 mR/HR |
| 10 mR/HR | Auto | 10.52 mR/HR | 10.52 mR/HR |
| 40 mR/HR | Auto | 40.2 mR/HR | 40.2 mR/HR |
| | | | |
| | | | |

**SUMMARY OF FINDINGS:** THIS METER MEETS CNSC REGULATIONS YES ( ✓ ) NO ( )
EACH SCALE IS CALIBRATED TO 20% AND 80% AS PER SECTION 4.5C OF C.N.S.C. REGULATIONS. This calibration certificate shall not be reproduced except in full without the express written consent of R-Metrics Ltd.

| | (Year/Month/Date) |
|---|---|
| Calibration Date: | 2011/03/30 |
| Calibration Due Date: | 2012/03/30 |

BY: Steve Gilbert (Print Name) — (Signature)

ORIGINAL COPY TO: LICENCEE

RETAIN COPY IN R-METRICS LTD. FILE

# LUDLUM MODEL 44-9
# ALPHA, BETA, GAMMA DETECTOR

**February 2010**
**Serial Number PR090405 and Succeeding**
**Serial Numbers**

# LUDLUM MODEL 44-9
# ALPHA, BETA, GAMMA DETECTOR

**February 2010**
**Serial Number PR090405 and Succeeding**
**Serial Numbers**


**LUDLUM MEASUREMENTS, INC.**
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

# Table of Contents

# Introduction

The Ludlum Model 44-9 GM (Geiger-Mueller) Detector detects alpha, beta, and gamma radiation. Its size and shape (pancake) provide easy handling for surveying or personnel monitoring. The detector is energy dependant, over-responding by a factor of 6 in the 60 keV to 100 keV range when normalized to $^{137}Cs$.

The thin mica window is protected by a 79% open stainless steel screen. The GM tube can be easily removed for replacement if necessary.

This detector operates between 850-1000 volts, with a recommendation from the tube manufacturer of approximately 900 Vdc. Recommended instrument input sensitivity is approximately 30 mV or higher to prevent the detector from double pulsing (where the detector "counts" a single pulse from the instrument multiple times.)

**Caution!**

The GM tube face can rupture above 8000 feet in altitude. When transporting this detector by air, use an airtight container in order to avoid sudden atmospheric changes resulting in tube failure.

The Ludlum Model 44-9 will operate with any Ludlum instruments or equivalent instruments that provide 900 Vdc and an input sensitivity of approximately 30 mV or higher.

# Unpacking and Repacking

Remove the calibration certificate or detector functional check certificate and place it in a secure location. Remove the detector(s) and accessories (if applicable) and ensure that all items listed on the packing list are in the carton. If multiple detectors are included, refer to the calibration certificates for serial number (SN) matches. The Model 44-9 serial number is located on the detectors' bottom plate.

To return an instrument or detector for repair or calibration, provide sufficient packing material to prevent damage during shipment (see "Caution!" in Introduction section) and affix appropriate warning labels to promote careful handling. The following items and information should also be included to ensure quick turnaround time of your equipment.

- instrument(s) and related cable(s)
- brief description as to the reason for return
- description of service requested
- return shipping address
- customer name and telephone number

# Specifications

Efficiency (**4π geometry**): typically 5% for $^{14}C$; 22% for $^{90}Sr/^{90}Y$; 19% for $^{99}Tc$; 32% for $^{32}P$; 15% for $^{239}Pu$; $\leq$ 1% for $^{99m}Tc$

Sensitivity: typically 3300 cpm per mR/hr ($^{137}$ Cs gamma)

Energy Response: energy dependent (please see graphs on page 7)

Background: 60 cpm

Dead Time: typically 80 μs

Window: 1.7 ± 0.3 mg/cm$^2$ mica

**Window Area:** active is 15 $cm^2$; open is 12 $cm^2$

**Detector:** pancake-type halogen quenched GM

**Detector Operating Voltage:** 900 Vdc

**Compatible Instruments:** general purpose survey meters, ratemeters, and scalers.

**Connector:** series "C" (others available)

**Construction:** aluminum housing with beige powder-coat finish; stainless steel protective screen (79% open)

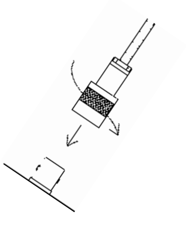
**Temperature Range:** -15 to 50 °C (5 to 122 °F); may be certified for -40 to 65 °C (-40 to 150 °F)

**Size:** 4.6 x 6.9 x 27.2 cm (1.8 x 2.7 x 10.7 in.) (H x W x L)

**Weight:** 0.5 kg (1 lb)

# Operating Procedures

## Connecting to an Instrument



Connect one end of the cable provided to the detector by firmly pushing the connector together while twisting clockwise a quarter of a turn until latched. Repeat the process in the same manner with the other end of the cable and the instrument.

## Testing the Detector

1. Ensure that the instrument high voltage (HV) is at the proper setting for the detector (900 volts)

2. Connect the detector to the instrument and check for a proper background reading (typically 25-50 cpm at 8-15 μR/hr).
3. Expose the detector to a check source and verify that the instrument indicates within 20% of the check source reading from the last calibration. Alternatively, expose the detector to a source of known value and verify that the detector detects greater than or equal to the efficiency listed in the specification section of this manual.
4. Instruments and detectors that meet these criteria are ready for use. Failure to meet these criteria may indicate a malfunction in the detector.

# Tube Replacement

Refer to drawing 2 × 206 located on page 7 of this manual to assist with replacement.

1. Remove the back plate by removing the three screws.
2. Loosen the three set screws on the side of the tube housing.
3. Remove the old tube from the detector housing.
4. Remove the anode clip from the old tube.
5. Push the clip onto the anode housing.

Note:

Do not over-flex the wire when installing the clip, as damage may occur.

Caution!

The mica window of this tube is extremely thin and fragile. There is also a thin layer of material to prevent UV interference. This material may come off if touched, causing the detector to malfunction. DO NOT TOUCH!

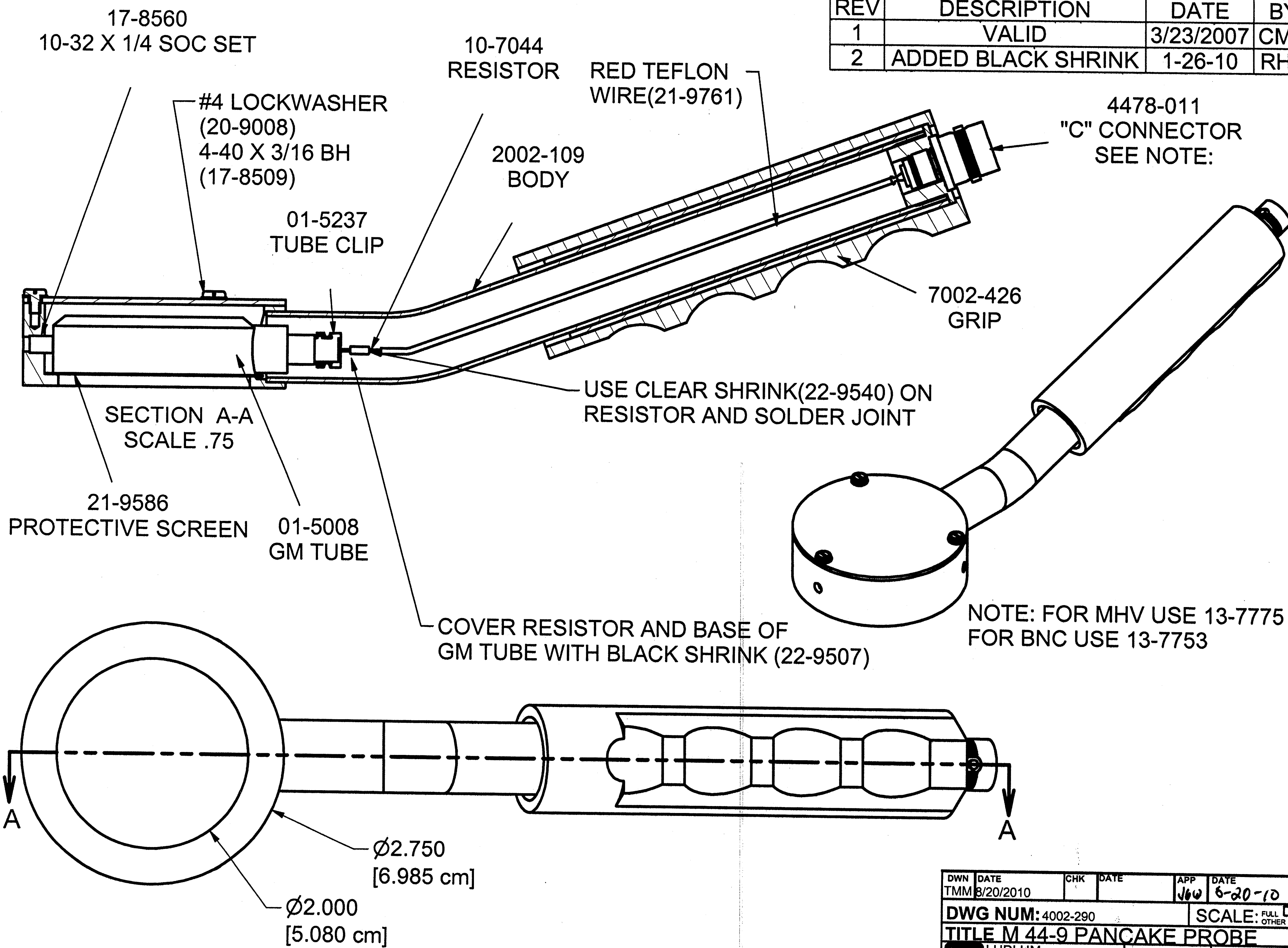
6. Carefully install the tube with the window facing down in the housing.
7. Ensure the tube is flush against the screen and tighten the set screws.
8. Replace the back plate and retaining screws.
9. Recalibrate the instrument and detector before use.

# Parts List

Model 44-9 Alpha-Beta-Gamma Detector

| Reference | Description | Part Number |
| --- | --- | --- |
| UNIT | Completely Assembled Model 44-9 Alpha-Beta-Gamma Detector | 47-1539 |
| * | DETECTOR BODY | 2002-109 |
| * | HANDLE GRIP | 7002-426 |
| * | GM TUBE (LND 7311, TGM N1002) | 01-5008 |
| 3 EA | SOCKET SET SCREWS (10-34 × ¼) | 17-8560 |
| * | PENCIL CLIP | 01-5237 |
| * | RESISTOR 3.3M | 10-7044 |
| * | CONNECTOR, UG706/U | 4478-011 |
| * | HV RED TEFLON WIRE | 21-9761 |
| * | PROTECTIVE SCREEN | 21-9586 |
| * | SNAP-IN FRONT COVER | 7002-1037 |

| REVISION HISTORY | | | |
|---|---|---|---|
| REV | DESCRIPTION | DATE | BY |
| 1 | VALID | 3/23/2007 | CMC |
| 2 | ADDED BLACK SHRINK | 1-26-10 | RHS |




NOTE: FOR MHV USE 13-7775
FOR BNC USE 13-7753

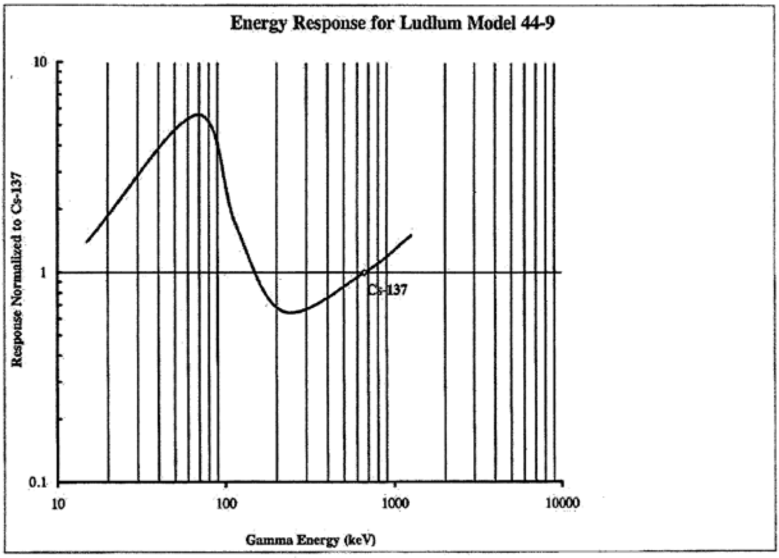
| DWN | DATE | CHK | DATE | APP | DATE |
|---|---|---|---|---|---|
| TMM | 8/20/2010 | | | J6W | 8-20-10 |

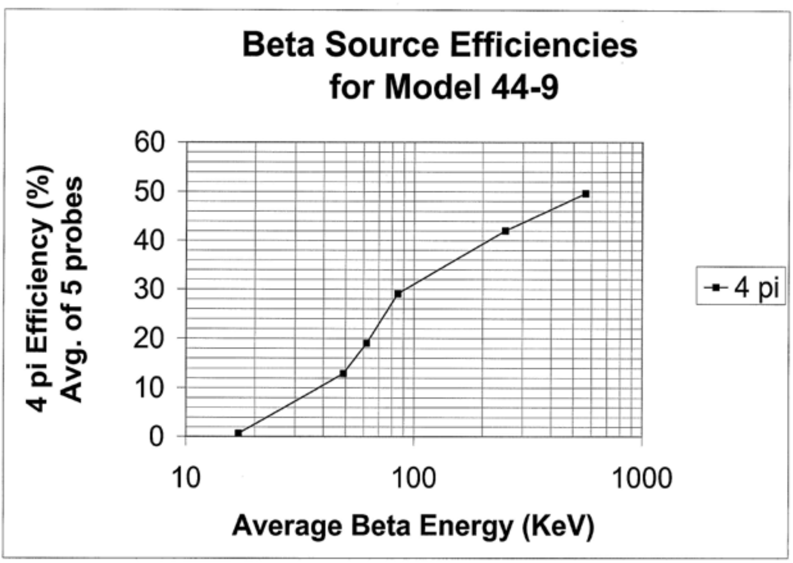
DWG NUM: 4002-290 SCALE: FULL / OTHER

TITLE M 44-9 PANCAKE PROBE

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556

SERIES 2 SHEET 206


Energy Response for Ludlum Model 44-9
Response Normalized to Cs-137
10
1
0.1
10
100
1000
10000
Cs-137
Gamma Energy (keV)


Beta Source Efficiencies
for Model 44-9
4 pi Efficiency (%)
Avg. of 5 probes
60
50
40
30
20
10
0
10
100
1000
Average Beta Energy (KeV)
4 pi

# LUDLUM MODEL 2241
# SURVEY METER

**March 2011**

**Serial Number 238822 and Succeeding**

**Serial Numbers**

# LUDLUM MODEL 2241
# SURVEY METER

**March 2011**

**Serial Number 238822 and Succeeding**

**Serial Numbers**

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

# Table of Contents

# Section 1

# Introduction

The Model 2241 is a portable microprocessor-based digital scaler/ ratemeter designed for use with scintillation, Geiger-Mueller (GM), and proportional type detectors to measure ionizing radiation. Data is presented on a four-digit (six digits in the Scaler mode) Liquid Crystal Display (LCD) with moving decimal point. A three-position switch labeled OFF/RATEMETER/SCALER selects the desired operating mode for the instrument.

Programmable display units (RATEMETER mode only) are represented in either R/hr, Sv/h, cpm, or cps with multipliers of micro (µ) or milli (m) for R/hr and Sv/h and kilo (k) for cpm or cps. The display units are auto-ranging, enabling the readout to display a broad range of radiation levels. The display also offers lower limit capability. For example, the display can be set to show only values that are greater than or equal to1 µR/hr.

This instrument incorporates independent adjustable alarms for RATEMETER and SCALER operating modes. The RATEMETER mode has two alarm indicators. The first-level alarm is indicated by display of the word "ALERT" on the LCD. The second-level alarm is indicated by display of the word "ALARM" and by the emitting of a continuous audible tone. The SCALER alarm condition will also display the word "ALARM" and produce the same audible tone. Both audible alarms may be silenced (acknowledged) by depressing the RESET switch. All alarms are concurrent.

Other features include Dead Time Correction (DTC) to compensate for detector dead time; audible click-per-event with programmable 1, 10, 100, and 1000 divide-by; LCD backlight with programmable "ON" time; programmable fixed or variable response time; and count overflow visual alarm, indicating that the counting circuitry is nearing the maximum counting capability.

All of the features described above may be programmed manually using the internal switch board or by computer through the RS-232 port. Two different detector operating parameters may be stored in non-volatile memory. The switch board can be removed after entering or changing parameters to prevent tampering with setup parameters.

A regulated high-voltage power supply, set-point control adjustable from 400 to 2400 volts with detector overload detection, and adjustable discrimination levels add versatility to the instrument. This supports operation for a broad range of detectors and connecting cable lengths. All of the calibration controls are covered to prevent any inadvertent adjustments to the detector operating parameters.

The instrument is powered by two standard ″D″ cell batteries. The unit body is made of cast-and-drawn aluminum with beige powder coating, which aids in the decontamination of surfaces.

Section

2

# Getting Started

## Unpacking and Repacking

Remove the calibration certificates and place them in a secure location. Remove the instrument, detectors, and accessories (batteries, cable, etc.), and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 2241 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

**Important!**

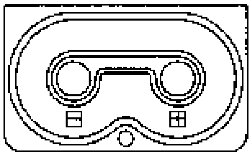
If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to a specific detector(s), and is therefore not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration. Include brief information as to the reason for return, as well as return shipping instructions:

- **Return shipping address**
- **Customer name or contact**
- **Telephone number**
- **Description of service requested and all other necessary information**

## Battery Installation

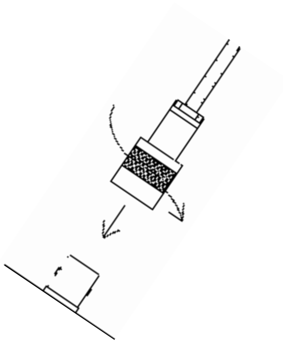
Ensure the OFF/SCALER/RATEMETER switch is in the OFF position. Open the battery lid by turning the quarter-turn thumb screw counterclockwise.



Install two "D" size batteries in the compartment. Note the (+) and (–) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid.

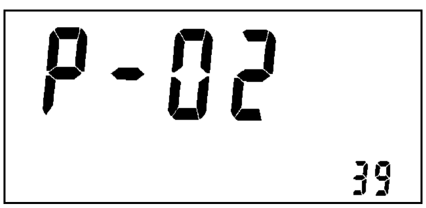
> Note:
>
> The center post of a "D" size battery is positive.

## Operational Check



Connect a detector to the Model 2241 by using the cable provided; firmly pushing the connectors together while twisting clockwise until the connector latches (one-quarter turn). The diagram to the left illustrates how this is done.

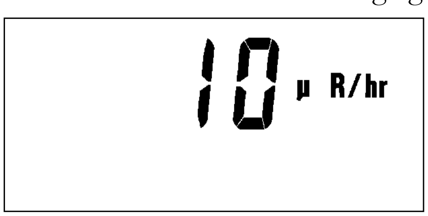
Turn the OFF/SCALER/RATEMETER switch to the RATEMETER position. Notice that the display goes through an initialization sequence. The display will show all 8s with decimal points. Check to make sure all segments display, as illustrated in the diagram to the left.




The LCD then displays the firmware number in the format "P-XX YY." The "XX" is the firmware number, and the "YY" is the firmware version. (The figure to the left is for example only; to illustrate location of display.)

The minimum displayable value (for example 00.0 µR/hr) should be shown. When switched to the SCALER position, a single 0 will be displayed.

The display will auto range to the current level (see figure at left). When auto ranging down, the Model 2241 uses multiples of 5. This technique keeps the decimal point from jumping between numbers when viewing values around multiples of 10.




Check for a proper background reading:

If using a Ludlum Model 44-9 detector, a typical reading would be 25-50 cpm or 8-15 uR/hr.

If using a Ludlum Model 44-2 detector, a typical reading would be 1.4-2.6 kcpm or 8-15 uR/hr.

A reference reading (or readings) with a check source should be obtained with the detector(s) in a constant and reproducible manner at the time of calibration or at the time the instrument is received in the field.

If at any time the instrument fails to read within 20% of the reference reading when using the same check source, it should be sent to a calibration facility for recalibration and/or repair. If desired, multiple readings may be taken at different distances and/or with different sources so that other ranges or scales are checked.

Switch the AUD ON/OFF switch to the ON position and confirm that the external unimorph speaker produces an audible click for each event detected (audio divide by 1 parameter). The AUD ON/OFF switch will silence the clicks if in the OFF position; however, an audible alarm condition will still be heard.

Increase the source activity or lower the alert and alarm points to initiate an ALERT and ALARM condition. (Refer to section 8, "Entering or Changing Switchboard Parameters.") Depress the RESET switch to acknowledge the audible alarm. Decrease the radiation activity below the ALERT and ALARM threshold and depress the RESET switch to clear the alarm conditions. If an alarm condition is not present, depressing the RESET switch the first time will reset the alert condition and zero the ratemeter.

Position a check source to produce a ratemeter reading of 100 to 2000 counts/minute or 10-100 μR/hr. While observing the ratemeter fluctuations, select between the fast and slow response time (F/S) positions to observe variations in the display. The "S" position should respond approximately five times slower than the "F" position (for fixed response mode) and three times slower when in variable response mode. The slow response position is normally used when the Model 2241 is displaying low numbers, which require a more stable display. The fast response position is used at high count levels.

Move the OFF/SCALER/RATEMETER switch to the SCALER position. Depress the COUNT switch located in the end of the carrying handle in order to initiate a count cycle. The word COUNTING should be flashing on the LCD during the count cycle and should disappear at the end of the predetermined count time. If a scaler ALARM condition occurs, the RESET switch can be depressed to acknowledge the alarm; however, the COUNT switch must be depressed to clear the visual ALARM and to restart the count cycle.

Depress and release the LIGHT switch. The backlight located behind the LCD should illuminate (for pre-programmed ON time). Select the desired F/S, AUD ON/OFF, and RATEMETER or SCALER parameters and proceed to use the instrument.

# Section 3

# Specifications

Instrument:

Linearity: Readings are within 10% of true value with a detector connected.

Warm-up Time: Unit may be used immediately after the LCD initialization sequence is completed (approximately five seconds after power-up).

Display: A four-digit Liquid Crystal Display (LCD) with digits one half inch in height. Two additional 0.5 cm (0.2 in.) digits are used for the overflow counter (SCALER mode) and exponential powers (parameter setup). Enunciators are provided for display units, ALERT, ALARM, low battery, detector OVERLOAD, counting OVERFLOW, and scaler COUNTING.

RATEMETER: Depending upon how the instrument was calibrated, the RATEMETER can display in either R/hr, Sv/h, cpm or cps when the control switch is in the RATEMETER position.

SCALER: activated by pushbutton in handle when the three-position switch is in the SCALER position. Count time is adjustable.

Calibration Controls: Accessible from the front of the instrument (protective cover provided). These controls are preset at the factory or calibration lab and should not be adjusted by field personnel.

Discriminator / Input Sensitivity: adjustable from 2 to 100 mV; negative pulse response

Overload: ondicated by OVERLOAD on the display; adjustable

High Voltage: adjustable from 400-2400 volts; regulated within 0.2% at 1000 Vdc; maximum load of 50 µA

RESET: a pushbutton for zeroing the display, acknowledging and/or resetting the alarm

**Note:**

The RESET button only silences the alarm in the current mode that the instrument is in. For example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

LIGHT: Display backlight activated by pushbutton.

Audio: built-in audio speaker (unimorph) with AUD ON/OFF switch; greater than 60 dB at 2 feet

Alert/Alarm: indicated by either an ALERT or ALARM enunciator on the display (RATEMETER mode only) and by an audible tone

Power: two each, ˝D˝ cell batteries housed in an externally accessible sealed compartment. Current draw is approximately 35 mA with the backlight OFF. Minimum battery voltage is 2.2 ± 0.1 Vdc.

Battery Dependence: Meter readings vary by less than 3% from fully charged batteries until the battery symbol appears, indicating the need for recharge or replacement.

Battery Life: typically 200 hours with alkaline batteries (display indicates low battery condition). Instrument will operate for approximately 24 hours after the battery symbol first appears.

Size: 16.5 x 8.9 x 21.6 cm (6.5 x 3.5 x 8.5 in.) (H x W x L)

Weight: 1.6 kg (3.5 lb), including batteries

Removable Switchboard Adjustable Parameters:

Backlight ˝ON˝ Time: 5, 15, 30, 60, 90, 120, 180. or 240 seconds for the backlight to stay on when activated by the pushbutton; factory set at ˝5˝.

Set Minimum Display: allows lower limit of the auto-ranging display to be fixed. For example, the display can be set to only show values above or equal to 1 µR/hr.

RS-232 Data Dump Mode: Enables or disables dump mode to the RS-232 port (˝D˝ type connector). When enabled, the data will be dumped every two seconds.

RS-232 Detector Setup Mode: allows for input of detector parameters via the RS-232 port

Baud Rate: selects either 150, 300, 600, 1200, 2400, 4800, 9600, or 19200 bps

Detector Dead Time Compensation (DTC): adjustable from 0 to 9999 microseconds

Calibration Constant: Adjustable from 0.001 to $280 \times 10^9$ counts/display unit

Display Units: can display in R/hr, Sv/h, cpm, or cps

Display Range: auto ranging from 0.0 μR/hr – 9999 R/hr; 0.000 μSv/hr – 9999 Sv/h; 0 cpm – 999 kcpm; or 0 cps – 100 kcps

Time Base: can display in seconds or minutes

Audio Divide: 1, 10, 100, or 1000 events per click

Response Time: variable or fixed ratemeter response (All stated times correspond to a range of 10% to 90% of the final reading.) Factory default is ˝variable˝ so that the instrument will automatically adjust the response time to the best setting for the current count rate.

> Variable Response: Dependent on the number of counts present. Typically 4 to 25 seconds for FAST, and 4 to 60 seconds for SLOW.
>
> Fixed Response: The parameter is adjustable from 1 to 25 resulting in a FAST response from approximately 2 to 50 seconds. The SLOW response is approximately 10 to 250 seconds. For MDA-type measurements, the fixed response mode is recommended.

Ratemeter Alert/Alarm: set at any point corresponding to the pre-selected ratemeter range

Scaler Alarm: adjustable from 1 to 999999 counts

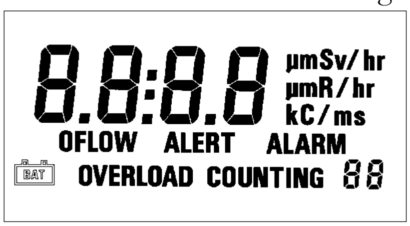
Scaler Count Time: adjustable from 1 to 9999 seconds

Section 4

# Identification of Controls and Functions

## Display

The Model 2241 utilizes a four-digit liquid crystal display (LCD) with two-digit overflow (SCALER mode) and moving decimal point. The two smaller digits located in the lower right corner of the display indicate counter OVERFLOW when in the scaler counting mode (equivalent to a six-digit scaler) or exponential power when in the parameter setup mode. The upper right corner of the LCD displays units and multiplier(s) - R/hr, mR/hr, or µR/hr; Sv/h, mSv/h or µSv/h; C/m, kC/m, C/s or kC/s. The bottom part of the readout displays the ALARM, ALERT, OFLOW, OVERLOAD annunciators and the low battery icon. COUNTING indicates that the scaler mode has been initiated and is in the counting process.




## Display Status Definitions

ALARM: Ratemeter or scaler count has increased above the preset alarm threshold. An audible continuous tone will accompany the "latching" ALARM condition. Depressing RESET will acknowledge the audible ratemeter and/or scaler alarm. Depressing RESET a second time will reset the ratemeter reading and ratemeter alarm. To reset the scaler ALARM, depress the COUNT switch located in the carrying handle to re-initiate the scaler count cycle.

ALERT: Ratemeter count has increased above the preset alert threshold. To reset an ALERT condition, press RESET once if in the non-alarm condition, and twice if in an alarm condition. (The first depression in the alarm condition acknowledges the audible alarm.) The ratemeter will reset to the minimum displayable reading each time the alert is reset.

OFLOW (Overflow): RATEMETER mode - Indicates that the incoming count exceeds the capability to display stable or reliable readings corresponding to the radiation level being measured. The overflow symbol will appear when the ratemeter exceeds 100k cps or if the dead time correction is greater than 75%. OFLOW will appear in the SCALER mode when the six-digit display (four digits display and 2 overflow digits in the right corner) reaches 999999 and starts to roll over again.

OVERLOAD: indicates that the detector is being exposed to radiation intensities greater than the detector maximum operating limit. For alpha and/or beta-type scintillation detectors, an OVERLOAD may indicate that the detector face has been punctured, allowing external light to saturate the photomultiplier tube inside the detector. The overload alarm point is set by adjusting the OVL control located underneath the calibration cover.

"low battery" icon: indicates that the batteries have decreased to the minimum operating voltage of 2.2 ±0.1 Vdc. Instrument will continue to operate for approximately 24 hours thereafter.

COUNTING: indicates that the scaler count switch has been depressed and that the scaler is accumulating counts for the pre-determined count time

## Front-Panel Controls

OFF/RATEMETER/SCALER Switch: a three-position rotary switch that applies power to the instrument and selects RATEMETER or SCALER counting mode.

AUD ON/OFF Switch: The clicks-per-event audio may be silenced or enabled via this front-panel toggle switch. The audible alarm is independent of the AUD ON/OFF switch and will override the audible clicks per event. An audible alarm can only be silenced by depressing the RESET button.

F/S (Fast/Slow) Response Switch: a two-position toggle switch that selects fast or slow counting response time

Variable Response: The “F” position allows the time constant (TC) to vary from 1 to 10 seconds, while the “S” position varies from 1 to 30 seconds. The response time is automatically adjusted in proportion to the incoming count rate between the “F/S” TC variables.

Fixed Response: The “F” position corresponds to the selected fixed response time - TC. The “S” position is five times slower than the selected fast TC.

LIGHT (LCD Backlight): A pushbutton switch, when depressed, illuminates the LCD for a pre-programmed time. The backlight ON time can be selected between 5 and 240 seconds during the parameter setup.

RESET Pushbutton Switch: In the non-alarm condition, depressing the RESET switch resets the ratemeter display to the minimum display readout. In an alarm condition (ratemeter or scaler), depressing RESET will silence the audible alarm. Depressing RESET a second time will reset the ratemeter alarm and/or alert condition. The scaler alarm can only be reset by depressing the scaler COUNT switch located in the end of the Model 2241 handle.

Note:

The RESET button only silences the alarm in the current mode that the instrument is in, for example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

Scaler COUNT Switch: Pushbutton switch located in the end of the Model 2241 carrying handle which, when depressed, initializes the start of the scaler count accumulation for the preset scaling time. The SCALER/RATEMETER switch must be in the SCALER position to initiate the counting cycle. The scaler display uses the two digits in the lower right-hand corner for the two most significant digits of the six-digit readout. Scaling time can be set from 1 to 9999 seconds in the parameter setup by way of the switch board. Depressing the COUNT switch after a scaler ALARM will reset the scaler display to 0, resetting the alarm condition.

## Front-Panel Calibration Controls

Note:

Remove the front-panel calibration cover to expose the following calibration controls:

DISC (Discriminator): a multi-turn potentiometer (approximately 20 revolutions), used to vary the detector pulse-counting threshold from 2 to 100 millivolts. A Ludlum Model 500 Pulser or equivalent should be used in checking or adjusting the pulse discrimination parameter.

**Note:**

When making adjustments to the HV potentiometer, make note of the following precautions: Use a Ludlum Model 500 Pulser or high-impedance voltmeter with a high-voltage probe to measure the high voltage at the detector connector. If a Ludlum Model 500 Pulser is not available, ensure that the impedance of voltmeter used is 1000 megohms or greater.

HV: a multi-turn potentiometer (approximately 20 revolutions) that varies the detector voltage from 400 to 2400 volts. The maximum high voltage output is adjusted by the HV LIMIT potentiometer located on the internal main board.

OVL (Detector Overload): A multi-turn potentiometer (approximately 20 revolutions) that adjusts the detector current level that must be exceeded to initiate an OVERLOAD alarm. This control adjusts the current level discrimination point from 0.5 and 40 microamperes, corresponding to the specific detector saturation point.

## Main Board Controls

**Note:**

To access the internal circuit boards, unlatch the latches at each end of the Model 2241. Carefully separate the top chassis from the bottom cover (referred to as a "can"). The can has the audio speaker (unimorph) with a two-conductor cable attached to the main board. The audio plug may be disconnected during the internal control adjustments.

HV LIMIT (R027): A multi-turn potentiometer (approximately 20 revolutions) sets the maximum HV limit with the front-panel HV control adjusted to the maximum clockwise position. It is adjustable from 1250 to 2400 Vdc.

VOLUME (R002): A multi-turn potentiometer (approximately 20 revolutions) varies the audible click-per-event and alarm audio. Adjust the control to the maximum clockwise position for maximum volume. If the VOLUME control is adjusted to the maximum counterclockwise position the clicks-per-event or the audible alarm(s) will not be audible when active.

## Switch Board Controls

The switch board utilizes a 16-position rotary switch (FUNCTION) to select the 16 setup parameters. (Refer to schematics and component layout drawing near the end of the manual.) All of the setup parameters are stored in the non-volatile EEPROM, which will retain data even after the Model 2241 batteries are removed. After the parameters are entered, the switch board can be removed and the Model 2241 will continue to operate from the previously programmed information. Changing parameters and information on switchboard controls are covered in detail in Section 8 of this manual.

Section 5

# Safety Considerations

## Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F)

Maximum relative humidity of less then 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

## Detector Connector

**Caution:**

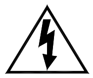
The detector operating voltage (HV) is supplied to the detector by way of the input connector. A mild electric shock may occur if contact is made with the center pin of the input connector. Switch the Model 2241 to the OFF position before connecting or disconnecting the cable or detector.

## Warning Markings and Symbols

**Caution!**

The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

The Model 2241 Survey Meter is marked with the following symbols:



**CAUTION, RISK OF ELECTRIC SHOCK** (per ISO 3864, No. B.3.6): designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.

**CAUTION** (per ISO 3864, No. B.3.1): designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

> Warning!
>
> The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:
>
> 1. Turn the instrument power OFF and remove the batteries.
> 2. Allow the instrument to sit for one minute before accessing any internal components.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding. Each material must be separated. The symbol is placed on the battery compartment. See Section 9, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union.

Section 6

# Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2241 instrument may be externally cleaned with a damp cloth (using only water as the wetting agent). Do not immerse the instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.

2. Allow the instrument to sit for one minute before performing any external cleaning or accessing internal components for maintenance.

## Recalibration

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered to be maintenance and do not normally require the instrument to be recalibrated.

> **Note:**
>
> Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate regulations to determine required recalibration intervals.

Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments, but most other manufacturers' instruments as well.

See Section 8, "Instrument Setup," for further details on instrument calibration.

## Batteries

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very dusty or corrosive atmosphere, more frequent battery servicing should be used. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removing the handle will facilitate access to these contacts.

**Note:**

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure can occur at temperatures as low as 38 °C (100 °F).

Section 7

# Technical Theory of Operation

Refer to the Main Board schematic for the following:

## Detector Input/Amplifier

Negative-going detector pulses are coupled from the detector through C021 to Amplifier U021. R024 and CR021 protect the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R022, divided by R025. Transistor pins 4, 5, and 6 of U021, provide amplification. Pins 10-15 of U021 are coupled as a constant current source to pin 6 of U021. The output is self-bias to 2 Vbe (approximately 1.4 volts) at pin 7 of U021. This provides just enough bias current through pin 6 of U021 to conduct all of the current from the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminator (U011) through R031 and C012.

## Discriminator

Positive pulses from amplifier U021 are coupled to pin 2 of U011 comparator. The discrimination level is set by the DISC control connected to pin 3 of U011. As the positive pulses at pin 2 of U011 increase above DISC reference at pin 3, pin 1 goes low, producing a low pulse. Pin 1 of U011 is normally held high (+5 volts) by R014.

The low pulse from pin 1 of U021 is coupled to univibrator U001. U001 shapes and fixes the pulse width to approximately 10 µs. The Univibrator is configured in the non-retriggerable mode. Negative pulses from pin 9 of U001 are coupled to the µP for counting.

## Low-Voltage Supply

Battery voltage is coupled to DC-DC converter U231. U231 and related components provide +5V to power the µP, op-amps, and logic circuitry. R135 and R136 provide voltage division for low-battery detection. Pin 6 of U231 provides a low signal when the battery voltage decreases to +2.2 ±0.1 Vdc. U121 provides the +2.5 Vdc reference for the HV and DISC control references.

## High-Voltage Supply

High voltage is developed by blocking oscillator Q241, T141, and C244 and rectified by voltage multiplier CR041-CR043, C041-C043, and C141. High voltage increases as current through R241 increases, with maximum output voltage with Q241 saturated. High voltage is coupled back through R034 to op-amp pin 2 of U131. Resistor network R027, R132 completes the HV division circuit to ground. R027 provides HV limit from 1250-2400 when the HV control on the calibration board is at maximum. The regulated HV output is controlled by the HV1 and HV2 potentiometers located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U131. During stable operation, the voltage at pin 2 of U131 will equal the voltage at pin 3 of U131. Pin 1 of U131 will cause conduction of Q141 to increase or decrease until the HV finds a level of stability.

## Detector Overload

A voltage drop is developed across R031 and sensed by comparator pins 5, 6, and 7 of U131 as detector current increases. When the voltage at pin 5 of U012 goes below pin 6, pin 7 goes low, signaling U111 (µP) to send the OVERLOAD alarm to the LCD. OVL (underneath CAL cover) control provides adjustment for the overload set point.

## Microprocessor (µP)

U111 controls all of the data, control inputs, and display information. The clock frequency is crystal-controlled by Y221 and related components at 6.144 MHz. The µP incorporates internal memory (ROM), storing the program information. U1 resets the µP at power-up to initiate the start of the program routine. During the program loop, the µP looks at all the input switches for initiation or status changes and responds accordingly. U122 is a 256 x 8 bit EEPROM used to store the setup parameters. The information is transferred serially from the µP. The EEPROM is non-volatile and retains memory even after power is removed.

## Audio

Click-per-event, divide-by, and alarm audio pulse frequency is generated by the µP and coupled to Q101. Q101 then inverts the pulses and drives the bottom of T101. Bias voltage is provided by the volume control (R002) to the top of T101.

Refer to the Switch Board schematic for the following:

## S1 (FUNCTION)

S1 is a 16-position binary rotary switch, which selects the programmable parameters for the Model 2241. The switch selects the parameters using the hexadecimal numbering system via buss lines SW1-SW4.

## S2-S4

S2-S4 are pushbutton switches that enter/change the variables for each of the 16 parameters.

## U1

U1 is a +5V powered RS-232 driver/receiver used to interface the Model 2241 to a computer.

Refer to Display Board schematic for the following:

## LCD Drive

U1 and U2 are serial input 32-bit LCD drivers. The data is loaded serially into the 32-bit shift registers (internal) via the "D" IN input. The LOAD input instructs the shift register to receive data while the CLOCK input shifts the data through the 32-bit registers. After all the data is loaded, the LOAD line is pulsed by the µP, instructing the registers to transfer the data to the LCD drivers. The backplane (BP) signal from U2 provides the reference signal (approximately 125 Hz at 5 Vdc) to the LCD (DSP1) BP connection. When a segment is illuminated, the signal to that segment will be out-of-phase with the BP signal. If the segment is OFF, the signal will be in-phase with the BP signal.

## Backlight Drive

Depressing the LIGHT button instructs the µP to set the BACKLIGHT line, pin 31 on µP, "low" for the predetermined backlight ON time. (Refer to main board schematic for details.) A "low" condition on pin 31 causes Q212 to conduct, sending +3V to P8-3 on display board (refer to display board schematic). Backlight oscillator Q011, T011 and related components start to oscillate, producing a 2.5 kHz sine wave signal. The signal is amplified by T011 to 150 volts peak-to-peak to drive the LCD backlight.

Section
8

# Instrument Setup

## Entering or Changing Switch Board Parameters

On the switch board, select the desired parameter to enter or change by using the corresponding FUNCTION switch position. Depress the ENTER button and a character on the LCD will start to flash. The flashing character indicates that the program is in the parameter change mode.

To change the character, press the UP button until the desired variable is reached. To shift to another character, increment the LEFT pushbutton until the desired character is reached. The LEFT pushbutton enables the operator to sequence through all the characters on the LCD associated with a particular parameter.

Once the desired data is entered, depress the ENTER button. The LCD characters should stop flashing and the new parameter data should display.

To read pre-programmed setup parameters, switch the FUNCTION switch to position A and select the pre-programmed detector setup number, using the parameter change procedure above. Once the detector setup number is entered, sequence through the parameters by varying the function switch to read the variables for that specific detector number.

Note:

Once the detector setup number has been entered, the function switch can be rotated either direction to view the parameter variables.

### THE FUNCTION SWITCH

FUNCTION Switch: a 16-position rotary switch labeled "0-9" and "A-F." This switch selects a parameter setup mode for the Model 2241. If the board is not installed, the normal operation mode (counting mode) is selected. If the switch board is installed, the selector switch must be set to the 0 position for normal instrument operation. The following may be changed using the switch board, and are discussed in detail in this section:

Detector Parameters
Current Detector Setup in Use
RS-232 Communication Baud Rate
RS-232 Data Dump Mode
RS-232 Detector Parameters Set/Read Mode

## FUNCTION SWITCH POSITION DESCRIPTIONS AND VARIABLES

POSITION 0: NORMAL OPERATION places the Model 2241 in the normal (counting) operating mode. Unplugging the switch board from the Model 2241 main board defaults to the normal operating mode.

POSITION 1: DEAD TIME (µs) allows changing the detector dead time correction for the current detector setup. Setting this parameter to 0 disables dead time correction. The dead time adjusts from 0 to 9999 microseconds (µs). The incoming counts are adjusted for dead time using the following formula: where,

$$n = \frac{m}{1 - m\tau}$$

n = corrected counts per second
m = incoming count per second
τ = system dead time

POSITION 2: CALIBRATION CONSTANT allows changing the calibration constant for the current detector setup. The calibration constant (CC) adjusts from 0.001 to 280 X $10^9$. The calibration constant converts counts/time base to units/time base. The CC must be set to 1 to readout in cps (counts per second) or cpm (counts per minute).

$$CC = \frac{cps \times time\ base}{rate}$$

CC CONVERSION TABLE

| Conversion Rate | Multiply by to get CC |
|---|---|
| cps/µR/hr | $3.6 \times 10^9$ |
| cps/mR/hr | $3.6 \times 10^6$ |
| cps/R/hr | $3.6 \times 10^3$ |
| cpm/µR/hr | $6.0 \times 10^7$ |
| cpm/mR/hr | $6.0 \times 10^4$ |
| cpm/R/hr | $6.0 \times 10^1$ |
| cps/µSv/h | $3.6 \times 10^7$ |
| cps/mSv/h | $3.6 \times 10^4$ |
| cps/Sv/h | $3.6 \times 10^1$ |
| cpm/µSv/h | $6.0 \times 10^5$ |
| cpm/mSv/h | $6.0 \times 10^2$ |
| cpm/Sv/h | 0.6 |

**Example:**

The Model 44-9 GM detector produces approximately 3300 cpm/mR/hr for $^{137}Cs$: $\rightarrow$ 6.0 x $10^4$ x 3300 = 198 x $10^6$ for CC.

POSITION 3: DISPLAY UNITS selects the display units for the associated detector setup number. The Model 2241 and detector may be calibrated in either exposure rate (R/hr or Sv/h) by entering the appropriate Calibration Constant (position 2) and Dead Time correction (position 1). The Model 2241 will automatically convert to the correct reading when switching between R and Sv.

The time base for count "C" is set independently in position 4. The display units may be set to:

R/hr (Roentgens per hour)
Sv/h (Sieverts per hour)
C/time base (Counts per time)

The display is auto-ranging with the appropriate multiplier symbol appearing in front of the "R," "Sv," or "C," indicating the range:

μR/hr, mR/hr, R/hr
μSv/h, mSv/h, Sv/h
C/s, kC/s, C/m, kC/m

POSITION 4: TIME BASE is set to CPS or CPM, which selects the display time base for the current detector setup. This time base only applies if the units are set to C/ (Counts/time). The time base for R/hr and Sv/h is fixed in "hr." For "true" reading (Pulser calibration) cpm or cps calibrations, set the Calibration Constant (CC, parameter 2) to read "1." For geometry calibrations, the detector efficiency can be entered for CC.

**Example:**

For alpha scintillation detector with 25% 2π efficiency, enter 250 x $10^{-3}$ in the CC parameter setup.

The display time base may be set to:

seconds (**s**)
minutes (m)

POSITION 5: AUDIO DIVIDE BY selects the audible clicks-per-event division rate for the current detector setup. If the AUD ON OFF switch is in the OFF position, no audible clicks per event will be heard.

This parameter ranges from:

0 / Divide-By 1
1 / Divide-By 10
2 / Divide-By 100
3 / Divide-By 1000

POSITION 6: RESPONSE TIME allows changing the time constant (TC) for the current detector setup. If the response is set to 0, the Model 2241 automatically calculates (for variable mode) the time constant based on the incoming cps. If a variable of 1-199 is entered for TC, the response time becomes fixed.

Variable Response: Response time is varied in proportion to the incoming count rate. The two-position F/S (Fast/Slow) toggle switch selects the maximum time constant (TC) for the variable mode. The fast position varies the TC from 4-25 seconds, and the slow position varies from 4-60 seconds.

Fixed Response: The Fast (F) response position is programmable from 2-50 seconds, and the slow response is five times slower than the fast TC. For MDA-type measurements, the fixed response time mode is recommended.

POSITION 7: RATEMETER ALARM/ALERT allows changing the ratemeter alarm for the current detector setup. The units of this alarm are the same as the units for the ratemeter display. The fifth push of the left button allows the decimal point to be moved. The ratemeter alarm adjusts from 1 to 999 R/hr (or Sv/h), 1 to 999 kcpm, or 1 to 999 kcps. The units of the alarm are determined by the units for the ratemeter.

POSITION 8: SCALER ALARM/COUNT TIME sets the scaler alarm variable from 1-999999, corresponding to the accumulated scaler count. After the scaler alarm variable is entered, the scaler count time is prompted. The scaler count time is adjustable from 1-9999 seconds.

POSITION 9: NOT USED

POSITION A: DETECTOR SETUP NUMBER allows the current detector setup to be changed to one of the six different detector setups. The detector setups are stored in EEPROM. Enter the detector setup number first before entering or changing the related detector parameters.

POSITION B: LCD Backlight ON TIME is the amount of time that the LCD backlight will stay on after pressing the front-panel switch labeled LIGHT. This value is stored in EEPROM.

Available values are:

5 seconds
30 seconds
60, 90 seconds
180, 240 seconds.

POSITION C: SET MINIMUM DISPLAY sets the ratemeter minimum displayable reading. Depressing the RESET button displays the minimum ratemeter units. The readout will auto-range up to the maximum displayable but will display 0 for ratemeter readings below the user-programmed minimum variable.

Minimum displayable values are:

00.0 µ, 000 µ, 0.00 m, 00.0 m, 000 m, 0.00, 00.0, 000 R/hr

.000 µ, 000 µ, 00.0 m, 000 m, 0.00, 00.0, 000 Sv/h

0.00, 00.0, 000, 0.00 k, 00.0 k, 000 kcpm or cps

POSITION D: RS-232 DATA DUMP MODE allows the RS-232 port to dump ratemeter data every two seconds. The Model 2241 is fully functional during RS-232 data dump with the exception of the audio function. The LCD will alternate between display of the ratemeter and the word "**dUP**" (representing "dump").

POSITION E: RS-232 DETECTOR PARAMETERS SETUP MODE allows the RS-232 port to accept/send a string of parameters corresponding to the current detector setup values.

POSITION F: BAUD RATE configures the RS-232 port for the following baud: 150, 300, 600, 1200, 2400, 4800, 9600, and 19200. The data is 8 data bits, 1 stop bit with no parity bit. This value is stored in EEPROM. The baud rate can only be programmed through the switch board.

RS-232 PORT CONNECTOR: This 9-pin "D" type connector is designed as a DCE port. A straight wire cable (extension cable) connects the Model 2241 to a computer's 9-pin RS-232 port.

RS-232 CONNECTOR PIN OUT:

| PIN | FUNCTION |
|---|---|
| 1 | NC (No Connection) |
| 2 | DATA OUT |
| 3 | DATA IN |
| 4 | NC |
| 5 | NC |
| 6 | NC |
| 7 | HANDSHAKING IN |
| 8 | HANDSHAKING OUT |
| 9 | NC |

**Note:**

Ludlum Measurements, Inc. offers a PC compatible software program, which incorporates the read/write commands necessary to communicate between the PC and the Model 2241. The program also incorporates an algorithm to calculate the detector Calibration Constant and Dead Time Constant. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024).
Read the Software License Agreement at the end of this section prior to installing any LMI software. If you cannot comply with the agreement, DO NOT install the software.

## Loading Default Parameters

To load the default parameters for all detector setups, hold down the UP pushbutton on the switch board until DEF is displayed on the LCD. The following table shows the default values.

| **Model 2241** | **cpm** | **cpm** | **cpm** | **cpm** | **cpm** | **cpm** |
|---|---|---|---|---|---|---|
| | **Setup 01** | **Setup 02** | **Setup 03** | **Setup 04** | **Setup 05** | **Setup 06** |
| | | | | | | |
| Dead Time | 0 s | 0 µs | 0 µs | 0 µs | 0 µs | 0 µs |
| Cal Const | 100e-2 | 100e-2 | 100e-2 | 100e-2 | 100e-2 | 100e-2 |
| Rate Alarm | 50.0 kcpm | 50.0 kcpm | 50.0 kcpm | 50.0 kcpm | 50.0 kcpm | 50.0 kcpm |
| Scaler Alarm | 85000 | 85000 | 85000 | 85000 | 85000 | 85000 |
| Count Time | 12 Secs | 12 Secs | 12 Secs | 12 Secs | 12 Secs | 12 Secs |
| Time Base | Mins | Mins | Mins | Mins | Mins | Mins |
| Units | cpm | cpm | cpm | cpm | cpm | cpm |
| Audio Divide-By | 1 | 1 | 1 | 1 | 1 | 1 |
| Response | 0 | 0 | 0 | 0 | 0 | 0 |
| Check Source | 0 | 0 | 0 | 0 | 0 | 0 |
| Percent CS | 0 | 0 | 0 | 0 | 0 | 0 |
| Rate Alert | 20.0 kcpm | 20.0 kcpm | 20.0 kcpm | 20.0 kcpm | 20.0 kcpm | 20.0 kcpm |
| Min Display | 0.00 cpm | 0.00 cpm | 0.00 cpm | 0.00 cpm | 0.00 cpm | 0.00 cpm |
| | | | | | | |
| Baud Rate | 9600 | | | | | |
| LCD Time Off | 5 seconds | | | | | |
| Detector | 0 | | | | | |

## Calibration

The Model 2241 calibration routine consists of entering detector parameters into memory by way of the switch board and adjusting the CAL controls (HV, DISC, and OVL) for the specific detector operating requirements.

The first subsection of calibration will give a general overview of detector setup, including the determination of various detector operating voltages (HV) and the adjustment of counter input sensitivity (DISC).

The next subsection deals with pulse generator counts-per-minute calibration. The counts-per-minute parameter setup is used in the initial instrument checkout procedure, and the variables are saved under detector setup number “1” when shipped from Ludlum Measurements, Inc.

The following subsection deals with exposure-rate calibration. The detector Calibration Constant (CC) and Dead Time Correction (DTC) are the two primary parameters used in the exposure-rate calibrations (R/hr and Sv/h). These two constants are alternately varied to achieve linearity at the detector non-linear operating regions. An example of the Ludlum Model 44-9 GM detector calibration is given at the end of this section to illustrate the algorithm used in determining the CC and DTC variables.

The last subsection of calibration deals with the Detector Overload (OVL).

### GENERAL DETECTOR SETUP INFORMATION

The operating point for the instrument and probes is established by setting the probe voltage and instrument sensitivity (HV and DISC). The proper selection of this point is the key to instrument performance. Efficiency, background sensitivity, and noise are fixed by the physical makeup of the given detector and rarely vary from unit to unit. However, the selection of the operating point makes a marked difference in the apparent contribution of these three sources of count.

In setting the operating point, the final result of the adjustment is to establish the system gain so that the desirable signal pulses (including background radiation) are above the discrimination level and the unwanted pulses from noise are below the discrimination level and are, therefore, not counted.

The total system gain can be controlled by adjusting either the instrument sensitivity or the high voltage. HV controls the gain of the detector; and DISC (Discriminator) controls the instrument counting threshold (sensitivity).

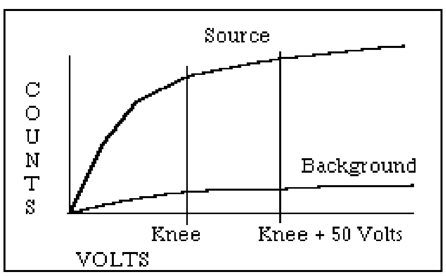
In the special case of GM detectors, a minimum voltage must be applied to establish the Geiger-Mueller characteristic. Further changes in HV will have little effect on this type of detector.

GM Detectors: The output pulse height of the GM detector is not proportional to the energy of the detected radiation. Adjusting DISC will have minimal effect on observed count rate unless the DISC setting is so low that the instrument will double pulse.

For most GM detectors, set DISC for 30-40 millivolts and adjust HV to the GM detector recommended high voltage. Most GM detectors operate at 900 volts, although some miniature detectors operate at 450-550 volts. If a recommended setting is unavailable, plot count rate versus HV to produce a plateau graph. Adjust the HV for 25-50 volts above the knee or start of the plateau. For mixed detector use, both sensitivity and high voltage may be "tailored" for other detectors as long as the GM detector is operated within the recommended voltage range. Caution must be observed in lowering the input sensitivity to ensure that the counter does not double or multi pulse.

Alpha Air-Proportional Detectors: For air proportional alpha detectors, set the DISC for 2-millivolt discrimination. Adjust HV until the detector just breaks down (shown by a rapid increase of count rate without a source present). Measure the HV output; then decrease the HV setting to operate 100 volts below breakdown.

Proportional Detectors: For proportional detectors, set the DISC control for 2-millivolt discrimination (near maximum clockwise). Expose the detector to a check source and plot count rate versus HV, similar to the one in the figure below. Refine the HV adjustment for optimum source efficiency with a minimum acceptable background count.




Scintillators: Set the DISC for 10 millivolts. Plot background and source counts versus HV to produce a plateau graph similar to the one in the figure. Adjust the HV to 25-50 volts above the knee or start of the plateau. This provides the most stable operating point for the detector.

### COUNTS PER MINUTE (C/M) CALIBRATION

This procedure will setup the Model 2241 for the counts per minute (C/m) mode of operation. Refer to Section 8, (Page 8-2 and following) for more information on setting up parameter variables.

A Ludlum Model 500 Pulser or equivalent is required. If the pulser does not have a high-voltage display, use a high-impedance voltmeter with at least 1000 megohms input resistance to measure the detector high voltage.

Switch SCALER/RATEMETER to the RATEMETER position.

Select FUNCTION switch positions "1-6" and adjust for the following parameters:

| Switch Pos. | Parameter | Function |
|---|---|---|
| 1 | 0000 $s_{-6}$ | Dead Time |
| 2 | 0100 -2 | Calibration Constant |
| 3 | c/ | Display Units |
| 4 | m | Timebase |
| 5 | 1 | Audio Divide-by |
| 6 | 000 s | Response Time |

Position 7 selects the desired ratemeter ALERT and ALARM trip points.

If the parameters are undetermined, arbitrarily choose "0050 kC/m" for the alarm and "0045 kC/m" for the alert to confirm operation of the alert/alarm function.

Position 8 selects the scaler ALARM parameter and the scaler count time.

If the values are unknown, set the scaler alarm to "$4500_{ALARM00}$" and the count time to "0060" (60 second count time).

Position 9 is not used, and position A is not used.

Switch to position B and enter "15" for a 15-second backlight "ON" time.

Switch to position C and enter "00.0 C/m" for the minimum displayable value.

Select position 0 to return to normal operation.

Connect the Model 500 Pulser to detector input and adjust HV and DISC to the specific detector operating parameters.

- Adjust the pulser amplitude to 1.5 times the Model 2241 discrimination level.
- Adjust the pulser output to 800 cpm and confirm that the Model 2241 reads 800 C/m ± 10% on the ratemeter setting.
- Adjust the pulser output to 200 cpm and confirm that the Model 2241 reads 200 C/m ± 10% on the ratemeter setting.
- Adjust the pulser output to 800 cpm, take a one-minute count, and confirm that the digital scaler readout displays 800 C/m ± 2%.
- Adjust the pulser output to 200 cpm, take a one-minute count, and confirm that the digital scaler readout displays 200 C/m ± 2%.
- Confirm that the 20% and 80% readings for the upper decades are within the pulser input by decading the pulser count output.
- Confirm that the scaler readout is within 2% of the pulser input rate.
- Ensure that the ALERT and ALARMs function by inputting the preset alarm levels as to initiate the alert and alarm conditions.

### R/hr CALIBRATION

The following calibration procedure assumes that detector Calibration Constant (CC) and Dead Time Constant (DTC) are already known. If these constants must be determined, reference the following subsection, "Determining CC and DTC."

Switch the toggle switch to DET2. Detector setup number 1 is usually reserved for the counts per minute parameter calibration. Rotate the FUNCTION switch counterclockwise to position 1 and enter the detector Dead Time in µs. Rotate to position 2 and enter the Calibration Constant. Enter the desired parameters for positions 3-F. Switch to position 0 for normal operation.

Expose the detector to calibrated radiation fields extending from the lower to the upper operating range of the detector. Confirm that the linearity is within 10% of each respective reading. If the readings are off on the lower detector operating region, vary CC. If the readings are off at the upper end of the detector operating region, adjust DTC.

### DETERMINING CC AND DTC

This procedure contains the algorithm (*hi-lo method)* for determining the CC (Calibration Constant) and the DTC (Dead Time Correction). An example of the Ludlum Model 44-9 GM detector calibration is used in conjunction with the algorithm calculations to aid in solving the equations.

> **Note:**
>
> Ludlum Measurements, Inc. offers a PC-compatible software program, which incorporates the read/write commands necessary to communicate between a PC and the Model 2241. The program also incorporates the algorithm to calculate the detector CC and DTC. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024).

Hi-Lo Method: The hi-lo method refers to the placement of the detector in a radiation field using a two-point (CC and DT) calibration to make the detector response linear, even in the non-linear operating regions of the detector. The low-radiation field (CC) should be a field that yields from 2 to 5% count loss. The high radiation field (DT) should be a field that yields from 30 to 60 percent count loss. The algorithm ignores background counts, and therefore, the low field must be at least 10 times the background count.

The following summary lists the calibration constraints.

Calibration and Dead Time Calibration Constraints

| FIELD | CONSTRAINT |
|---|---|
| BACKGROUND | *10 times less than low field |
| LOW FIELD | Yields from 2 to 5 percent count loss |
| HIGH FIELD | Yields from 30 to 60 percent count loss |

* This constraint only applies when using two sources (two fields) or a radiation range calibrated without background consideration.

Preliminary CPS Setup

Refer to Section 8, subsection, "Function Switch Position Descriptions and Variables," for cps readout variables.

Starting with FUNCTION switch position 1,enter the following variables:

| SWITCH POS. | PARAMETER | FUNCTION |
|---|---|---|
| 1 | $0000s_{-6}$ | Dead Time |
| 2 | 0100 -2 | Calibration Constant |
| 3 | C/ | Display Units |
| 4 | m | Timebase |
| 5 | N/A | Audio Divide-By |
| 6 | N/A | Response Time |
| 7 | N/A | Ratemeter Alm./Alert |
| 8 | 0060 s | ScalerAlm./Count Time |
| 9 | Not Used | |
| A | Not Used | |
| B | N/A | LCD Backlight |
| C | 000 C/s | Set Minimum Display |
| D-F | N/A | RS-232 Parameters |

Equation 1

$$CPS^{LO_{2\%}} = \frac{1}{49 \ x \ DT}$$

Equation 2

$$CPS^{LO_{5\%}} = \frac{1}{19 \ x \ DT}$$

Equation 3

$$CPS^{HI_{30\%}} = \frac{1}{2.3333 \ x \ DT}$$

Equation 4

$$CPS^{HI_{60\%}} = \frac{1.5}{DT}$$

The equations to the left (Equations 1-4) determine the *hi* and *lo* radiation fields used to acquire counts for the CC and DTC algorithm. These calculations require an unknown variable, DT (Dead Time). Typical dead times for some of the standard LMI detectors are referenced in the table at the end of this section. The *lo* count field should be a field that yields between 2 and 5% count loss. The *hi* count field ($CPS^{HI}$) should be a field that yields between 30 and 60% count loss.

Reference the table at the end of this section to determine the cps/exposure rate (cps/ER). The conversion can be determined by placing the detector in a radiation field that produces from 50 to 200 cps. Calculate the count/exposure rate using the equation to the left.

$$\frac{cps}{radiation\ \ field\ \ in\ exposure\ \ rate\ \ units} = cps\ /\ ER$$

For example, exposing a LMI Model 44-9 to a 2 mR/hr $^{137}Cs$ field yields approximately 110 cps so that:

$$\frac{110\ cps}{2\ mR/hr} = 55\ cps/mR/hr$$

The typical dead time for a Model 44-9 is approximately 85 µs. Therefore, using 85 µs for "DT" in equations 1-4, the *lo* field should be between 240 and 619 cps, and the *hi* field is between 5040 and 17,650 cps. Dividing the cps values by the 55 cps/mR/hr conversion equates to between 4 and 11 mR/hr for the *lo* field and 91 and 320 mR/hr for the *hi* field.

Select a calibrated field between the *lo* and *hi* data points determined above:

*lo* ($CAL_{lo}$) = 8 mR/hr

*hi* ($CAL_{hi}$) = 200 mR/hr

The following procedure outlines the hi-lo method

Abbreviations used:

units = Sv, R, counts.

$CAL_{lo}$ = *lo* field calibration point.
$CAL_{hi}$ = *hi* field calibration point.

$CORR_{lo}$ = recorded field at low calibration point.
$CORR_{hi}$ = recorded field at high calibration point.

DT = dead time constant entered into Model 2241.
CC = calibration constant entered into Model 2241.

$f_d$ and $a_d$ are intermediate steps in calculating DT.
$f_{cal}$ is an intermediate step in calculating CC.

CC and DTC Algorithm

Equations (5) and (6) convert units per time (R/hr Display Units) to units per second:

$$\frac{units}{time} \Rightarrow \frac{units}{second}$$

Insert the cps *lo* data point (8 mR/hr for the Model 44-9 example) determined from equations (1) and (2):

Equation 5

$$CAL_{lo} = (0.008\frac{R}{h})\,x\,(\frac{1\,h}{60\,m})\,x\,(\frac{1\,m}{60\,s}) = \quad 2.22\,x\,10^{-6}\ \ s$$

Insert the cps hi data point (200 mR/hr for the Model 44-9 example) determined from equations (3) and (4):

Equation 6

$$CAL_{hi} = (0.200\frac{R}{h})x(\frac{1\,h}{60\,m})x(\frac{1\,m}{60\,s}) = \quad 55.6\,x\,10^{-6}\ \ s$$

Place the detector in the low field and enter the counts per second:

Equation 7

$$CORR_{lo} = \frac{SAMPL_{lo}}{count\ time} = \qquad \frac{counts}{s}$$

**Note:**

The low-field count sample should be ≥ 3000 counts. Use the Scaler and adjust the count time to accumulate count ≥ 3000.

As an example, assume a 60-second count sample in a low field of 8 mR/hr:

Example

$$CORR_{lo} = \frac{26{,}427}{60} = 440\ C/s$$

Place detector in the high field and enter the counts per second:

Equation 8

$$CORR_{hi} = \frac{SAMPL_{hi}}{count\ time} = \frac{counts}{s}$$

Counts/second sample in high field of 200 mR/hr:

Example

$$CORR_{hi} = \frac{5830}{1} = 5830\ C/s$$

Insert the values calculated in equations (5), (6), (7), and (8) and solve for $f_d$:

Equation 9

$$f_d = CAL_{hi} - \frac{CORR_{hi}\ x\ CAL_{lo}}{CORR_{lo}} = \frac{units}{s}$$

Example

$$f_d = 55.6\ x\ 10^{-6} - \frac{5830\ x\ 2.22\ x\ 10^{-6}}{440} = 26.2\ x\ 10^{-6}\ \ s$$

Solve for $a_d$:

Equation 10

$$a_d = (CAL_{hi}\ x\ CORR_{hi}) - (CAL_{lo}\ x\ CORR_{hi}) = \frac{units \times count}{s^2}$$

Example

$$a_d = (55.6\ x\ 10^{-6}\ x\ 5830) - (2.22\ x\ 10^{-6}\ x\ 5830) = 31.1\ x\ 10^{-6}$$

Enter the results of equations (9) and (10) into equation (11) to solve for DT:

Equation 11

$$DT = \frac{f_d}{a_d} = \frac{s}{count}$$

Example

$$DT = \frac{26.2x10^{-6}}{31.1x10^{-2}} = 8.4x10^{-6} s$$

Solve for $f_{cal}$:

Equation 12

$$f_{cal} = CAL_{lo} - (CAL_{lo} \; x \; CORR_{lo} \; x \; DT) = \frac{units}{s}$$

Example

$$f_{cal} = 2.22 \; x \; 10^{-6} - (2.22 \; x \; 10^{-6} \; x \; 440 \; x \; 84 \; x \; 10^{-6}) = 2.14 \; x \; 10^{-6} \; s$$

Enter the result of equation (12) into:

Equation 13

$$CC = \frac{CORR_{lo}}{f_{cal}} = \frac{count}{units}$$

and solve for CC:

Example

$$CC = \frac{440}{2.14 \; x \; 10^{-6}} = 206 \; x \; 10^{6}$$

Enter the CC and DT values (positions 1 and 2 of the FUNCTION switch), derived from the equations above. Perform an "R/hr calibration" as described in the previous subsection in order to ensure that the instrument and detector have been correctly calibrated.

Model 44-9 Detector Parameter Setup

| FUNCTION | PARAMETER |
|---|---|
| 1 | 0084 $s_{-6}$ |
| 2 | 0206 $_{06}$ |
| 4 | N/A |
| 5-8 | as desired |
| B-C | as desired |
| D-F | if applicable |

Typical Count Rate and Dead Time for LMI Detectors

| MODEL & TYPE | COUNT RATE | DEAD TIME in µs (microseconds) |
|---|---|---|
| 44-6, GM | 20 cps/mR/hr | 90-110 µs |
| 44-9, GM | 55 cps/mR/hr | 80-90 µs |
| 44-7, GM | 35 cps/mR/hr | 240-290 µs |
| 133-2, GM | 17.5 cps/mR/hr | 40-55 µs |
| 133-4, GM | 2 cps/mR/hr | 40-55 µs |
| 133-6, GM | 0.3 cps/mR/hr | 40-55 µs |
| 44-2, Gamma Scint. | 2800 cps/mR/hr | 8-12 µs* |
| 44-10, Gamma Scint. | 15,000 cps/mR/hr | 18-20 µs |
| 44-3, Low-Energy Gamma Scint. | N/A, operated in Counts/units mode | 8-12 µs* |
| 44-21, Beta/Gamma Scint. | N/A, operated in Counts/units mode | 8-12 µs* |
| 43-5, Alpha Scint. | N/A, operated in Counts/units mode | 20-28 µs |

**Note:**

The data represented in the table above is typical. Actual values may vary among detector and instrument combinations. This table represents some of the common detectors operated with the Model 2241. Consult the LMI sales department for information concerning detectors not listed in the table above.

*The dead time values for these scintillation detectors are due to the dead time of the Model 2241 electronics.

## DETECTOR OVERLOAD (OVL) CALIBRATION

Note:

The detector operating voltage (HV) must be determined and adjusted before the OVL adjustment is performed. If the HV is varied or another detector is substituted, OVL must be readjusted. If the overload feature is not used, adjust the control to the maximum counterclockwise position.

The detector overload circuit senses current flow through the detector. As the radiation intensity is increased, the detector may start to saturate (decrease pulse production), and the readout may decrease or read 0. But as the pulse output continues to decrease in the saturated field, the detector current drain continues to increase. This increase in current is detected by a comparator circuit, which triggers the OVERLOAD enunciator on the LCD by way of the microprocessor.

For GM and gamma scintillation detectors, the OVL trip point is adjusted to the point to where the readout no longer increases with increasing radiation intensity. In the event that the overload point cannot be determined due to radiation field limitations, adjust the overload point from 5 to 10 times the upper operating range of the detector.

Adjust the OVL control to the maximum counterclockwise position.

Place the detector in an increasing radiation field in which the readout no longer increases. Adjust the OVL control until the OVERLOAD alarm appears. Position the detector between the upper operating limit and the OVL set point and ensure the OVERLOAD alarm is defeated. Adjust the OVL control accordingly.

Example:

Ludlum Model 44-9 is calibrated with Model 2241 in the R/hr units display, utilizing DT. The upper linear operating point is 400 mR/hr for the Model 44-9. Place the detector at the 1000 mR/hr point and adjust the OVL control to initiate the OVERLOAD alarm. Place the detector in the 600-700 mR/hr field and ensure that the OVERLOAD is off.

The detector overload or saturation point for alpha and/or beta scintillation detectors is when the detector face (Mylar) has been punctured, allowing light to saturate the photomultiplier tube (PMT). The pulse output will decrease or even appear non-responsive to any radiation activity, depending upon the size of the puncture and the light intensity to the PMT.

Expose the detector PMT to a small light leak by loosening the detector window. Some scintillators incorporate a screw in the detector body, which when removed, will simulate a detector face puncture. The ratemeter readout should start to decrease as the light saturates the PMT.

Adjust the OVL control until the OVERLOAD just appears on the display. Reseal the light leak connection and expose the detector to a radiation source that will produce a near full-scale reading. Confirm that the OVERLOAD alarm does not initiate. Readjust the OVL control as required.

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# Software License Agreement

**Rev. (number) 1.0**
**Written by (or Revised by):** Richard Sroka **Date:** 20Jan06
**Approved by:** Ed Emr **Date:** 20JAN06

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# Section 9

# Recycling

Ludlum Measurements, Inc. supports the recycling of the electronic products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronic products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

| | | |
|---|---|---|
| Batteries | Glass | Aluminum and Stainless Steel |
| Circuit Boards | Plastics | Liquid Crystal Display (LCD) |

Ludlum Measurements, Inc. products, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding. Each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such: 

Section 10

# Parts List

Model 2241 Survey Meter

| Reference | Description | Part Number |
|---|---|---|
| UNIT | Completely Assembled Model 2241 Survey Meter | 48-2444 |

Main Circuit Board, Drawing 408 × 223

| Reference | Description | Part Number |
|---|---|---|
| BOARD | Completely Assembled Main Circuit Board | 5408-223 |

CAPACITORS

| Reference | Description | Part Number |
|---|---|---|
| C1 | 0.1µF, 50V | 04-5663 |
| C3 | 0.1µF, 50V | 04-5663 |
| C001-C002 | 47pF, 100V | 04-5660 |
| C011 | 0.001µF, 100V | 04-5659 |
| C012 | 0.1µF, 50V | 04-5663 |
| C021 | 100pF, 3KV | 04-5532 |
| C031 | 0.0047µF, 3KV | 04-5547 |
| C032 | 100pF, 3KV | 04-5532 |
| C033 | 0.0047µF, 3KV | 04-5547 |
| C041-C043 | 0.0047µF, 3KV | 04-5547 |
| C101 | 47µF, 10V | 04-5666 |
| C121 | 47µF, 10V | 04-5666 |
| C122-C123 | 27pF, 100V | 04-5658 |
| C131 | 0.0047µF, 3KV | 04-5547 |
| C132-C133 | 0.1µF, 50V | 04-5663 |
| C134 | 0.01µF, 50V | 04-5664 |
| C135 | 47µF, 10V | 04-5666 |
| C136 | 0.01µF, 50V | 04-5664 |
| C137 | 47µF, 10V | 04-5666 |
| C138 | 100pF, 100V | 04-5661 |
| C139 | 0.001µF, 100V | 04-5659 |
| C141 | 0.0047F, 3KV | 04-5547 |
| C241 | 1µF, 35V | 04-5656 |
| C242 | 68µF, 10V | 04-5654 |
| C243 | 0.1µF, 50V | 04-5663 |
| C251 | 68µF, 10V | 04-5654 |

| | Reference | Description | Part Number |
|---|---|---|---|
| TRANSISTORS | Q101 | 2N7002L | 05-5840 |
| | Q141 | MMBT3904LT1 | 05-5841 |
| | Q211 | 2N7002L | 05-5840 |
| | Q212 | MMBT4403LT1 | 05-5842 |
| | Q241 | MJD210 RL | 05-5843 |
| INTEGRATED CIRCUITS | U1 | MAX810LEUR | 06-6424 |
| | U001 | CD74HC4538M | 06-6297 |
| | U011 | TLC372ID | 06-6290 |
| | U021 | CA3096M; 16=GND | 06-6288 |
| | U111 | N87C51FC | 06-6303 |
| | U121 | LM285MX-2.5 | 06-6291 |
| | U122 | X24C02S8T5 | 06-6299 |
| | U131 | LM358D | 06-6312 |
| | U231 | LT1073CS8-5 | 05-5852 |
| | * | SOCKET-44P | 06-6613 |
| DIODES | CR021 | MMBD7000LT1 | 07-6355 |
| | CR031 | GI250-2 | 07-6266 |
| | CR041-CR044 | GI250-2 | 07-6266 |
| | CR231 | CXSH-4 EB33 | 07-6358 |
| | CR241 | MMBD914LT1 | 07-6353 |
| | CR242 | CXSH-4 EB33 | 07-6358 |
| POTENTIOMETERS / TRIMMERS | R002 | 10K; 3269X1-103 | 09-6921 |
| | R027 | 1M; 3269X1-105; HV LIMIT | 09-6906 |
| RESISTORS | R001 | 100K, 1/4W, 1% | 12-7834 |
| | R011-R012 | 10K, 1/4 W, 1% | 12-7839 |
| | R013 | 1K, 1/4W, 1% | 12-7832 |
| | R014 | 10K, 1/4W, 1% | 12-7839 |
| | R015 | 100K, 1/4W, 1% | 12-7834 |
| | R021 | 1M, 1/4W, 5% | 10-7028 |
| | R022 | 392K, 1/8W, 1% | 12-7841 |
| | R023 | 10K, 1/4W, 1% | 12-7839 |
| | R024-R025 | 4.75K, 1/4W, 1% | 12-7858 |
| | R026 | 8.25K, 1/8W, 1% | 12-7838 |
| | R031 | 4.7M, 1/4W, 5% | 10-7030 |
| | R032 | 1M, 1/4W, 5% | 10-7028 |
| | R033-R034 | 1G, FHV-1, 2% | 12-7686 |
| | R111-R113 | 22.1K, 1/4W, 1% | 12-7843 |
| | R121 | 100 Ohm, 1/4W, 1% | 12-7840 |
| | R122 | 6.81K, 1/4W, 1% | 12-7857 |

| | Reference | Description | Part Number |
|---|---|---|---|
| | R131 | 1M, 1/4W, 1% | 12-7844 |
| | R132 | 511K, 1/8W, 1% | 12-7896 |
| | R133 | 750K, 1/4W, 1% | 12-7882 |
| | R134 | 1M, 1/4W, 1% | 12-7844 |
| | R135 | 82.5K, 1/8W, 1% | 12-7849 |
| | R136 | 10K, 1/4W, 1% | 12-7839 |
| | R141 | 22.1K, 1/4W, 1% | 12-7843 |
| | R211 | 2.21K, 1/4W, 1% | 12-7835 |
| | R231 | 100Ohm, 1/4W, 1% | 12-7840 |
| | R241 | 2.21K, 1/4W, 1% | 12-7835 |
| | R242 | 200Ohm, 1/8W, 1% | 12-7846 |
| CRYSTALS | Y221 | 6.144 MHZ, 2=GND, 3=GND | 01-5262 |
| INDUCTOR | L231 | 100µH, CTX100-2 | 21-9740 |
| TRANSFORMERS | T101 | 4275-083, AUDIO | 4275-083 |
| | T141 | L8050 | 40-0902 |
| MISCELLANEOUS | P1 | 1-640456-2, MTA100×12 | 13-8061 |
| | P2 | 1-640456-3, MTA100×13 | 13-8100 |
| | P3 | 640456-6, MTA100×6 | 13-8095 |
| | P4 | 640456-2, MTA100×2 | 13-8073 |
| | P5 | 1-640456-2, MTA100×12 | 13-8061 |
| | * | CLVRLF | 18-8771 |
| Calibration Board, Drawing 408 × 12 | BOARD | Completely Assembled Calibration Board | 5408-007 |
| POTENTIOMETERS | R1 | 100K, DISC | 09-6813 |
| | R2 | 1M, OVERLOAD | 09-6814 |
| | R3 | 1M, HV | 09-6814 |
| RESISTORS | R4 | 10K, 1/3W, 1% | 12-7748 |
| | R5-R6 | 1M, 1/3W, 1% | 12-7751 |
| | R7 | 1K, 1/3W, 1% | 12-7750 |
| CONNECTOR | P7 | CONN-640456-6, MTA100×6 | 13-8095 |
| Display Board, MMMDrawing 408 × 259 | BOARD | Completely Assembled Display Board | 5408-259 |
| CAPACITORS | C1 | 27PF, 100V | 04-5658 |

| | Reference | Description | Part Number |
|---|---|---|---|
| INTEGRATED CIRCUITS | U1 | AY0438-I/L | 06-6358 |
| | U2 | AY0438-I/L | 06-6358 |
| RESISTORS | R001-R004 | 10.0K, 1%, 125mW | 12-7839 |
| | R005 | 392 Ohm, 1%, 1/8 W | 12-7054 |
| MISCELLANEOUS | J1 | CONN-640456-8, MTA100 | 13-8039 |
| | DS1 | EL-BACKLIGHT-LED | 07-6527 |
| | DSP1 | MAIN DISPLAY; LCD-8246-365-4E1-A/W-REV1 | 07-6383 |
| Switch Board, Drawing 408 × 45 | BOARD | Completely Assembled Switch Board | 5408-052 |
| CAPACITORS | C1-C2 | 4.7µF, 10V | 04-5578 |
| | C3-C4 | 10µF, 20V | 04-5592 |
| | C5 | 4.7µF, 10V | 04-5578 |
| | C6 | 100µF, 10V | 04-5576 |
| INTEGRATED CIRCUITS | U1 | MAX220EPE | 06-6359 |
| SWITCHES | S1 | 350134GSK; FUNCTION; 16 POS | 08-6721 |
| | S2 | LEFT | 08-6716 |
| | S3 | UP | 08-6716 |
| | S4 | ENTER | 08-6716 |
| RESISTORS | R1-R2 | 22K | 10-7070 |
| MISCELLANEOUS | P6 | CONN-1-640456-3, MTA100 | 13-8100 |
| | P10 | CONN-208006-2 | 13-8451 |
| Chassis Wiring Diagram, Drawing 408 × 103 | | | |
| AUDIO | DS1 | UNIMORPH | 21-9251 |
| CONNECTORS | J1 | CONN-1-640442-2, MTA100×2 | 13-8407 |

| | Reference | Description | Part Number |
|---|---|---|---|
| | J2 | CONN-1-640442-3, MTA100×3 | 13-8138 |
| | J3 | CONN-640442-6, MTA100×6 | 13-8171 |
| | J4 | CONN-640442-2, MTA100×2 | 13-8178 |
| | J5 | CONN-1-640442-2, MTA100×2 | 13-8407 |
| | J6 | CONN-1-640442-3, MTA100×3 | 13-8138 |
| | J7 | CONN-640442-6, MTA100×6 | 13-8171 |
| | J8 | CONN-640442-8, MTA100×8 | 13-8184 |
| | J9 | Series "C" -UG706/U | 13-7751 |
| | J10 | JACK-09-9011-1-419 | 18-9080 |
| | P10 | HANDLE PIN | 7408-055 |
| SWITCHES | S1 | 30-1-PB GRAYHILL | 08-6517 |
| | S3-S4 | 7101-SYZ-QE C&K | 08-6511 |
| | S5 | 30-1-PB GRAYHILL | 08-6517 |
| | S6 | PA-600-210 | 08-6501 |
| | S7 | MPS-103F | 08-6699 |
| | * | SWTCH CAP, BLK C-22 | 08-6698 |
| BATTERIES | B1-B2 | "D" Duracell Battery | 21-9313 |
| MISCELLANEOUS | * | DIGITAL BEZEL ASSY. | 4408-020 |
| | * | DIGITAL BEZEL W/GLASS | 4408-051 |
| | * | BEZEL BACK | 7408-025 |
| | * | BEZEL BACK GASKET | 7408-026 |
| | * | BATTERY CONTACT SET | 40-1707 |
| | * | MAIN HARNESS | 8408-048 |
| | * | MODEL 2241 CASTING | 7408-043 |
| | * | Portable HARNESS CAN WIRES | 8363-462 |
| | * | CAN ASSY. | 4363-441 |
| | * | PORTABLE KNOB | 08-6613 |
| | * | BATTERY LID WITH CNTCT | 2363-191 |
| | * | PORTABLE LATCH KIT WITHOUT BATTERY LID | 4363-349 |

| Reference | Description | Part Number |
|---|---|---|
| * | PORT CALIBRATION COVER WITH SCREWS | 9363-200 |
| * | MODEL 2241-2 RLLD HNDLE ASSY. | 4408-178 |

Section 11

# Drawings

Optional Source Holder Assembly, Drawings 62 × 166 & 62 × 166B

Main Circuit Board, Drawings 408 × 223 (3 sheets)

Main Circuit Board Component Layout, Drawing 408 × 224

Calibration Board, Drawing 408 × 12

Calibration Board Component Layout, Drawing 408 × 13 (2 sheets)

Display Board, Drawing 408 × 259

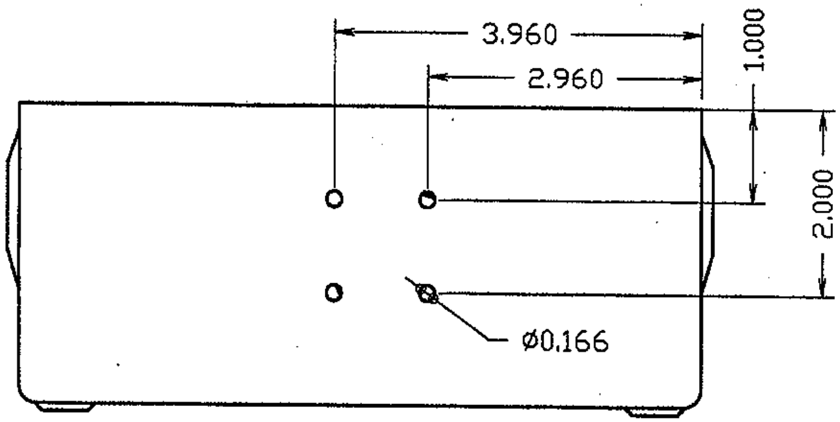
Display Board Component Layout, Drawings 408 × 260 (2 sheets)

Switch Board, Drawing 408 × 45

Switch Board Component Layout, Drawing 408 × 46

Wiring Diagram, Drawing 408 × 103

| REV # | ALTERATIONS | DATE | BY |
|---|---|---|---|
| 2 | VALID EC-381 | 4-25-97 | JGW |
| 3 | VALID EC-1017 | 10-20-98 | TJR |

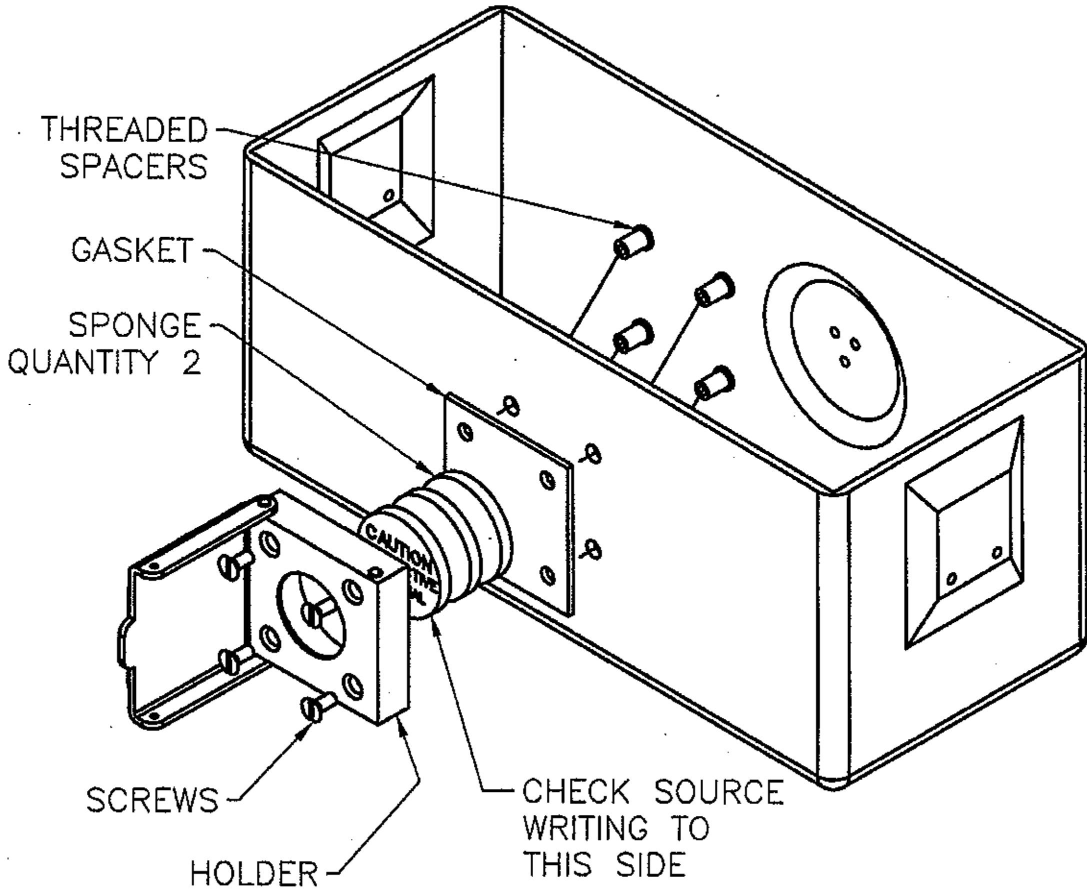



# MOUNTING CHECK SOURCE

Normally, the check source holder is mounted on the side of the can opposite of the speaker. Use the drawing to the left to drill the holes in the can, or the holder can be used as a template to locate the holes. Insert the spacers into the holes with the flange inside the can and the spacer protruding to the outside of the can. Assemble the parts as shown in the lower left drawing. The printed side of the check source is the active side and should be facing out.

For check source readings, open the cover, place detector against the source, and note reading. It may be necessary to change to a higher range multiplier for an accurate reading.

To conform to 10 CFR 35.51, the licensee shall check each survey instrument for proper operation with the dedicated check source each day of use.

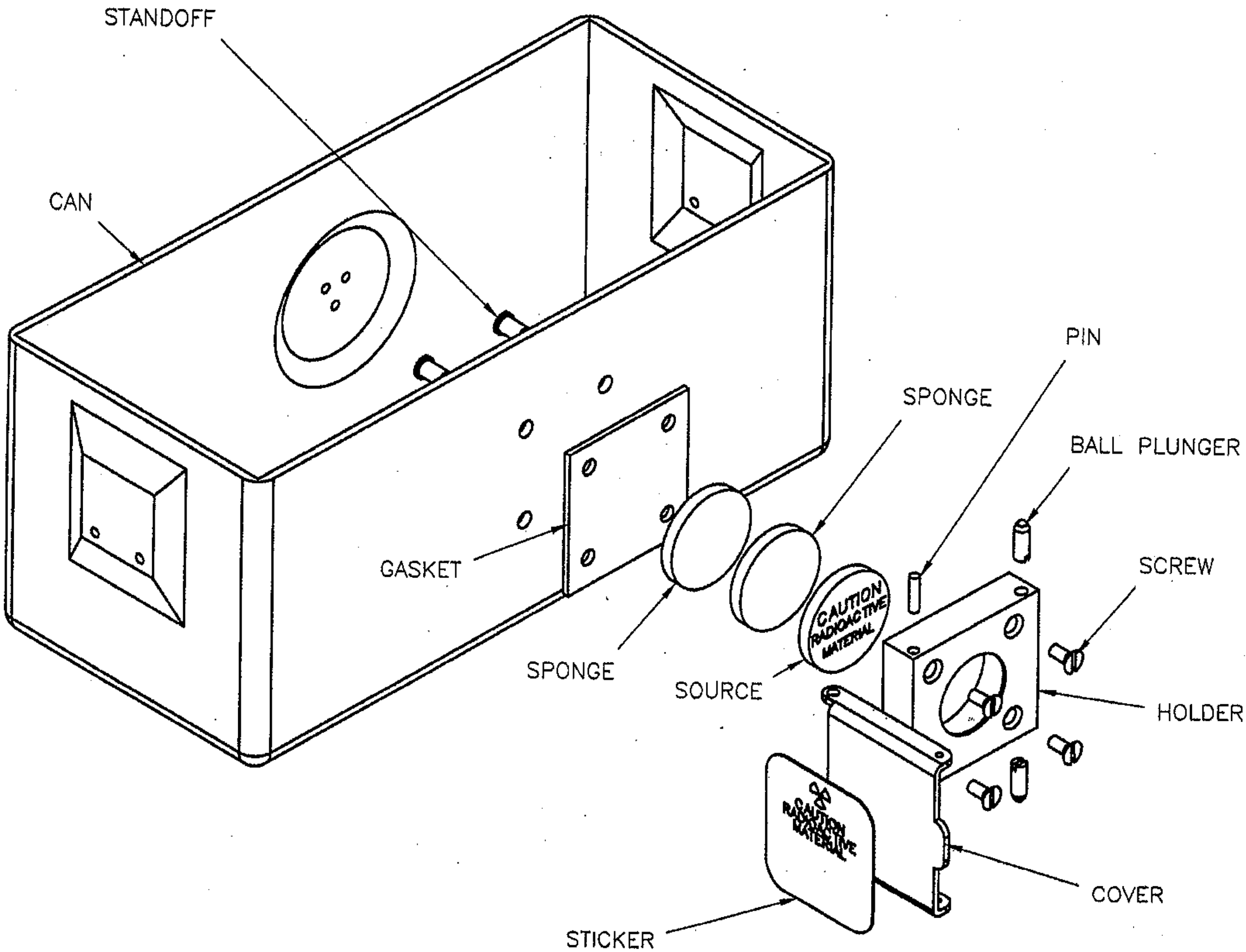



| DWN | DATE | CHECKED | APPROVED |
|---|---|---|---|
| JGV | 10-5-01 | RSS 10-5-01 | 10-5-01 |

TITLE: SOURCE HOLDER ASSEMBLY

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556 | SERIES 62 | SHEET 166

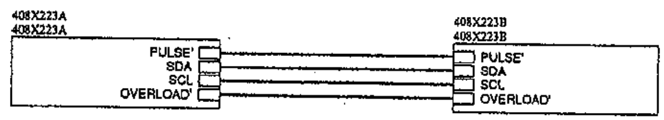
| REV # | ALTERATIONS | DATE | BY |
|---|---|---|---|
| 2 | VALID EC-381 | 4-25-97 | JGW |
| 3 | VALID EC-1017 | 10-20-98 | TJR |




| DWN | DATE | CHECKED | APPROVED |
|---|---|---|---|
| JGW | 10-5-01 | 10-5-01 | 10-5-01 |

TITLE: SOURCE HOLDER ASSEMBLY

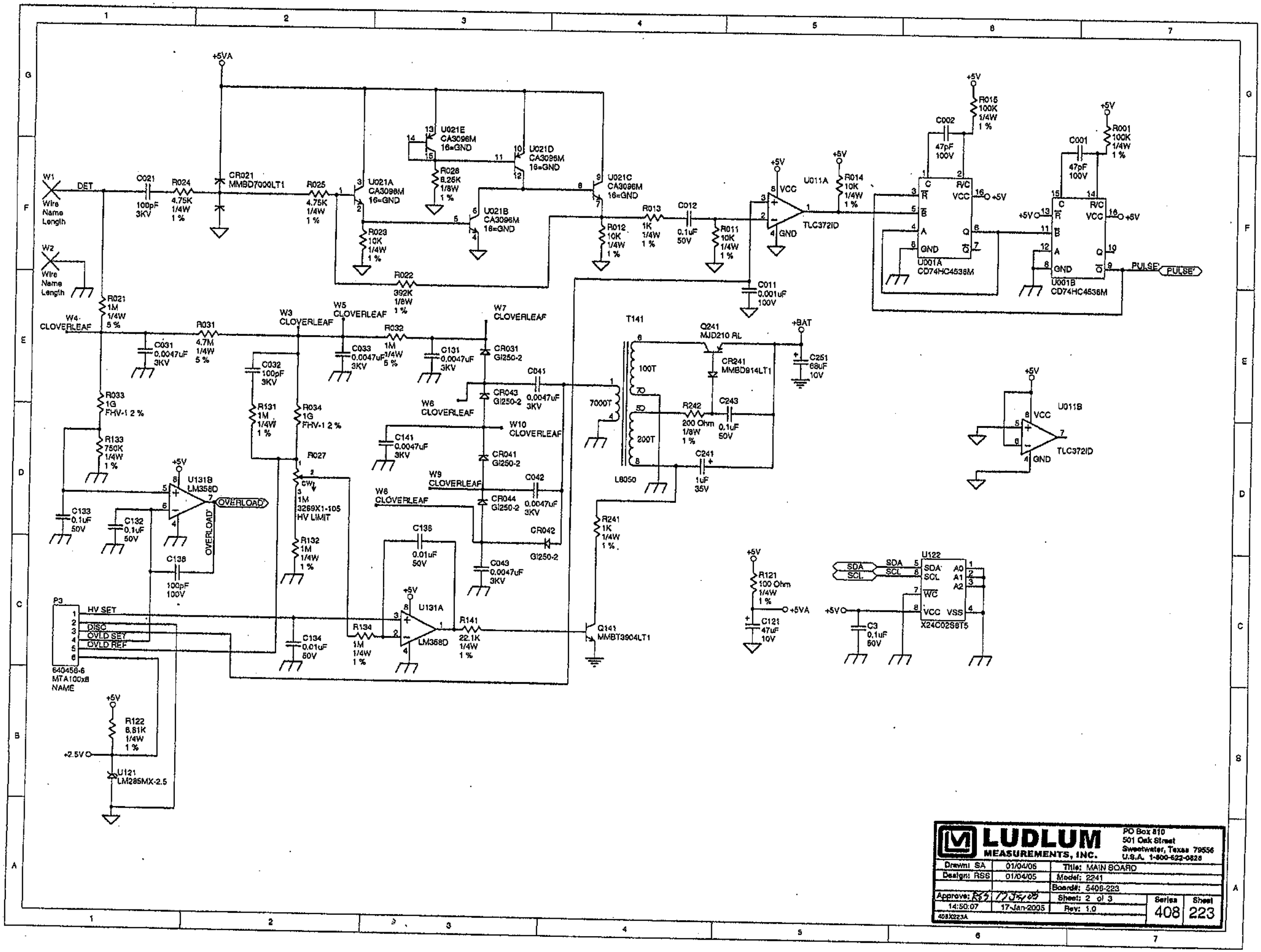
| LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556 | SERIES | SHEET |
|---|---|---|
| | 62 | 166B |



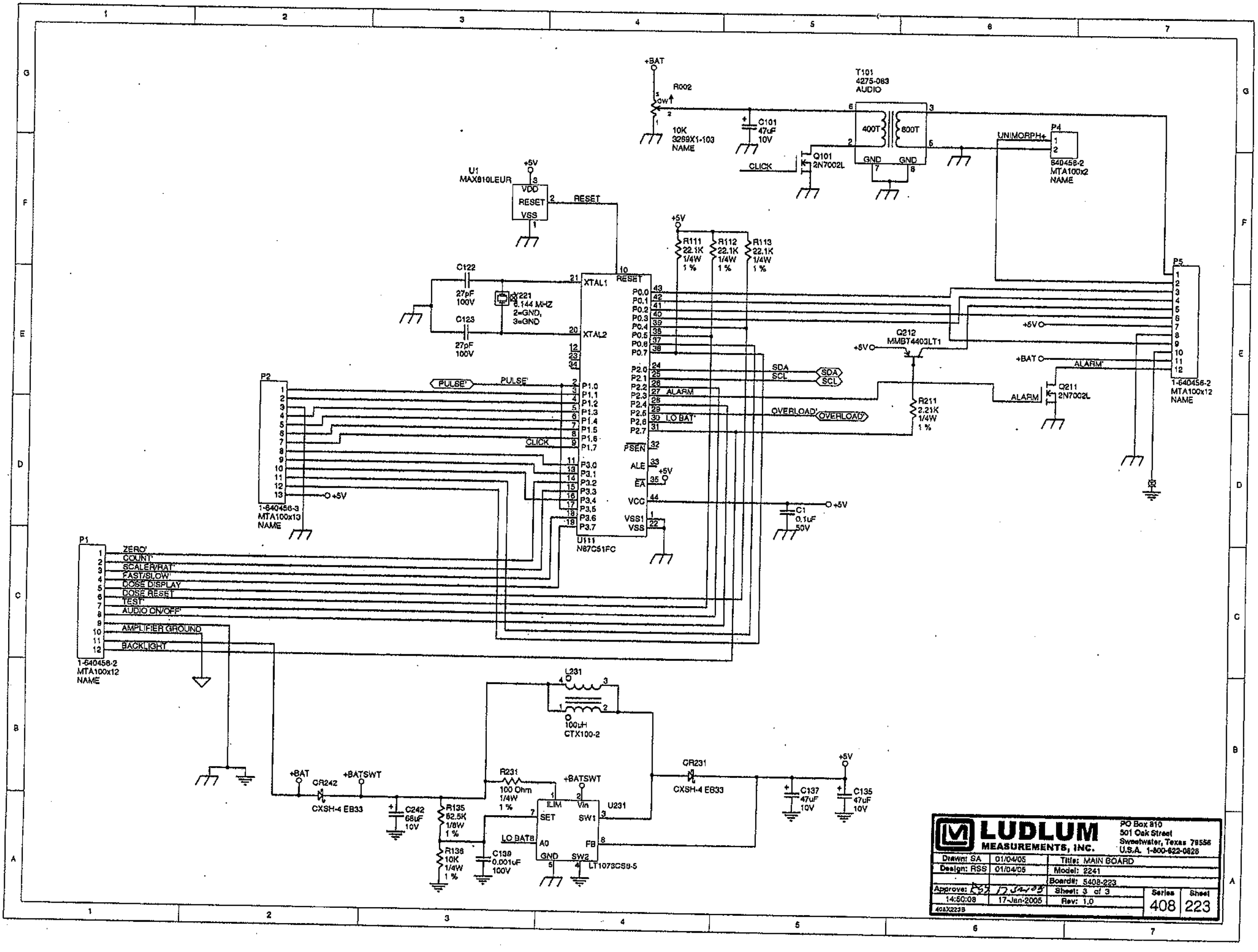

**LUDLUM MEASUREMENTS, INC.**


PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

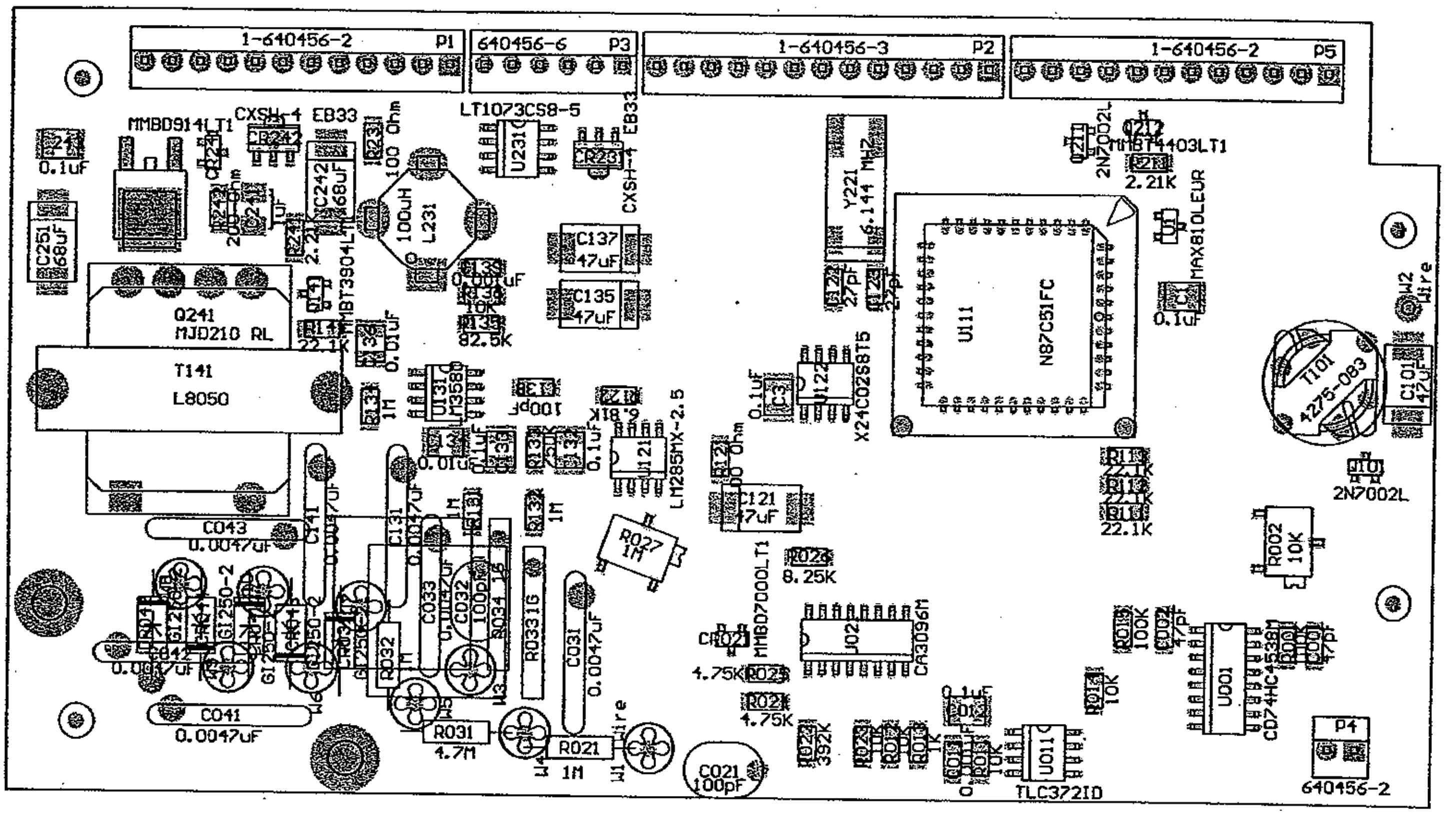

| | | | | |
|---|---|---|---|---|
| Drawn: SA | 01/04/05 | Title: MAIN BOARD | | |
| Design: RSS | 01/04/05 | Model: 2241 | | |
| | | Board#: 5408-223 | | |
| Approve: | | Sheet: 1 of 3 | Series | Sheet |
| 14:50:07 | 17-Jan-2005 | Rev: 1.0 | 408 | 223 |
| 408x223 | | | | |



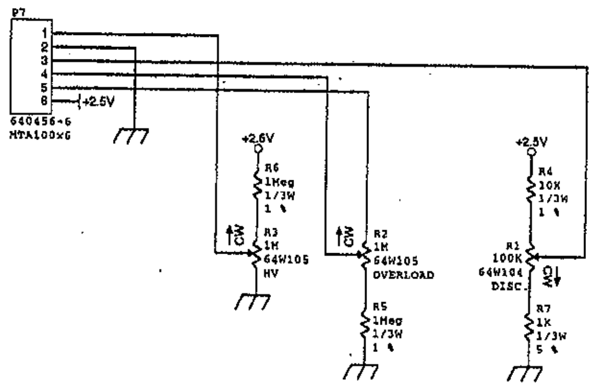
LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: SA 01/04/05
Design: RSS 01/04/05
Approve: RSS 17Jan05
14:50:07 17-Jan-2005
Title: MAIN BOARD
Model: 2241
Board#: 5408-223
Sheet: 2 of 3
Rev: 1.0
Series 408
Sheet 223
408X223A
W1 Wire Name Length
W2 Wire Name Length
DET
C021 100pF 3KV
R024 4.75K 1/4W 1 %
CR021 MMBD7000LT1
+5VA
R025 4.75K 1/4W 1 %
U021A CA3096M 16=GND
U021B CA3096M 16=GND
U021C CA3096M 16=GND
U021D CA3096M 16=GND
U021E CA3096M 16=GND
R026 8.25K 1/8W 1 %
R023 10K 1/4W 1 %
R022 392K 1/8W 1 %
R012 10K 1/4W 1 %
R013 1K 1/4W 1 %
C012 0.1uF 50V
R011 10K 1/4W 1 %
C011 0.001uF 100V
U011A TLC372ID
R014 10K 1/4W 1 %
R015 100K 1/4W 1 %
C002 47pF 100V
U001A CD74HC4538M
R001 100K 1/4W 1 %
C001 47pF 100V
U001B CD74HC4538M
PULSE
R021 1M 1/4W 5 %
W4 CLOVERLEAF
R031 4.7M 1/4W 5 %
C031 0.0047uF 3KV
W3 CLOVERLEAF
W5 CLOVERLEAF
C033 0.0047uF 3KV
R032 1M 1/4W 5 %
C131 0.0047uF 3KV
W7 CLOVERLEAF
CR031 GI250-2
C032 100pF 3KV
R131 1M 1/4W 1 %
R034 1G FHV-1 2 %
R033 1G FHV-1 2 %
R133 750K 1/4W 1 %
W6 CLOVERLEAF
CR043 GI250-2
C041 0.0047uF 3KV
W10 CLOVERLEAF
C141 0.0047uF 3KV
CR041 GI250-2
W9 CLOVERLEAF
C042 0.0047uF 3KV
W8 CLOVERLEAF
CR044 GI250-2
CR042 GI250-2
C043 0.0047uF 3KV
R027 1M 3269X1-105 HV LIMIT
R132 1M 1/4W 1 %
U131B LM358D
OVERLOAD
C133 0.1uF 50V
C132 0.1uF 50V
C138 100pF 100V
C136 0.01uF 50V
U131A LM358D
R134 1M 1/4W 1 %
C134 0.01uF 50V
R141 22.1K 1/4W 1 %
Q141 MMBT3904LT1
P3
HV SET
DISC
OVLD SET
OVLD REF
640456-6 MTA100x6 NAME
R122 8.81K 1/4W 1 %
+2.5V
U121 LM285MX-2.5
T141
7000T
100T
200T
L6050
Q241 MJD210 RL
CR241 MMBD914LT1
+BAT
C251 68uF 10V
R242 200 Ohm 1/8W 1 %
C243 0.1uF 50V
C241 1uF 35V
R241 1K 1/4W 1 %
U011B TLC372ID
R121 100 Ohm 1/4W 1 %
C121 47uF 10V
U122 X24C02S8T5
SDA
SCL
C3 0.1uF 50V



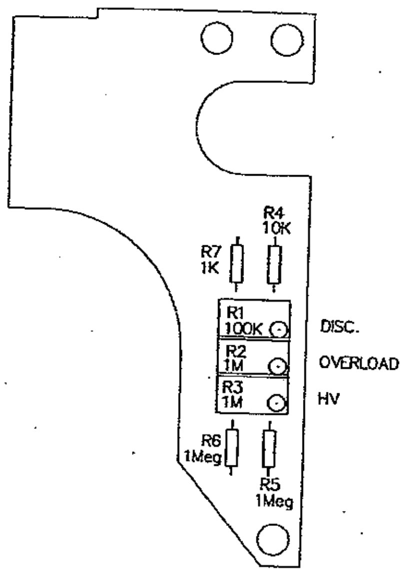
LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: SA 01/04/05
Design: RSS 01/04/05
Title: MAIN BOARD
Model: 2241
Board#: 5408-223
Sheet: 3 of 3
Rev: 1.0
14:50:08 17-Jan-2005
Series 408
Sheet 223
U1 MAX810LEUR
U111 N87C51FC
U231 LT1073CS8-5
T101 4275-083 AUDIO
Q101 2N7002L
Q211 2N7002L
Q212 MMBT4403LT1
X221 6.144 MHZ
L231 100uH CTX100-2
CR231 CXSH-4 EB33
CR242 CXSH-4 EB33
R002 10K 3269X1-103
R111 22.1K 1/4W 1 %
R112 22.1K 1/4W 1 %
R113 22.1K 1/4W 1 %
R211 2.21K 1/4W 1 %
R231 100 Ohm 1/4W 1 %
R135 82.5K 1/8W 1 %
R136 10K 1/4W 1 %
C101 47uF 10V
C122 27pF 100V
C123 27pF 100V
C1 0.1uF 50V
C137 47uF 10V
C135 47uF 10V
C242 68uF 10V
C139 0.001uF 100V
P1 1-640456-2 MTA100x12
P2 1-640456-3 MTA100x13
P4 640456-2 MTA100x2
P5 1-640456-2 MTA100x12
ZERO'
COUNT'
SCALER/RAT'
FAST/SLOW'
DOSE DISPLAY
DOSE RESET
TEST'
AUDIO ON/OFF'
AMPLIFIER GROUND
BACKLIGHT
UNIMORPH+
PULSE'
CLICK
RESET
SDA
SCL
ALARM
ALARM'
OVERLOAD'
LO BAT'
+BAT
+BATSWT
+5V




| Drawn: SA | 01/12/05 | Title: MAIN BOARD | | |
|---|---|---|---|---|
| Design: RSS | 01/12/05 | | | |
| | | Model: 2241 | | |
| Approve: RSS | 20 Jun 05 | Board#: 5408-223 | | |
| Layer: Mech.1 Mech.2 | MID: | Rev: 1.0 | Series | Sheet |
| | 11:26:19 20-Jun-2005 | SCALE: 1.50 | 408 | 224 |
| BS408223 | | | | |

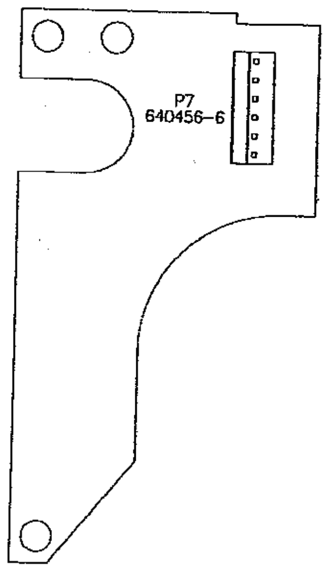



| | | | | |
|---|---|---|---|---|
| LUDLUM MEASUREMENTS, INC. | | PO Box 810, 501 Oak Street, Sweetwater, Texas 79556, U.S.A. 1-800-622-0828 | | |
| Drawn: CKB | 30-Nov-99 | Title: Calibration Board | | |
| Design: LL | 22-Mar-93 | Model: 2240, 2241 | | |
| Check: | | Board#: 5408-007 | | |
| Approve: JWS | 18-Nov-08 | Sheet: 0 of 0 | Series | Sheet |
| 14:30:37 | 6-Jun-2005 | Rev: 1.0 | 408 | 12 |
| 408x12.sch | | | | |




| Drawn: CKB | 30-Nov-99 | Title: | | |
|---|---|---|---|---|
| Design: LL | 22-Mar-93 | Calibration Board | | |
| Check: | | Model: 2240, 2241 | | |
| Approve: JWS | 18-Aug-2005 | Board#: 5408-007 | | |
| Layer: Mech.1 | MD: | Rev: 1.0 | Series | Sheet |
| | 14:50:59 6-Jun-2005 | SCALE: 1.00 | 408 | 13 |

X:\Projects\LM\M2240\m2240.Ddb\\Documents\5408-007\5408007.PCB




| | | | | | |
|---|---|---|---|---|---|
| Drawn: | CKB | 30-Nov-99 | Title: | | |
| Design: | LL | 22-Mar-93 | Calibration Board | | |
| Check: | | | Model: 2240, 2241 | | |
| Approve: | JWS | 18-Aug-2005 | Board#: 5408-007 | | |
| Layer: Mech.1 Mech.2 | BoptilPasBaste P1 P2 P3 P4 | | Rev: 1.0 | Series | Sheet |
| | MD: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 | | | | |
| | 14:50:59 | 6-Jun-2005 | SCALE: 1.00 | 408 | 13 |
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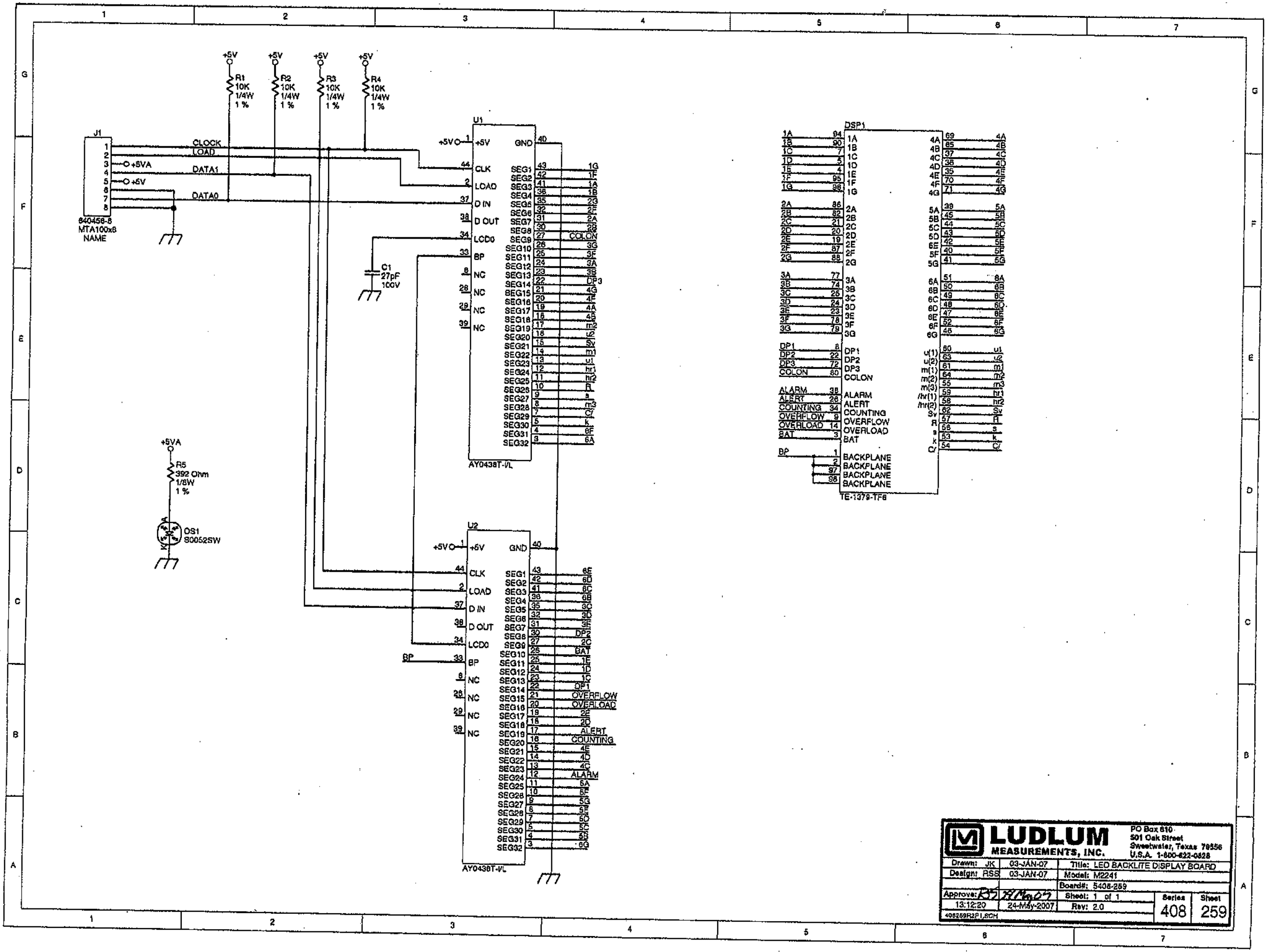
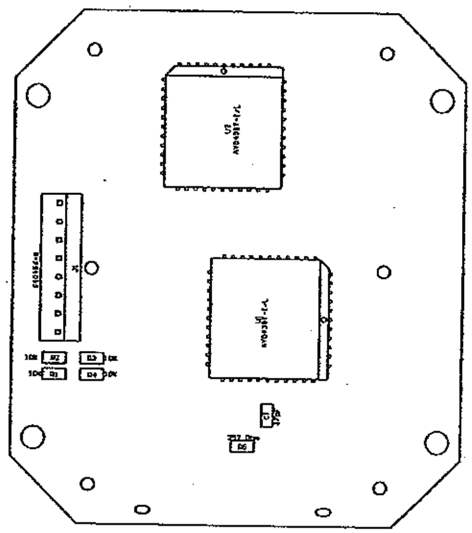
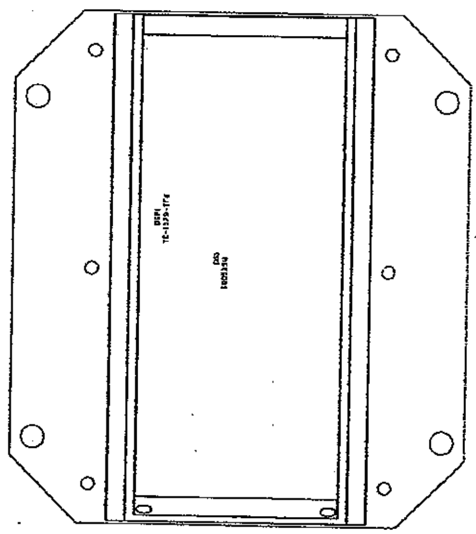

LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: JK 03-JAN-07
Design: RSS 03-JAN-07
Title: LED BACKLITE DISPLAY BOARD
Model: M2241
Board#: 5408-259
Sheet: 1 of 1
Rev: 2.0
Series 408
Sheet 259
13:12:20 24-May-2007
408259R2P1.SCH
J1
640456-8
MTA100x8
NAME
CLOCK
LOAD
DATA1
DATA0
R1 10K 1/4W 1 %
R2 10K 1/4W 1 %
R3 10K 1/4W 1 %
R4 10K 1/4W 1 %
C1 27pF 100V
R5 392 Ohm 1/8W 1 %
DS1 S0052SW
U1
AY0438T-I/L
U2
AY0438T-I/L
DSP1
TE-1379-TF6
BACKPLANE
ALARM
ALERT
COUNTING
OVERFLOW
OVERLOAD
BAT
COLON

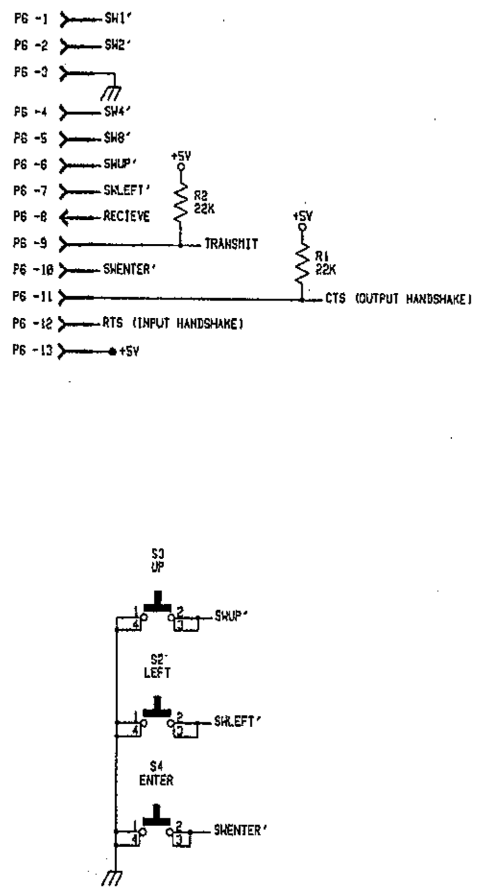


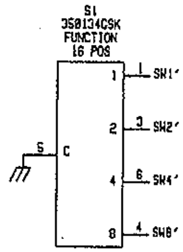
| Drawn: | JK | 23-FEB-07 | Title: LED BACKLITE DISPLAY BOARD | | |
|---|---|---|---|---|---|
| Design: | RSS | 23-FEB-07 | | | |
| | | | Model: M2241 | | |
| Approve: | RSS | [signature] | Board#: 5408-259 | | |
| Layer: | MID: | | Rev: 2.0 | Series | Sheet |
| | 13:15:16 | 24-May-2007 | SCALE: 1.00 | 408 | 260 |
| 408259R2X1.PCB | | | | | |



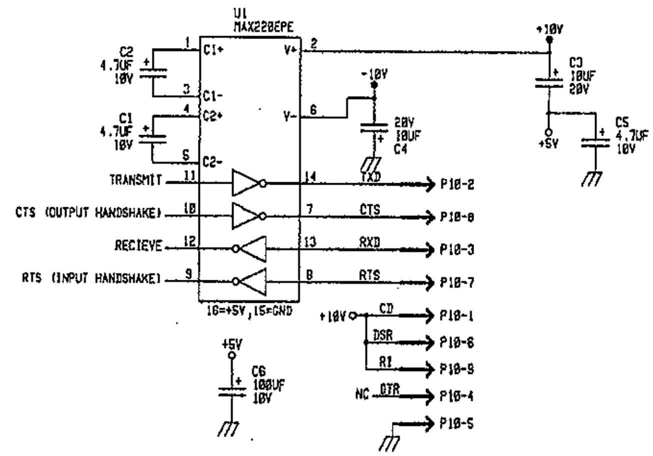
| | | | | | |
|---|---|---|---|---|---|
| Drawn: | JK | 23-FEB-07 | Title: LED BACKLITE DISPLAY BOARD | | |
| Design: | RSS | 23-FEB-07 | | | |
| | | | Model: M2241 | | |
| Approve: | RS | 24/May/07 | Board#: 5408-259 | | |
| Layer: | MID: | | Rev: 2.0 | Series | Sheet |
| | 13:15:16 | 24-May-2007 | SCALE: 1.00 | 408 | 260 |
| 408259R2X1.PCB | | | | | |

| EFF | AUTHORITY | ZONE | LTR | REVISIONS DESCRIPTION | DATE | APPROVED |
|---|---|---|---|---|---|---|

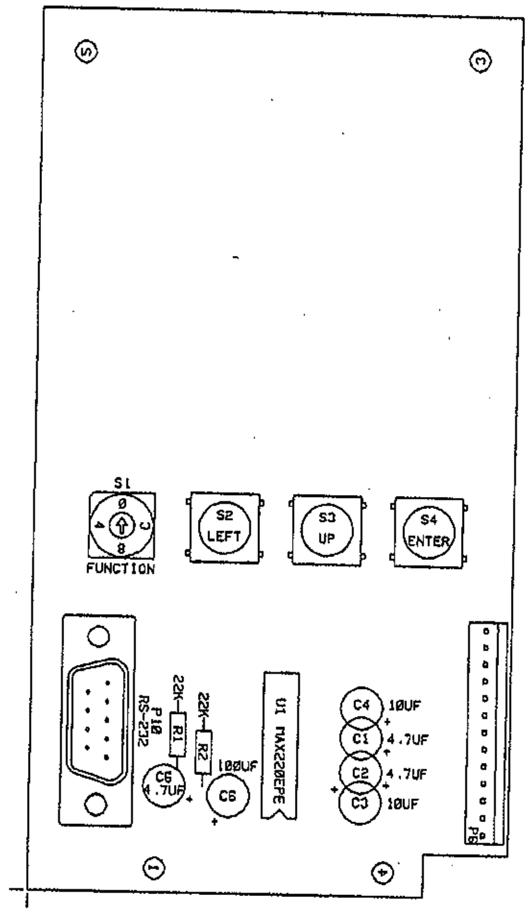


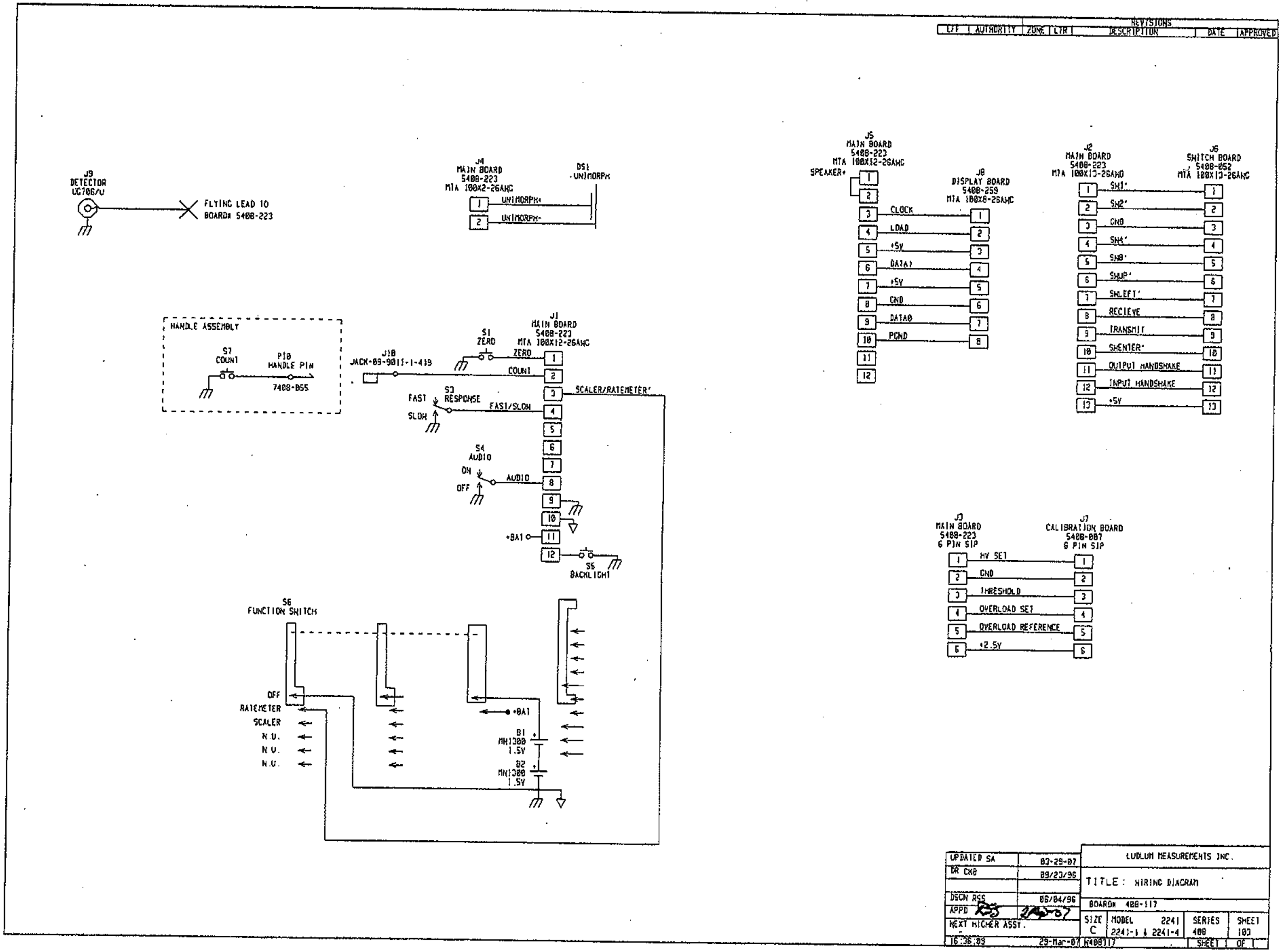

| POS | FUNCTION |
|---|---|
| 0 | NORMAL OPERATION |
| 1 | DEAD TIME (us) |
| 2 | CALIBRATION CONSTANT |
| 3 | DISPLAY UNITS |
| 4 | TIMEBASE: CPS, CPM |
| 5 | AUDIO DIVIDE BY |
| 6 | RESPONSE TIME |
| 7 | RATEMETER ALARM / ALERT |
| 8 | SCALER ALARM / COUNT TIME |
| 9 | NOT USED |
| A | DETECTOR SETUP NUMBER |
| B | LCD BACKLIGHT ON TIME |
| C | SET MINIMUM DISPLAY |
| D | RS-232 DATA DUMP MODE |
| E | RS-232 DETECTOR SETUP MODE |
| F | RS-232 BAUD RATE |




| | | | |
|---|---|---|---|
| UPDATED CKB | 21-DEC-00 | LUDLUM MEASUREMENTS INC. | |
| DR CKB | 06/24/96 | TITLE: SWITCH BOARD | |
| CHK RSS | 12-21-00 | | |
| DSGN LL | 3/17/93 | BOARD# 5408-052 | |
| APPD RDS | 21 Dec 00 | SIZE C / MODEL 2241 | SERIES 408 / SHEET 45 |
| NEXT HIGHER ASSY. | | | |
| 09:54:25 | 21-Dec-00 | S8408052 | SHEET 1 OF 1 |




| LUDLUM MEASUREMENTS INC. SWEETWATER, TX. | | | |
|---|---|---|---|
| DR CKB 06/24/96 | TITLE: SWITCH BOARD | | |
| CHK BSS 12-21-00 | BOARD: 5408-052 | | |
| DSGN LL 03/16/94 | MODEL: 2241 | | |
| APP RDS 21 Dec 00 | FILENAME: BS408052 | | |
| COMPONENT / SOLDER | 09:52:54 | 21-Dec-00 | |
| OUTLINE / OUTLINE | REVISION 1.0 | SERIES 408 | SHEET 46 |



REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
J9 DETECTOR UG706/U
FLYING LEAD TO BOARD# 5408-223
J4 MAIN BOARD 5408-223 MTA 100X2-26AWG
DS1 UNIMORPH
UNIMORPH+
UNIMORPH-
J5 MAIN BOARD 5408-223 MTA 100X12-26AWG
SPEAKER+
J8 DISPLAY BOARD 5408-259 MTA 100X8-26AWG
CLOCK
LOAD
+5V
DATA1
+5V
GND
DATA0
PGND
J2 MAIN BOARD 5408-223 MTA 100X13-26AWG
J6 SWITCH BOARD 5408-052 MTA 100X13-26AWG
SW1*
SW2*
GND
SW4*
SW8*
SWUP*
SWLEFT*
RECIEVE
TRANSMIT
SWENTER*
OUTPUT HANDSHAKE
INPUT HANDSHAKE
+5V
HANDLE ASSEMBLY
S7 COUNT
P10 HANDLE PIN 7408-055
J10 JACK-09-9011-1-419
S1 ZERO
J1 MAIN BOARD 5408-223 MTA 100X12-26AWG
ZERO
COUNT
SCALER/RATEMETER*
FAST
S3 RESPONSE
SLOW
FAST/SLOW
S4 AUDIO
ON
OFF
AUDIO
+BAT
S5 BACKLIGHT
S6 FUNCTION SWITCH
OFF
RATEMETER
SCALER
N.U.
N.U.
N.U.
+BAT
B1 MN1300 1.5V
B2 MN1300 1.5V
J3 MAIN BOARD 5408-223 6 PIN SIP
J7 CALIBRATION BOARD 5408-087 6 PIN SIP
HV SET
GND
THRESHOLD
OVERLOAD SET
OVERLOAD REFERENCE
+2.5V
UPDATED SA 03-29-07
DR CKB 09/23/96
DSGN RSS 06/04/96
APPD
NEXT HIGHER ASSY.
16:36:09 29-Mar-07 W408117
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
BOARD# 408-117
SIZE C
MODEL 2241 2241-1 & 2241-4
SERIES 408
SHEET 103
SHEET OF