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Final Report on the Design and Development of a Rolling Float Meter for Drilling-Fluid Outflow Measurement

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FINAL REPORT ON THE DESIGN AND DEVELOPMENT OF A ROLLING FLOAT METER FOR DRILLING-FLUID OUTFLOW MEASUREMENT

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Abstract

Lost circulation, which is the loss of well drilling fluids to the formation while drilling, is a common problem encountered while drilling geothermal wells. The rapid detection of the loss of well drilling fluids is critical to the successful and cost-effective treatment of the wellbore to stop or minimize lost circulation. Sandia National Laboratories has developed an instrument to accurately measure the outflow rate of drilling fluids while drilling. This instrument, the Rolling Float Meter, has been under development at Sandia since 1991 and is now available for utilization by interested industry users. This report documents recent Rolling Float Meter design upgrades resulting from field testing and industry input, the effects of ongoing testing and evaluation both in the laboratory and in the field, and the final design package that is available to transfer this technology to industry users.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Acknowledgments

The authors would like to acknowledge the technical support provided by Sandia Geothermal Research Department personnel, R. D. Jacobson and S. D. Knudsen during laboratory and field test evaluations of the Rolling Float Meter.

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Background

The common problem of well drilling fluid (mud) loss to the formation while drilling geothermal wells should be addressed promptly to minimize well completion costs. The added costs incurred as a result of this "lost circulation" for an average geothermal well are estimated to be from 5% to 10% of the total well cost[1]. Various methods to treat and control lost circulation are being investigated by the Geothermal Research Department at Sandia National Laboratories. All methods currently under consideration require accurate and prompt detection of drilling fluid loss in order to analyze the magnitude of the loss zone and minimize the lost circulation treatment costs. To detect drilling fluid loss, both an accurate inflow and outflow meter must be employed on the drill rig to monitor these flow rates while drilling.

The Rolling Float Meter (RFM), developed at Sandia beginning in 1991[2], has been used to accurately measure the outflow flow rate of well drilling fluids[3,4] in a partially-filled return line pipe. Commercially available non-intrusive inflow meters, such as the current state-of-the-art clamp-on Doppler ultrasonic flow meter, have been successfully employed on drill rigs to measure fluid inflow rates[5]. These commercial inflow meters are being evaluated by Sandia and compared to the industry-standard pump-stroke counter inflow measuring technique. Comparing the real time inflow and outflow rates, while drilling, provides the fast response delta flow (outflow minus inflow) needed to detect and treat lost circulation.

This report addresses the current design of the Sandia RFM, the results of recent laboratory and field tests, and the final design package being made available to industry to produce and market this instrument.

Current Design Features

As documented in Ref. #2 above, during development of the RFM several design configurations were examined before settling on the original field-prototype design. Using this design, several prototype units were built and loaned to interested drilling and well logging companies for field testing and evaluation. These prototype units basically consisted of a rotating polyurethane foam float wheel, with a counterbalance, attached to a horizontal support shaft and mounted in a sheet metal housing. A pendulum potentiometer was attached to the horizontal shaft in the housing to measure the angle (and thus the fluid depth) between the float wheel and the return pipe. After testing, the loaned meters were returned to Sandia for post-test evaluation. Results of these tests were mixed. When the RFM was loaned, an instruction manual on installation, calibration and operation was provided by Sandia. However, since this was still a developmental tool, instructions were not always followed as intended, and routine RFM maintenance was overlooked or neglected. We also found that the field-prototype design was not as robust as required for the rough handling encountered around drill rigs, and damage to the loaned units was common. The severe environmental conditions (high mud temperatures, abrasive cuttings, corrosive fluids, etc.) that the meter was exposed to while drilling geothermal wells, was also worse than expected. Examination of the polyurethane foam float wheel revealed that the foam was being eroded away during operation because of the abrasiveness of the return mud/cuttings, especially at the elevated temperatures encountered during geothermal drilling operations.

Meetings and telephone conversations with industry users provided us with additional features to improve the RFM design and make it more useful and acceptable to industry. One user, Inteq, Inc., chose to redesign the prototype RFM housing, making it more sturdy, so it could be employed on return lines where a sudden over pressurization, as from a well kick, would not damage the meter housing. This improved housing RFM was returned to Sandia by Inteq after their field evaluations. Several features of this design were incorporated into our design upgrade to improve the robustness of the RFM. In addition, the Inteq unit was modified by Sandia to test other design features that were later incorporated into our upgrade. Improvements in the design of the RFM were begun by Sandia in late 1995. A complete design-upgrade drawing package was prepared, using AutoCADlt software, and these files are available to interested industry manufacturers.

To improve the wear resistance of the float wheel we chose to fabricate a wheel from thin sheet metal instead of foam. The shape selected was similar to the prototype polyurethane foam wheel, see *Figure 1*, and the material was type 304 stainless steel (SS). Another feature added to the wheel assembly was an adjustable stop plate that allowed the wheel to be positioned close to, but not touching, the bottom ID of the return line pipe. This permits the wheel to begin rotation at a much lower flow rate than that required to lift the wheel off the bottom ID before it can start to rotate. Since the wheel is counterbalanced on the RFM, the buoyancy difference between the two wheels was minimized; however, the additional mass of the SS wheel did require higher fluid flow velocities, in contact with the convex dimple upsets on the wheel periphery, to initiate rotation. We also found that during rotation the shape of the prototype wheel caused it to be pulled deeper into the fluid than desired. Subsequent laboratory testing with a SS wheel that employed fins instead of upsets on the wheel periphery, reference *Figure 2*, provided a solution to the start-up rotation problem and resulted in a more stable wheel (less bounce) on the agitated surface of the fluid at high (>500 gpm) flow rates.

Accumulations of mud and other debris on the wheel sometimes necessitated field adjustments to the counterbalance to maintain desirable wheel stability. Since the counterbalance on the prototype was located internal to the RFM housing, adjustments were difficult. Changes were therefore incorporated into the upgrade to move the counterbalance outside of the RFM housing and to also provide a port in the housing to allow access to the wheel shaft for attaching a portable field scale that is used to measure the counterbalance/wheel weight differential when making counterbalance adjustments. To protect the counterbalance from exposure to the harsh drill rig environment, it was installed in a commercial steel instrument enclosure (NEMA Type 4) that was attached to the outside of the RFM housing.

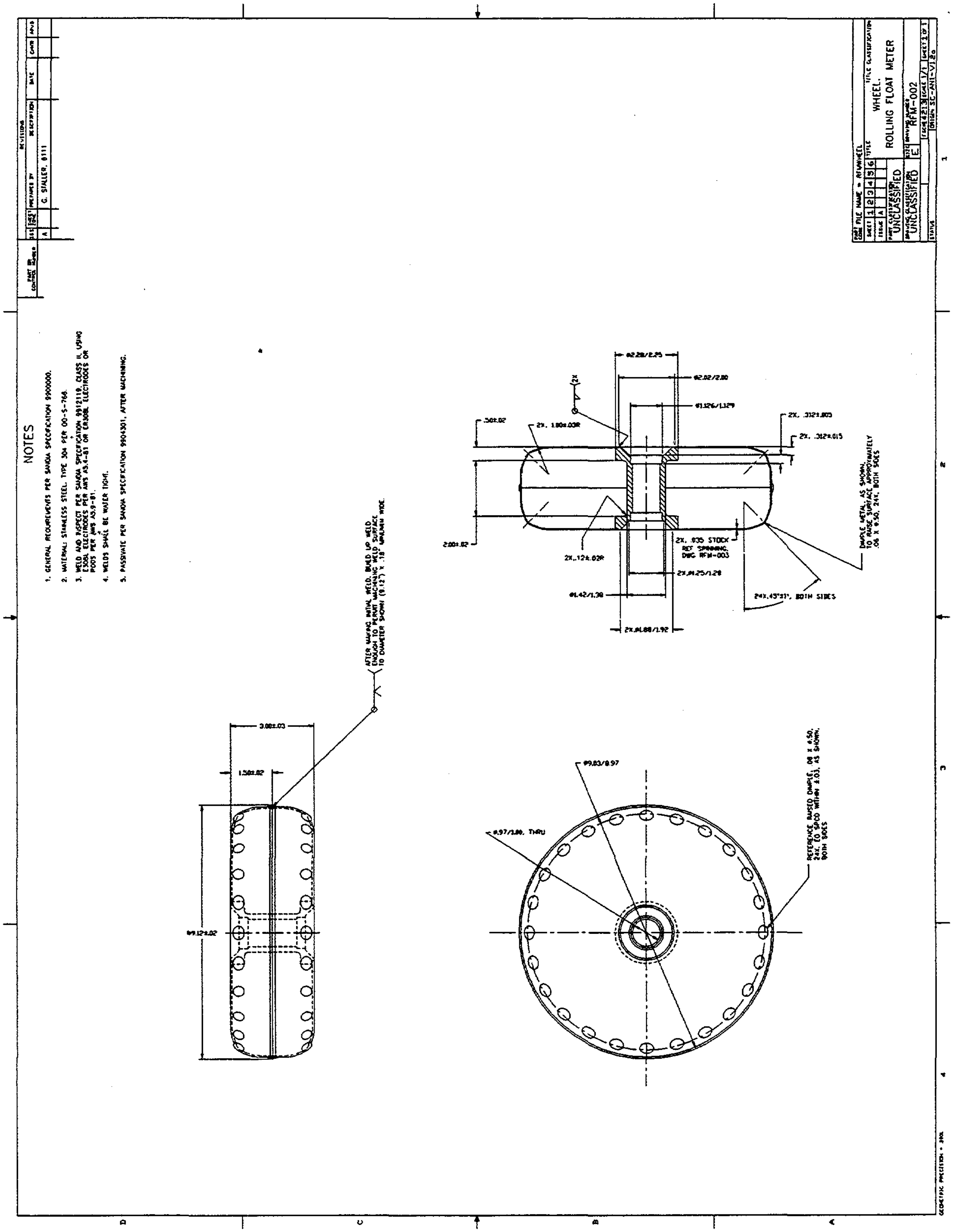

NOTES
1. GENERAL REQUIREMENTS PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304 PER QQ-S-766.
3. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308L ELECTRODES PER AWS A5.4-81 OR ER308L ELECTRODES OR RODS PER AWS A5.9-81.
4. WELDS SHALL BE WATER TIGHT.
5. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.
WHEEL,
ROLLING FLOAT METER
RFM-002
UNCLASSIFIED
UNCLASSIFIED
E

Figure 1

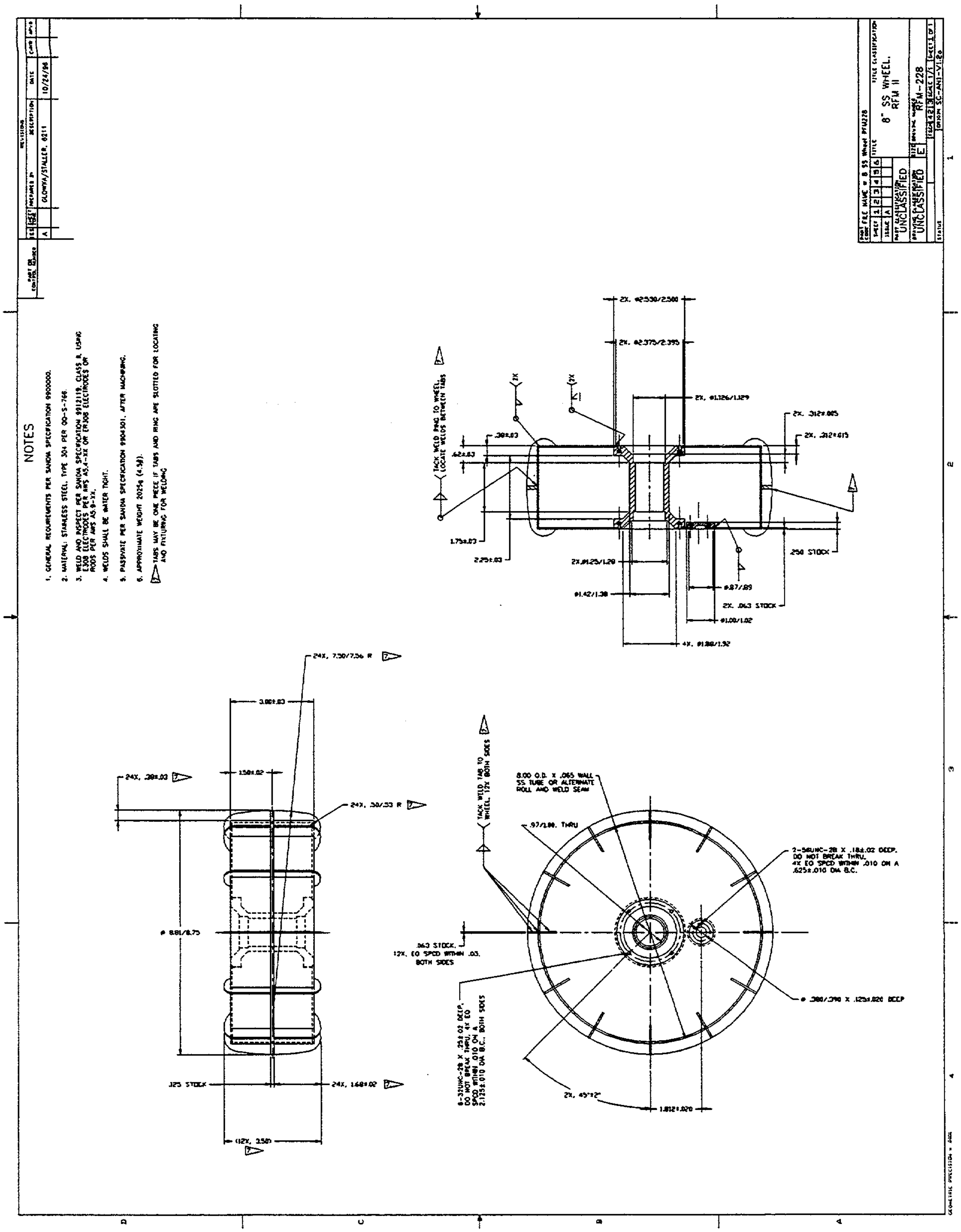


Figure 2

The resolution of the pendulum potentiometer, used to measure float-wheel-to-pipe angle and thus fluid depths in the return line pipe, was limited. The pendulum potentiometer was replaced with a rotary potentiometer to measure this angular displacement. The bias voltage applied to the rotary potentiometer was set higher than the voltage applied to the pendulum potentiometer, to provide a better output signal-to-noise ratio. In addition, a commercial precision speed-reducer gear box with a 4:1 multiplication factor was placed in series between the RFM shaft, used to measure the float-wheel-to-pipe angle, and the rotary potentiometer. This 4:1 increase per degree-of-change for the float angle, along with the higher output voltage signal, produced increased sensitivity to fluid depth (flow) in the outflow pipe. This equipment was mounted in the same instrument enclosure used to protect the counterbalance. Both the enclosure and this equipment were designed to be installed on either side of the RFM housing to facilitate access for calibration and maintenance when used on a drill rig.

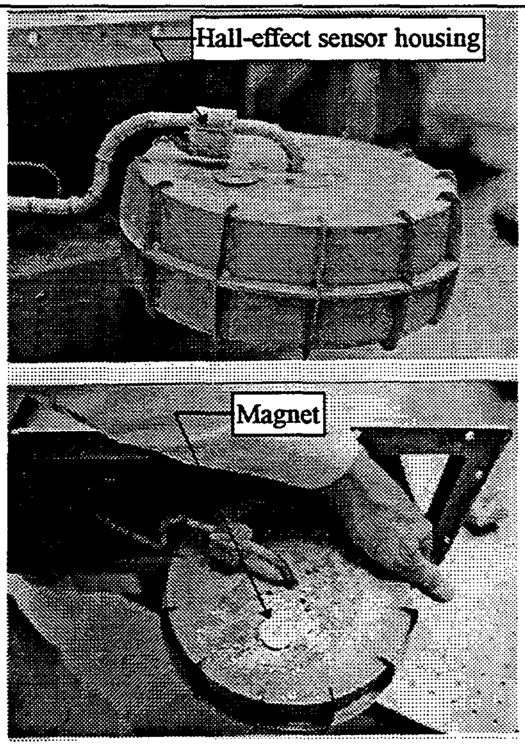


Figure 3

One of the problems encountered during field evaluations of the prototype RFM were false flow indications. When outflow was terminated and debris in the return line pipe prevented the float wheel from resting on the bottom ID of the pipe (zero flow position), a false flow indication was presented. As documented in Ref. #3, during initial development of the RFM, rotational speed of the wheel was eliminated as a method to measure return-line pipe flow. However, when wheel rotation was integrated with float angle (flow) indication, an "if" statement could be programmed into the flow data equation, such that flow indication was only valid when wheel rotation was occurring. To measure wheel rotation, a Hall-effect magnetic sensor was attached to the wheel shaft, and a magnet, to actuate the sensor, was mounted on the wheel (*Figure 3)*. The Hall-effect sensor is installed in a fabricated housing designed specifically for this sensor and epoxied in place to provide a water-tight assembly. When in use on an operating RFM, if the measured wheel rotation is zero, then the RFM outflow indication is presented as zero. This technique presents a problem if the Hall-effect sensor fails or if the wheel is jammed and prevented from rotating when outflow is obviously present. We incorporate a switch in our data acquisition software to bypass the "if" command and override a false zero indication, until the problem can be identified and resolved.

With the RFM configured this way, we were able to measure fluid outflow rates as low as 50 gpm and detect fluid losses as small as 2% of flow (10 gpm loss at 500 gpm flow) under laboratory conditions, (see *Figure 4*).

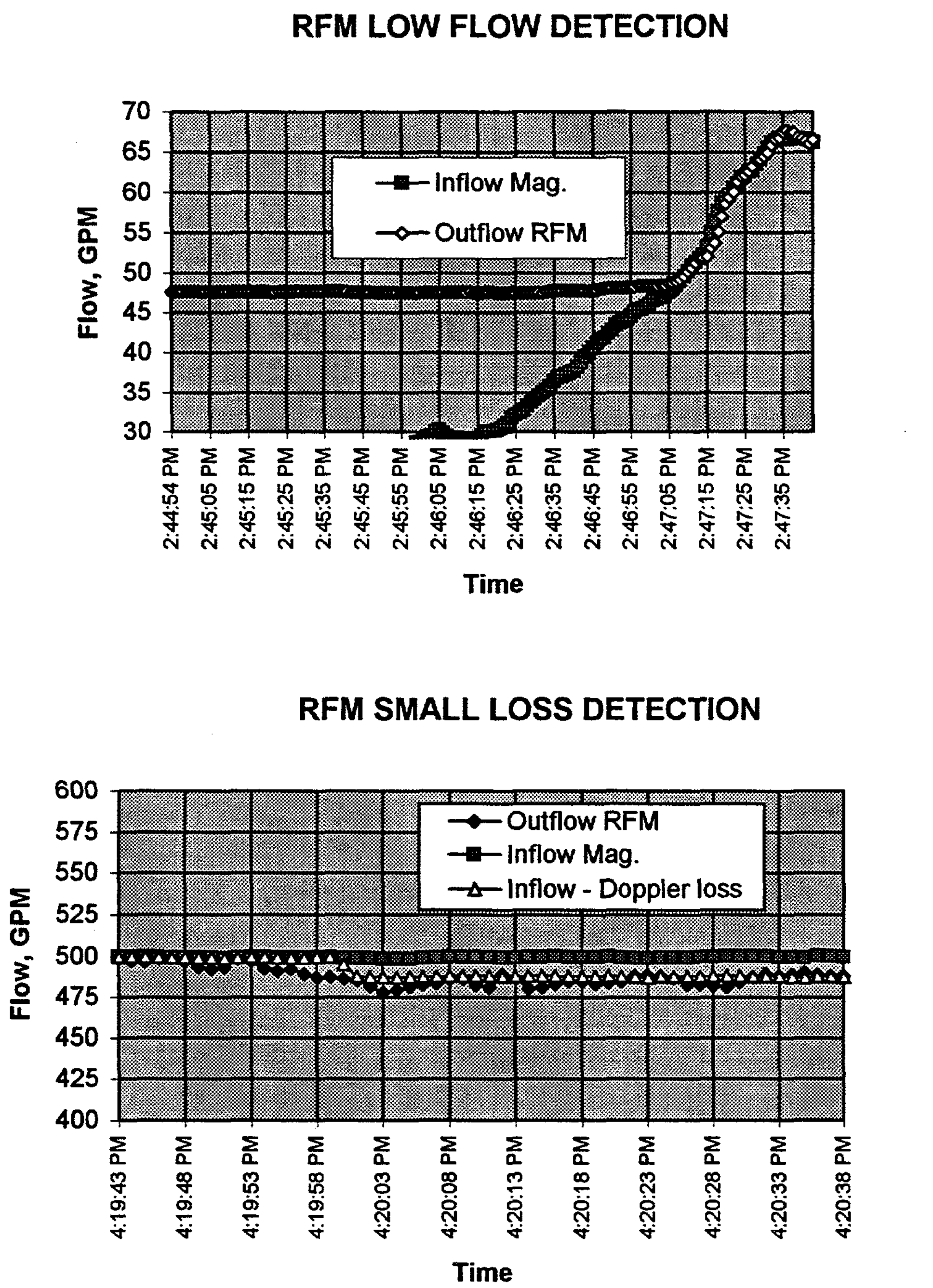
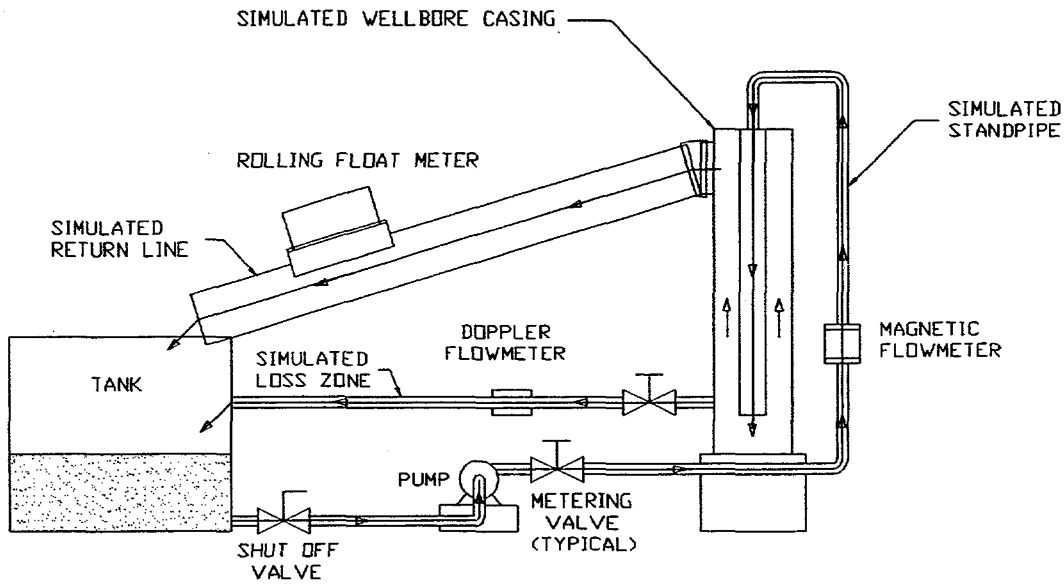


Figure 4

Intrinsically-safe barriers are provided on RFM electronics to meet the safety requirements of oil and gas drilling applications.

Laboratory Test Results

The Sandia Wellbore Hydraulics Flow Facility (WHFF), operated by the Geothermal Research Department, was used extensively to test and evaluate the RFM before it was employed in field operations. As shown in the WHFF diagram in *Figure 5*, the fluid flow



WELLBORE HYDRAULICS FLOW FACILITY DIAGRAM

Figure 5

rates can be controlled by metering valves and measured with magnetic and/or Doppler flow meters, and an independently measured flow loss can be introduced during testing to model a wellbore loss zone. Water was the primary fluid used during initial RFM testing, however, drilling muds were also used during final testing and evaluation prior to field application.

As stated previously the Sandia/Inteq modified RFM (MRFM) was altered to assess the upgrades prior to incorporating them into the final RFM design. This modified unit was then attached to the WHFF simulated return line, (*Figure 6*), for testing and evaluation.

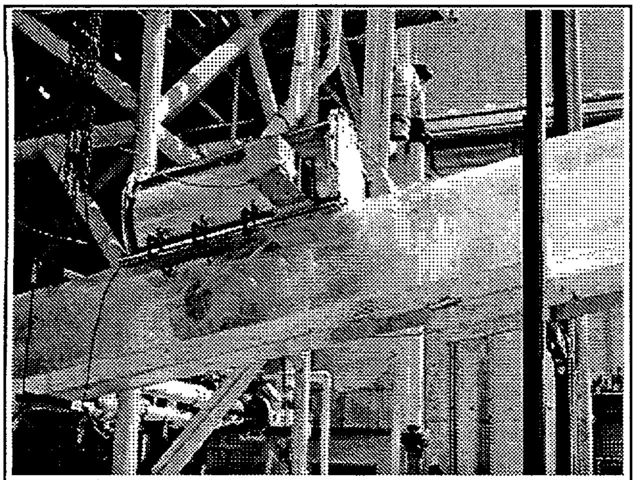


Figure 6

These upgrades included: the SS wheel with fins, the externally adjustable counterbalance, the rotary potentiometer with the 4:1 ratio gear-box multiplier, and the Hall-effect sensor to monitor wheel rotation. The MRFM power supply and data-acquisition circuits were designed and assembled by Sandia, and the data was recorded using National Instruments, Corp., LabView software.

The MRFM was calibrated in the laboratory against a magnetic flowmeter (4" Yokogawa ADMAG). Typical calibration data is shown in *Figure 7*. Testing was done to evaluate the effect of wheel weight on MRFM operation. The counterbalance was adjusted to vary the wheel down-weight from 50g to as much as 1000g. The return line flow rate was set at 500 gpm for these tests. The counterbalance was adjusted to provide minimal float wheel bounce at 500 gpm and still achieve lift-off from the stop plate at 30 to 50 gpm. Lift-off from the stop plate is the point at which the MRFM begins to register fluid depth in the return line or increasing flow. The best wheel down-weight for the MRFM was approximately 750g. Below 500g, wheel bounce was excessive, and above 1000g the flow required to lift the wheel off the stop plate was greater than 50 gpm. Additional testing was then conducted to evaluate the operation of the MRFM at various return line angles. The return line was positioned at the angles of, 2°, 5°, 8.5°, and 12°, and operational parameters like bounce, calibration, and minimum detectable loss were verified. No significant differences could be detected when the return line angle was changed. An opportunity to field test the MRFM became available when SNL was requested to oversee slimhole drilling operations for several exploratory geothermal wells. Prior to taking the MRFM to the field for

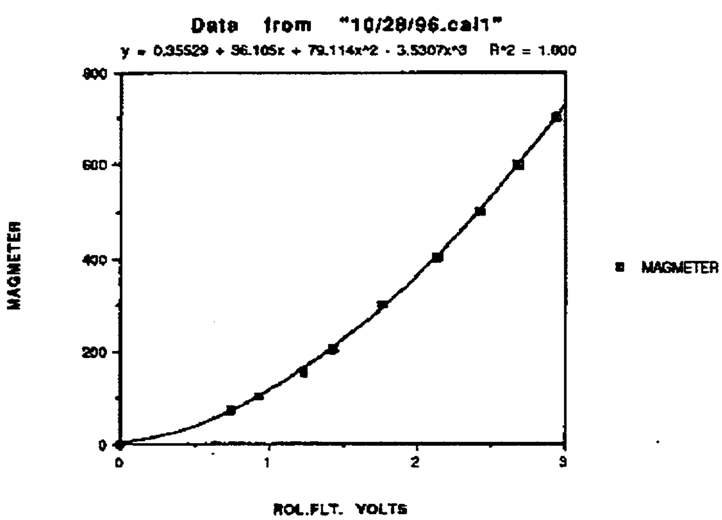


Figure 7

testing, a simulated return line pipe that modeled the expected field return line pipe was constructed at the WHFF and used to verify MRFM calibration and operation under these conditions.

Ktech Corporation, a technical contracting and manufacturing firm in Albuquerque, NM, was contracted by Sandia to fabricate and assemble a prototype RFM produced from our upgraded design package. This fabrication was done in parallel with MRFM laboratory testing, thus any changes resulting from MRFM testing could be quickly incorporated into the Ktech prototype RFM during production. No changes were required, and the completed RFM was delivered to Sandia on 10/22/96. This unit was installed on the WHFF and evaluated at various flow rates, return line angles and wheel down-weights. The RFM power supply and data-acquisition circuits were also designed and assembled by Sandia, and the data were recorded using National Instruments, Corp., LabView software. *Figure 8* shows a typical RFM calibration curve against the WHFF magnetic flowmeter at

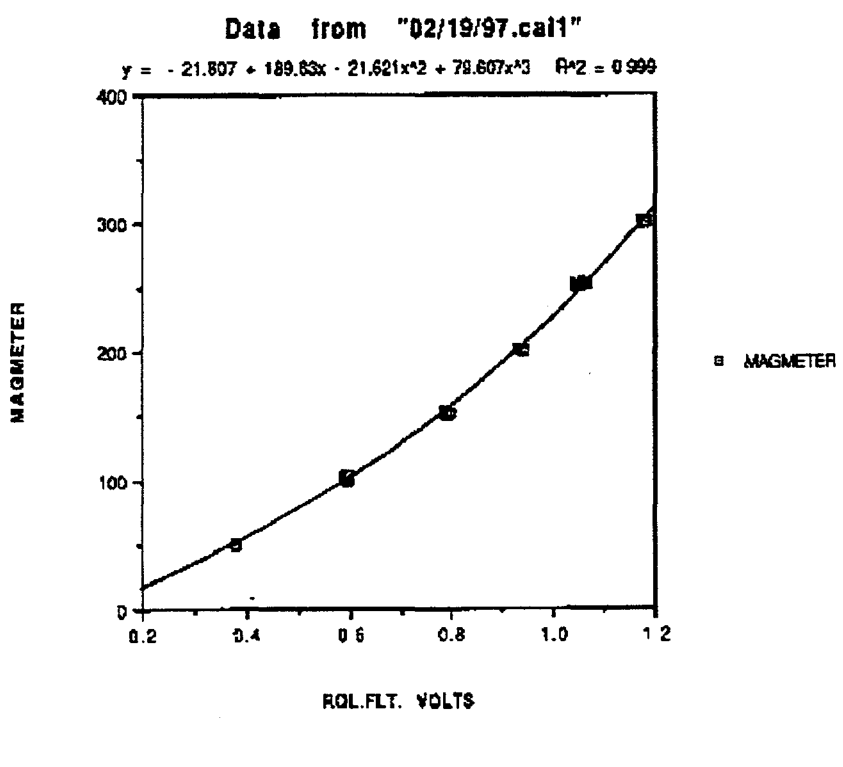


Figure 8

the optimal operating parameters of 750g wheel down-weight with a return line angle of 8.5°. The flow required to lift the wheel off the stop plate was approximately 50 gpm, and the peak flow applied to the RFM was 925 gpm, which is the maximum output of the WHFF pump.

The majority of the initial testing on the RFM was completed using water as the simulated wellbore fluid. However, the RFM was used during the evaluation of several commercial non-intrusive inflow meters on the WHFF. These meters required the use of drilling fluid/mud to adequately assess their performance. Therefore, the RFM was operated extensively with mud as the simulated wellbore fluid in the WHFF. *Figure 9* indicates a typical RFM calibration curve against the WHFF magnetic flowmeter while flowing drilling fluid/mud.

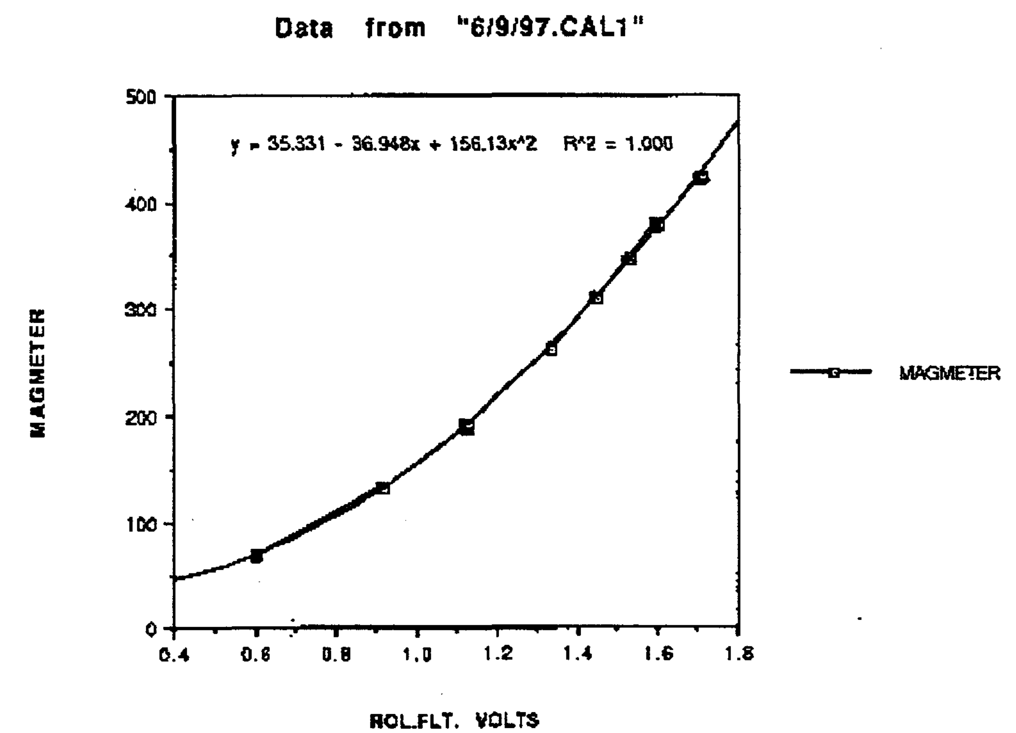


Figure 9

Field Test Location Summary

The MRFM was installed on several geothermal exploratory slim hole drilling operations[6] involving Sandia. The wells were drilled by the U.S. Army on the McGregor Range of the Fort Bliss Military Reservation near El Paso, TX. This work began in November 1996. The following is a short summary of MRFM use on these tests:
In all cases the MRFM was used only until a 4.5" casing was installed in the well and core drilling operations began.

> <u>Well 46-6</u>
> MRFM installed on 11/10/96 - 11/11/96.
> MRFM calibrated on 11/11/96.
> 4.5" casing cemented and MRFM removed on 11/25/96.
> Total depth of well drilled using MRFM was 707'.
> MRFM operation time was approximately 14 days.

Well 45-5
MRFM installed on 12/17/96.
MRFM calibrated on 12/18/96.
4.5" casing cemented and MRFM removed on 1/14/97.
Total depth of well drilled using MRFM was 596'.
MRFM operation time was approximately 15 days.

Well 61-6
MRFM installed on 2/17/97.
MRFM calibrated on 2/17/97.
4.5" casing cemented and MRFM removed on 2/22/97.
Total depth of well drilled using MRFM was 630'.
MRFM operation time was approximately 5 days.

Well 51-8
MRFM installed on 3/9/97.
MRFM calibrated on 3/9/97.
4.5" casing cemented and MRFM removed on 3/28/97.
Total depth of well drilled using MRFM was 529'.
MRFM operation time was approximately 19 days.

The RFM was installed on two large-diameter geothermal well drilling projects at sites in California to evaluate the current design. The first test was conducted solely to evaluate the RFM in a large-diameter geothermal well drilling environment. The second RFM evaluation test was done in conjunction with tests being conducted by Sandia for the Geothermal Drilling Organization (GDO) to evaluate the effectiveness of nitrogen-foamed cement when used to treat lost circulation in geothermal wells. The RFM was used to assist in monitoring the results of the cementing technique during the drilling operation. The following is a short summary of these tests:

California Energy Company, Inc., Imperial Valley Geothermal Field, Well location - Del Ranch #10
RFM installed on 3/4/97.
RFM calibrated on 3/5/97.
RFM removed on 4/9/97.
RFM operation time was approximately 35 days.

California Energy Company, Inc., Coso Geothermal Field, Well location - Navy II 76B-18
RFM installed on 8/27/97.
RFM calibrated on 8/28/97.
RFM removed on 10/27/97.
RFM operation time was approximately 60 days.

Field Test Results

Slimhole Well Drilling

The MRFM was selected for use during the Fort Bliss slimhole drilling operations because of its availability and the opportunity to further evaluate the MRFM performance during actual drilling operations. The original prototype RFM had been evaluated under similar conditions, and direct comparisons could be made to MRFM operation and thus to upgrade-feature performance.

The MRFM mounting flange was installed on the return line and the MRFM attached to the flange. The return line was 6", schedule-40 steel pipe with the output end attached directly to the possum belly on the rig mud-tank shaker box. The return line was positioned at a 9.7° angle from the pitcher/flow nipple on the rig mud riser to the mud tank shaker box. The MRFM underwent constant vibration as a result of being attached directly to the shaker box. Under normal conditions vibration on a large diameter geothermal drill rig is a common problem; thus the vibration from the shaker box was a good method to evaluate vibration effects on the MRFM upgrades.

These wells were drilled at a high altitude, semi-arid desert location during late fall and winter. Ambient air temperature variations at the well site were extreme, often very cold at night and warm during the day. Since the MRFM was only utilized during rotary drilling of the first 500' to 700' of each well, only minor changes in drilling fluid temperatures were encountered.

The MRFM operated as designed during each drilling operation. The only significant problem encountered was a sudden offset in the no-flow voltage signal at one point. This occurred while drilling the second well. Investigation of the MRFM gear box-to-rotary potentiometer connections revealed that a shaft connecting collar was loose, allowing slippage between the gear box and rotary pot shafts. This connection was tightened and the MRFM recalibrated. Ambient thermal cycling may have contributed to this collar clamping problem. No additional occurrences of this type were noted. Locktite adhesive is now employed on all critical threads to prevent this type of slippage.

The MRFM was employed to monitor and detect lost circulation that was occasionally encountered while drilling these wells. It was also used by the driller to help maintain his drilling rate by monitoring fluid returns while drilling. This assisted him in making decisions concerning possible booting (filling or plugging) of the drill pipe annulus with rock chips. The outflow data helped him decide when bit pull-back, to wash out the well, was desirable and when adequate flow was reestablished so he could put weight back on the bit and continue drilling.

Large-Diameter Well Drilling

The upgraded RFM was first employed on a large diameter geothermal drill rig at the California Energy Company, Inc., (CalEnergy) Imperial Valley Geothermal Field, Del Ranch #10 site. This well was drilled by CalEnergy, in an established geothermal field, as a production well for existing power plant utilization. The well is located near Calipatria, CA, and was drilled over a five-week period during the spring when air temperatures were mild both during the day and at night. Sandia was invited to conduct drilling fluid inflow and outflow instrument evaluations while this well was being drilled.

The RFM mounting flange was installed on the drilling fluid return line pipe during well spudding procedures. The return line was a 10", schedule-40 steel pipe and was positioned with a 9.8° slope from the pitcher/flow nipple on the rig mud riser to the mud tank. The RFM mounting flange was welded to the return line, as directed by Sandia, over a 6"-wide X 21"-long opening in the pipe. This opening was torch cut into the pipe, and the ragged edge from the cutting operation had to be ground smooth, along the 6" wide edges, in order for the RFM wheel axle to properly clear the 6" opening and operate correctly. The RFM mounting flange was positioned so access for installation and maintenance of the RFM was available from the drill-rig mud-tank work deck, (see *Figure 10*).

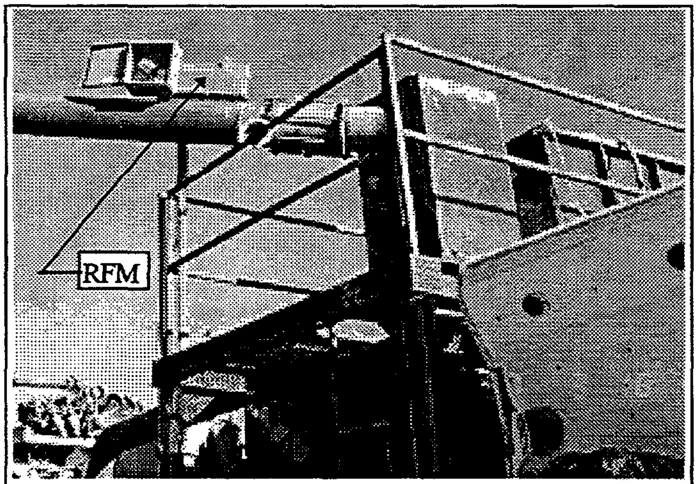


Figure 10

The RFM was secured to the mounting flange, and the float wheel was adjusted for zero-flow conditions. The RFM counterbalance was adjusted for approximately 750g float wheel down-weight. Calibration of the RFM against the drill-rig mud-pump stroke-counter was then completed.

The RFM, with several minor problems, operated satisfactorily during this five-week drilling period. The first problem encountered, two days after starting to drill, was caused by a large piece of debris (probably clay knocked off the wellbore by a drill-pipe centralizer) becoming lodged between the float wheel fins and the float wheel mounting shaft. This prevented the float wheel from rotating, and thus a no-flow condition was displayed on the RFM data-acquisition monitor. When the clay was removed, and the wheel was free to rotate, the RFM was returned to normal operation. Another problem occured with the Hall-effect sensor/float-wheel rotation-monitor several weeks into the operation. This was caused by the accumulation of a magnetic material (possibly magnetite or fine metal chips in the drilling fluid) on the float-wheel magnet. This material interfered with the Hall-effect sensor signal and resulted in the rotation indicator circuit displaying a no-flow condition when, in fact, flow remained constant and the float wheel was rotating. When this material was removed from the magnet, the Hall-effect sensor worked properly. The magnet was cleaned periodically, but eventually it had to be replaced to maintain Hall-effect sensor operation. The magnet was replaced twice during the five-week drilling period. The last magnet was coated with an epoxy to minimize exposure of the magnet's surface to the drilling fluid. The final problem, although not causing a malfunction, exposed the RFM to extreme temperatures and pressure pulses. To maintain the drilling fluid temperatures below 160° F, the rig operator installed a mud chiller in the drilling fluid system. At one point in the drilling operation, while the drill string was being tripped to replace a bottom hole assembly, the mud was not being circulated and the downhole mud temperatures rose significantly. When drilling operations resumed and the hot mud returned to the surface it flashed to steam. Some of this flashing occurred in the return line pipe, causing the RFM float wheel to be suddenly forced high enough in the pipe to impact the top of the RFM housing. This flashing and float wheel impact occurred several times before cool mud was circulated to the surface and the flashing subsided. The RFM operated normally during the remainder of the drilling operation. Post-test inspection of the RFM float wheel revealed a bent fin, see *Figure 11*, but no other apparent damage

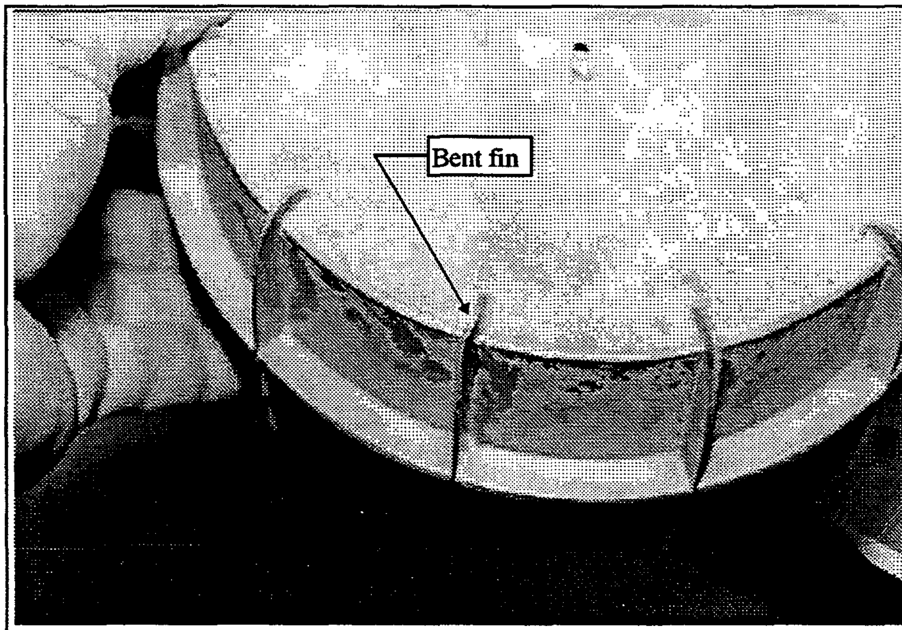


Figure 11

resulted from the high mud temperatures or flashing steam pulses. Since the fins are welded to the wheel, the bent fin was easily straightened.

The RFM was disassembled, inspected, cleaned and re-assembled in preparation for additional field testing. New bearings were installed in the wheel. A new magnet with a protective coating on all exposed surfaces was installed on the wheel to improve Hall-effect sensor reliability. In addition, an adapter plate for a hinge between the RFM housing and the RFM pipe flange was designed and fabricated to enable an operator to easily disconnect and rotate the RFM assembly off the pipe flange, for field repairs or maintenance, while it still remains attached to the return line pipe.

The second field test for the upgraded RFM was at another CalEnergy site. This well was in the Coso Geothermal Field, on the U.S. Navy's China Lake Naval Weapons Center located near Ridgecrest, CA. This new production well was located at the Navy II 76B-18 pad and was started in late summer and completed in early fall 1997. Weather conditions were mild with some periods of heavier-than-normal rain, but overall moderate ambient temperature conditions. Sandia was participating in this drilling project to evaluate the effectiveness of nitrogen-foamed cement when used to plug loss zones in geothermal wells. The RFM was used by Sandia to document the extent of the lost circulation both before and after applying the foam cement. Data output from the RFM was also provided to the on-site well logger.

After well spudding was completed, the RFM mounting flange was attached to the mud return line pipe. The return line was a 12", schedule-40 steel pipe that was positioned with a 5.0° slope between the pitcher/flow nipple on the rig mud riser and the mud tank. The RFM was located along the return line where access to the RFM, for maintenance and troubleshooting, was available from a sub-deck on the drill rig. Due to the large return-line pipe diameter and the new spacer plate and hinge addition to the RFM assembly, the as-designed stop-plate zero-flow adjustment limits were insufficient to permit the desired adjustment of the float wheel. Therefore, some minor modifications were required to the RFM stop-plate before final float wheel adjustments could be made. When the stop-plate modifications were completed, the RFM was secured to the mounting flange, and the float wheel was adjusted for zero-flow conditions. The counterbalance was adjusted for approximately 750 g wheel down-weight. The RFM flow was calibrated against the inflow flow rate that was measured with a commercial Doppler flowmeter provided by Sandia.

The RFM was used extensively during the 60-day period when mud was used while drilling. Only minor problems with the RFM were encountered, none of which required extensive down time. The float-wheel rotation magnet, as noted during the previous field evaluation test, began to accumulate metallic material on the magnet surface. This was noticed after several weeks of drilling and became more noticeable after casing was installed in the upper 4500' of the well. The protective epoxy coating over the magnet did help prolong the magnet life. However, ferrous metal in the mud return seems inevitable when the wellbore has a steel casing, steel drill pipe, and a steel bit that all are being burnished/rubbed against hard rock or against each other while in use. The buildup of this material on the magnet surface adversely affects the Hall-effect sensor operation by reducing the strength of the magnetic field required to trigger the sensor. Wiping the magnet periodically (once a day) seemed to minimize the problem, but a more permanent solution would be to replace this rotation detection method with one that did not require a magnetic field for operation.

Drilling fluid temperature is a concern during geothermal well drilling operations. To maintain the mud temperatures below 160°F a mud chiller was employed in the drilling fluid system. Frequent use of lost circulation materials during drilling necessitated bypassing the mud chiller, resulting in high temperature gaseous drilling fluids. When the downhole mud temperatures rose significantly, the hot gaseous mud being returned to the surface caused a kick or flashed to steam. This pressure pulse entered the return line pipe, causing the RFM float wheel to again be suddenly forced high enough in the pipe to impact the top of the RFM housing. This pulsing and float wheel impact occurred several times before the mud quality improved and the pulsing subsided. Post-test inspection of the float wheel again revealed bending damage to several fins as a result of impact initiated by the high temperature drilling fluids.

In *Figure 12*, selected data form the above field tests is plotted showing how typical drilling fluid losses were recorded using the RFM.

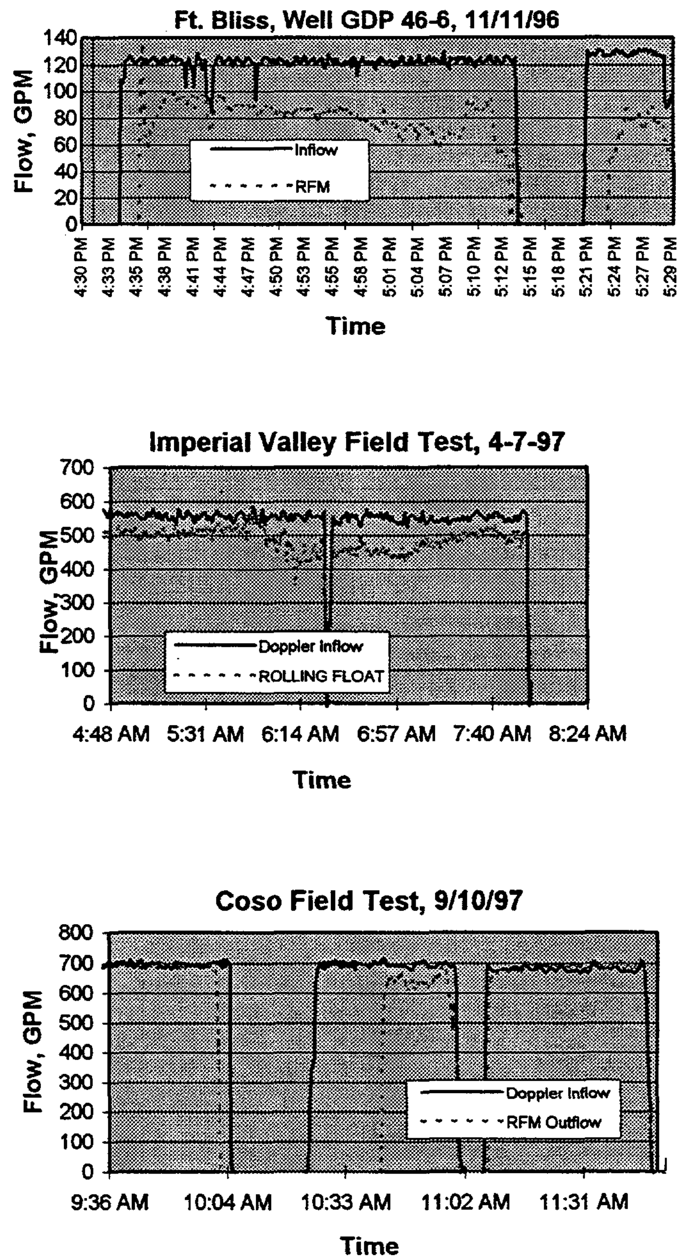


Figure 12

Final Design Package

The final design configuration of the RFM is shown in *Figure 13*.

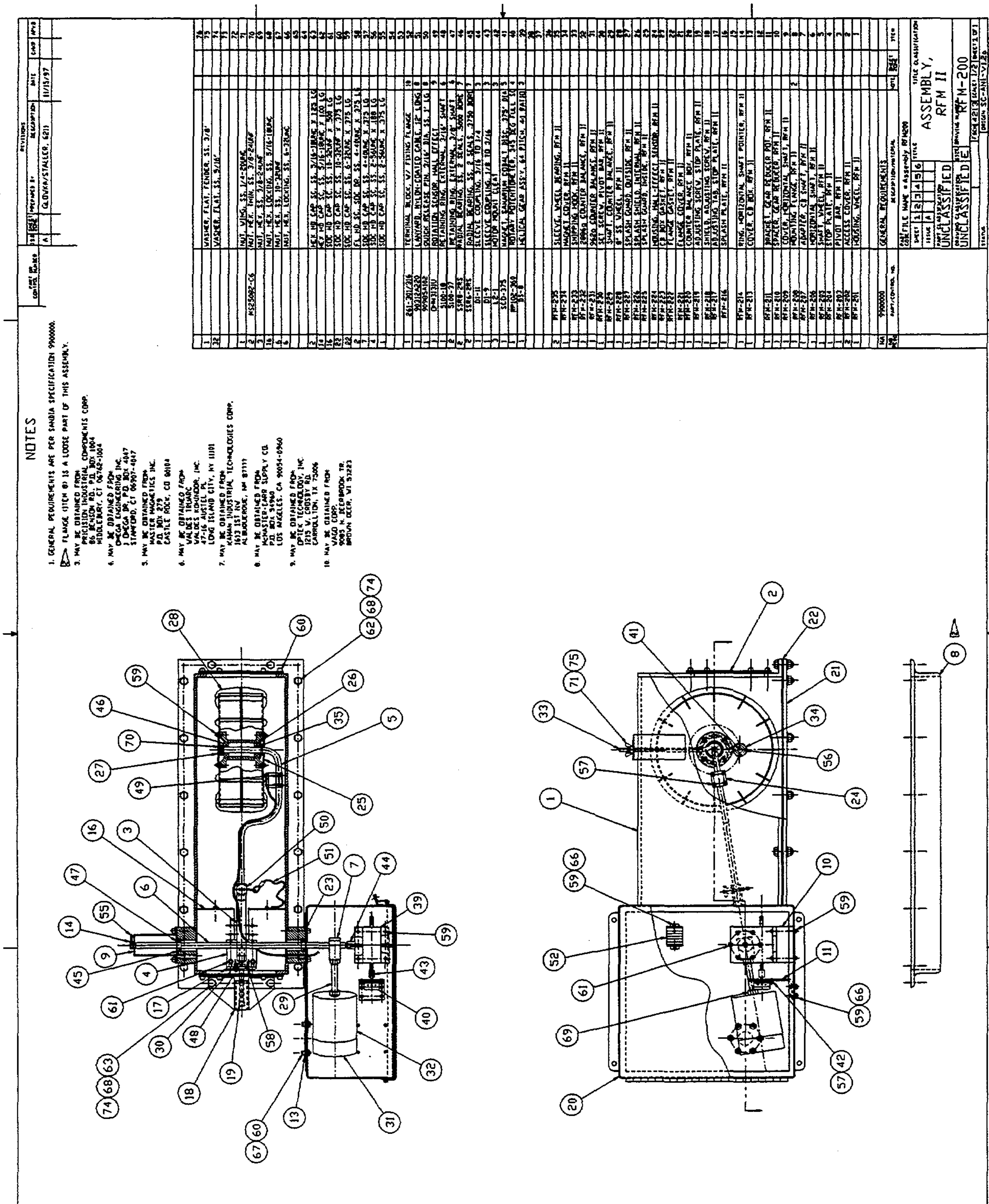


Figure 13

The complete drawing package is presented in Appendix A. Drawing revisions for the addition of the maintenance access hinge to the RFM housing and the new hinge spacer drawing are also included in Appendix A. AutoCADlt files of all mechanical drawings are available upon request. A schematic diagram of the electronic circuit and hardware used by Sandia to power the RFM flow-rate rotary potentiometer and float-wheel rotation Hall-effect magnetic sensor are provided in Appendix A.

Recommendations for RFM installation on a typical return line pipe, normal field maintenance procedures, post-field reconditioning and readiness techniques, and procedures used to prepare the Hall-effect sensor for RFM installation are included in Appendix B.

Conclusions

The RFM has been evaluated thoroughly by Sandia in the laboratory and during drilling operations at both large diameter and slimhole core wells. This instrument provides reliable accurate drilling fluid outflow measurements in a partially filled return line pipe. These measurements can be used to monitor drilling fluid flow rates, from less than 50 gpm to 1000 gpm or more, while drilling a well. The RFM design has undergone continuous improvement during its development process. This has produced a rugged, adaptable instrument that can function reliably under the severe environmental conditions encountered on a geothermal drill rig, while still providing a simple tool that is easy to install, maintain, and operate.

The cost to produce a single prototype RFM is estimated to be approximately $10,000, however, cost reductions are likely if it is produced in quantity.

The Sandia Geothermal Research Department is available to assist in transferring this technology to potential industry users via training on installation and operation of the RFM and to consult on design features or desired modifications that would lead to improvements and/or wider industry applications.

References

1. C.C. Carson, and Y.T. Lin, 1982, "The Impact of Common Problems in Geothermal Drilling and Completion," *Geothermal Resources Council Transactions*, Vol. 6, pp. 195-198.

2. G.E. Loeppke, D.M. Schafer, D.A. Glowka, D.D. Scott, M.D. Wernig, and E.K. Wright, 1992 "Development and Evaluation of a Meter for Measuring Return Line Fluid Flow Rates During Drilling," *Sandia Report, SAND91-2607*, Sandia National Laboratories, Albuquerque, NM, 87185-1033.

3. D.M. Schafer, G.E. Loeppke, D.A. Glowka, D.D. Scott, and E.K. Wright, 1992, "An Evaluation of Flowmeters for the Detection of Kicks and Lost Circulation During Drilling," *IADC/SPE 213935, Presented at the IADC/SPE Drilling Conference*, New Orleans, LA, February, 1992.

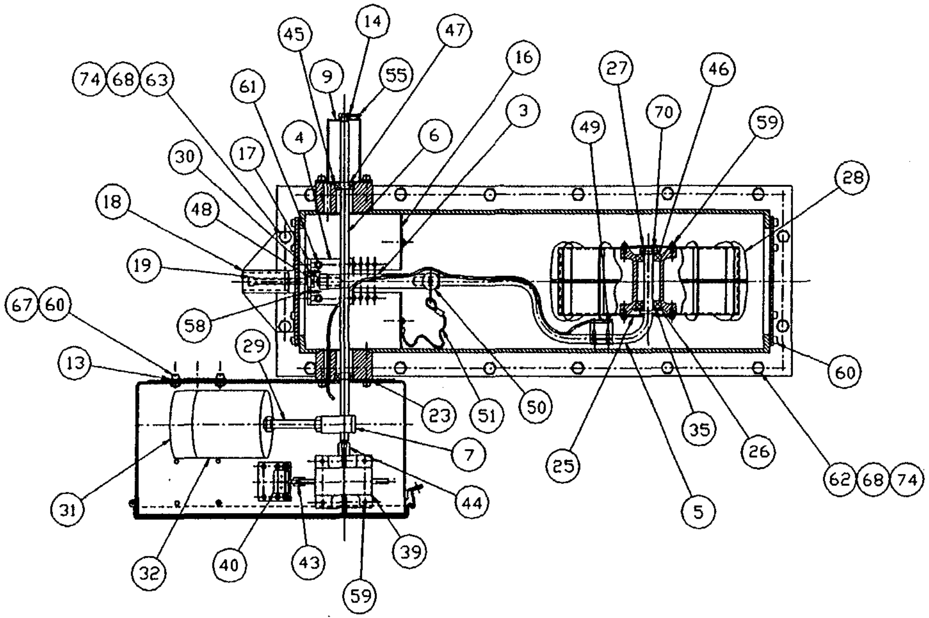
4. D.A. Glowka, D.M. Schafer, D.D. Scott, M.D. Wernig, and E.K. Wright, 1992, "Development and use of a Return Line Flowmeter for Lost Circulation Diagnosis in Geothermal Drilling," *Geothermal Resources Council Transactions*, Vol. 16, pp. 39-46.

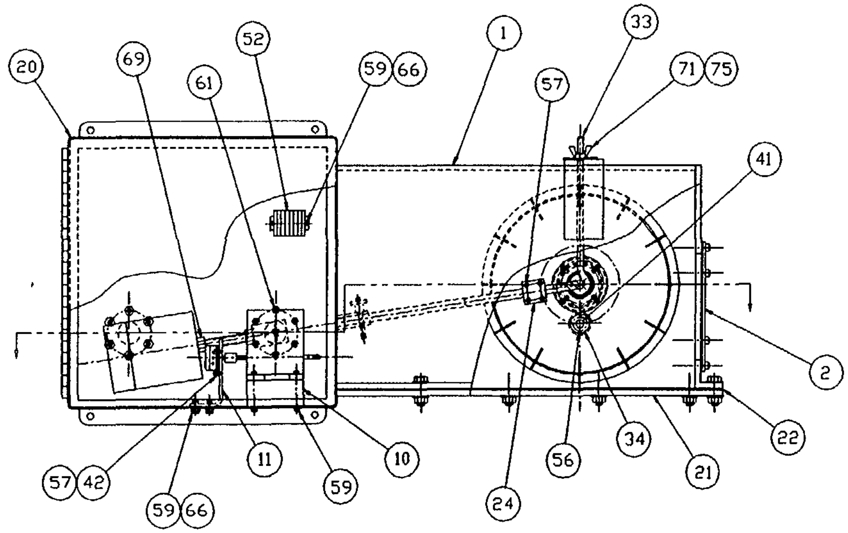
5. G.L. Whitlow, D.A. Glowka, and G.E. Staller, 1996, "Development and Use of Rolling Float Meters and Doppler Flow Meters to Monitor Inflow and Outflow While Drilling Geothermal Wells", *Geothermal Resources Council Transactions*, Vol. 20, pp. 515-521.

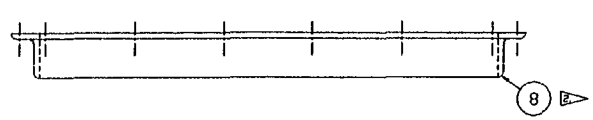
6. J.T. Finger and R.D. Jacobson, 1997, "Fort Bliss Exploratory Slimholes: Drilling and Testing", *Sandia Report, SAND97-3075,* Sandia National Laboratories, Albuquerque, NM, 87185-1033.

Appendix A

Drawing Package







NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. FLANGE (ITEM 8) IS A LOOSE PART OF THIS ASSEMBLY.
3. MAY BE OBTAINED FROM: PRICISION INDUSTRIAL COMPONENTS CORP. 86 BENSON RD., P.O. BOX 1004 MIDDLEBURY, CT 06762-1004
4. MAY BE OBTAINED FROM: OMEGA ENGINEERING INC. 1 OMEGA DR, P.O. BOX 4047 STAMFORD, CT 06907-4047
5. MAY BE OBTAINED FROM: MASTER MAGNETICS INC. P.O. BOX 279 CASTLE ROCK, CO 80104
6. MAY BE OBTAINED FROM: WALDES TRUARC WALDES KOHINOOR, INC. 47-16 AUSTEL PL LONG ISLAND CITY, NY 11101
7. MAY BE OBTAINED FROM: KAMAN INDUSTRIAL TECHNOLOGIES CORP. 1613 1ST NW ALBUQUERQUE, NM 87777
8. MAY BE OBTAINED FROM: McMASTER-CARR SUPPLY CO. P.O. BOX 54960 LOS ANGELES, CA 90054-0960
9. MAY BE OBTAINED FROM: OPTEK TECHNOLOGY, INC. 1215 W. CROSBY RD CARROLLTON, TX 75006
10. MAY BE OBTAINED FROM: WAGO CORP. 9085 N. DEERBROOK TR. BROWN DEER, WI 53223

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		

NO. REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
					76
1		WASHER, FLAT, FENDER, SS. 3/8'			75
32		WASHER, FLAT, SS, 5/16'			74
					73
					72
1		NUT, WING, SS, 1/4-20UNC			71
2	MS25082-C6	NUT, HEX, THIN, SS, 3/8-24UNF			70
3		NUT, HEX, SS, 3/8-24UNF			69
16		NUT, HEX, LOCKING, SS, 5/16-18UNC			68
6		NUT, HEX, SS, 10-32UNF			67
6		NUT, HEX, LOCKING, SS, 6-32UNC			66
					65
					64
2		HEX HD CAP SC, SS, 5/16-18UNC X 1.25 LG			63
14		HEX HD CAP SC, SS, 5/16-18UNC X 1.00 LG			62
16		SOC HD CAP SC, SS, 10-32UNF X .500 LG			61
22		SOC HD CAP SC, SS, 10-32UNF X .375 LG			60
22		SOC HD CAP SC, SS, 6-32UNC X .375 LG			59
2		FL HD SC, SOC DR, SS, 4-40UNC X .375 LG			58
7		SOC HD CAP SC, SS, 4-40UNC X .375 LG			57
4		SOC HD CAP SC, SS, 2-56UNC X .188 LG			56
1		SOC HD CAP SC, SS, 2-56UNC X .375 LG			55
					54
					53
1	261-301/316	TERMINAL BLOCK, W/ FIXING FLANGE	10		52
1	90312A220	LANYARD, NYLON-COATED CABLE, 12' LONG	8		51
1	90985A102	QUICK RELEASE PIN, 3/16' DIA, SS, 1' LG	8		50
1	OHN3131U	ROTATION SENSOR, HALL EFFECT	9		49
1	5100-18	RETAINING RING, EXTERNAL, 3/16' SHAFT	6		48
2	5100-37	RETAINING RING, EXTERNAL, 3/8' SHAFT	6		47
2	SSR8-2RS	RADIAL BEARING, SS, 2 SEALS, .5000 BORE	7		46
2	SSR6-2RS	RADIAL BEARING, SS, 2 SEALS, .3750 BORE	7		45
1	D1-11	SLEEVE COUPLING, 3/16 TO 1/4	3		44
1	D1-9	SLEEVE COUPLING, 1/8 TO 3/16	3		43
3	L2-1	MOTOR MOUNT CLEAT	3		42
1	SCD-375	MAGNET, SAMARIUM COBALT DISC, .375' DIA	5		41
1	RP102-360	ROTARY POTENTIOMETER, 345 DEG FULL SC	4		40
1	DS-8	HELICAL GEAR ASS'Y, 64 PITCH, 4:1 RATIO	3		39
					38
					37
					36
2	RFM-235	SLEEVE, WHEEL BEARING, RFM II			35
1	RFM-234	MAGNET COVER, RFM II			34
1	RFM-233	SHIPPING HOOK, RFM II			33
1	RFM-232	2886g COUNTER BALANCE, RFM II			32
1	RFM-231	962g COUNTER BALANCE, RFM II			31
1	RFM-230	SET SCREW, PIVOT BAR, RFM II			30
1	RFM-229	SHAFT, COUNTER BALANCE, RFM II			29
1	RFM-228	8' SS WHEEL, RFM II			28
1	RFM-227	SPLASH GUARD, OUTSIDE, RFM II			27
1	RFM-226	SPLASH SHIELD, INTERNAL, RFM II			26
1	RFM-225	SPLASH GUARD, INSIDE, RFM II			25
1	RFM-224	HOUSING, HALL-EFFECT SENSOR, RFM II			24
1	RFM-223	CB BOX GASKET, RFM II			23
1	RFM-222	FLANGE GASKET, RFM II			22
1	RFM-221	FLANGE COVER, RFM II			21
1	RFM-220	COUNTER BALANCE BOX, RFM II			20
1	RFM-219	ADJUSTING SCREW, STOP PLATE, RFM II			19
1	RFM-218	SHIELD, ADJUSTING SCREW, RFM II			18
1	RFM-217	ADJUSTING TAB, STOP PLATE, RFM II			17
1	RFM-216	SPLASH PLATE, RFM II			16
					15
1	RFM-214	RING, HORIZONTAL SHAFT POINTER, RFM II			14
1	RFM-213	COVER, CB BOX, RFM II			13
					12
1	RFM-211	BRACKET, GEAR REDUCER POT, RFM II			11
1	RFM-210	SPACER, GEAR REDUCER, RFM II			10
1	RFM-209	COVER, HORIZONTAL SHAFT, RFM II			9
1	RFM-208	MOUNTING FLANGE, RFM II	2		8
1	RFM-207	ADAPTER, CB SHAFT, RFM II			7
1	RFM-206	HORIZONTAL SHAFT, RFM II			6
1	RFM-205	SHAFT, WHEEL, RFM II			5
1	RFM-204	STOP PLATE, RFM II			4
1	RFM-203	PIVOT BAR, RFM II			3
2	RFM-202	ACCESS COVER, RFM II			2
1	RFM-201	HOUSING, WHEEL, RFM II			1
NA	9900000	GENERAL REQUIREMENTS			

PART CODE: FILE NAME = Assembly RFM200

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: ASSEMBLY, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED — SIZE E — DRAWING NUMBER RFM-200

FSCM 4213 — SCALE: 1/2 — SHEET 1 OF 1

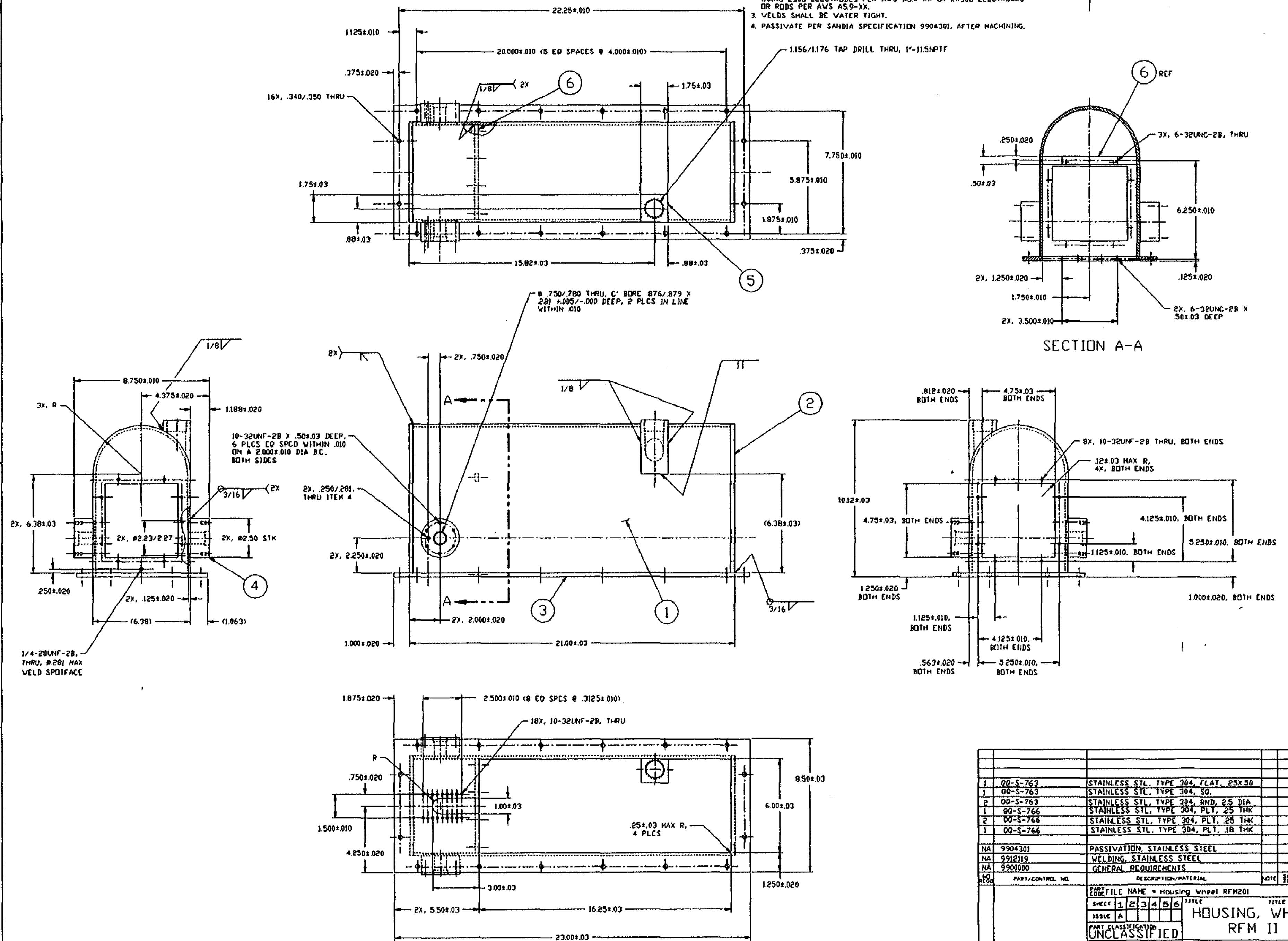
STATUS — ORIGIN SC-AN1-V1.2o

GEOMETRIC PRECISION • 0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. WELDS SHALL BE WATER TIGHT.
4. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



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1	00-S-763	STAINLESS STL, TYPE 304, FLAT, .25X.50			6
1	00-S-763	STAINLESS STL, TYPE 304, SQ.			5
2	00-S-763	STAINLESS STL, TYPE 304, RND, 2.5 DIA			4
1	00-S-766	STAINLESS STL, TYPE 304, PLT, .25 THK			3
2	00-S-766	STAINLESS STL, TYPE 304, PLT, .25 THK			2
1	00-S-766	STAINLESS STL, TYPE 304, PLT, .18 THK			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING, STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Housing Wheel RFM201

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: HOUSING, WHEEL RFM II

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED — SIZE E — DRAWING NUMBER RFM-201

FSCM 4213 — SCALE 1/2 — SHEET 1 OF 1

ORIGIN SC-AN1-V1.2a

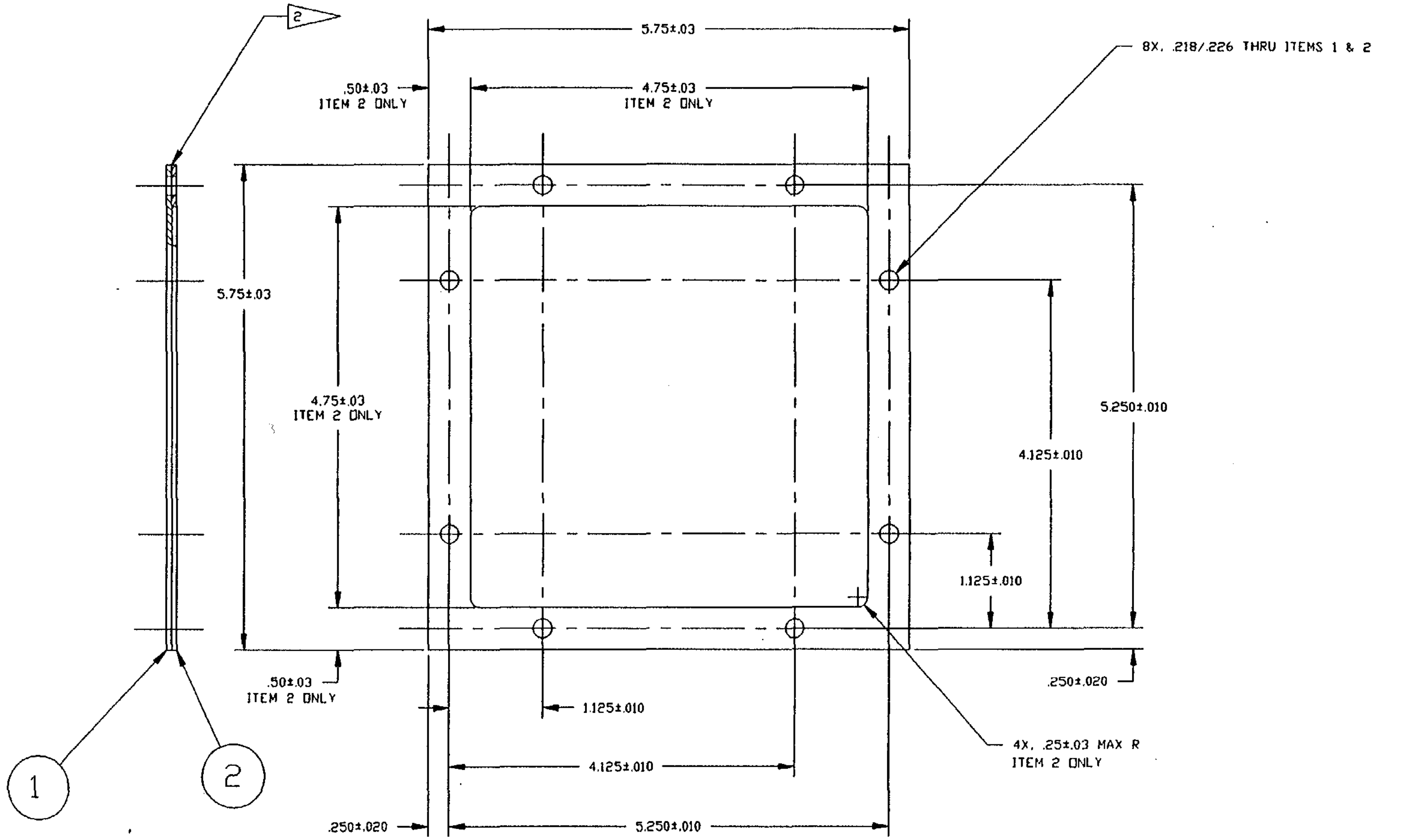
STATUS

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. BOND GASKET (ITEM 2) TO COVER (ITEM 1) USING ANY RUBBER BASED ADHESIVE PER THE MANFACTURER'S INSTRUCTIONS.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION (REVISIONS)	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



NO REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
1		RUBBER, SHEET, BUNA-N, 40 SHORE DUROMETER, .063 THK			2
1	QQ-S-766	STAINLESS STL, TYPE 304, SHT, .06 THK			1
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Access Cover RFM202

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: ACCESS COVER, RFM II — TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C — DRAWING NUMBER: RFM-202

FSCM 14213 — SCALE: 1/1 — SHEET 1 OF 1

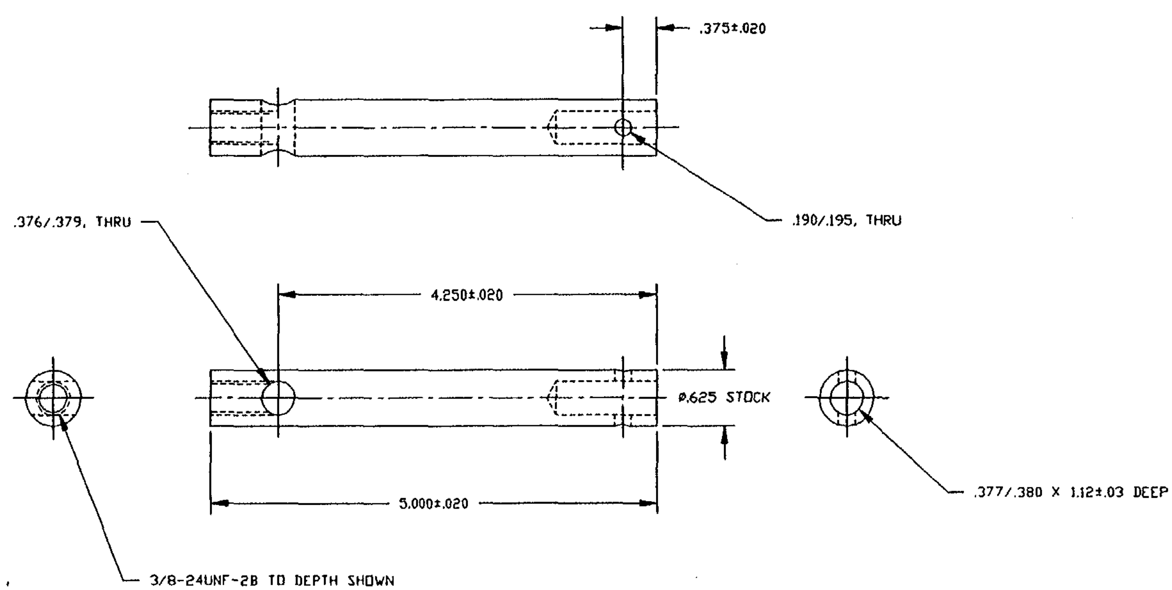
STATUS — ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304, ROUND.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE FILE NAME = Pivot Bar RFM203	
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ISSUE A	
PART CLASSIFICATION: UNCLASSIFIED	
DRAWING CLASSIFICATION: UNCLASSIFIED	SIZE C; DRAWING NUMBER RFM-203
	FSCM 14213; SCALE 1/1; SHEET 1 OF 1
STATUS	ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304, PLT, PER QQ-S-766, .250 THK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.

PART OR CONTROL NUMBER	REVISIONS					
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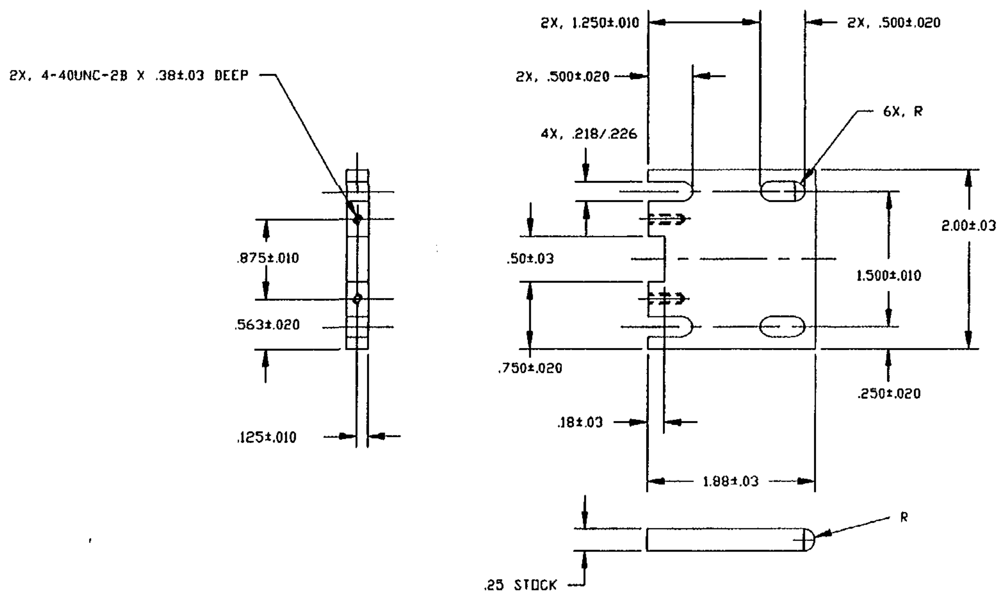
	A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE	FILE NAME = Stop Plate RFM204
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ISSUE	A
PART CLASSIFICATION	UNCLASSIFIED
DRAWING CLASSIFICATION	UNCLASSIFIED
TITLE	STOP PLATE, RFM II
TITLE CLASSIFICATION	
SIZE	C
DRAWING NUMBER	RFM-204
FSCM	14213
SCALE	1/1
SHEET	1 OF 1
STATUS	
ORIGIN	SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

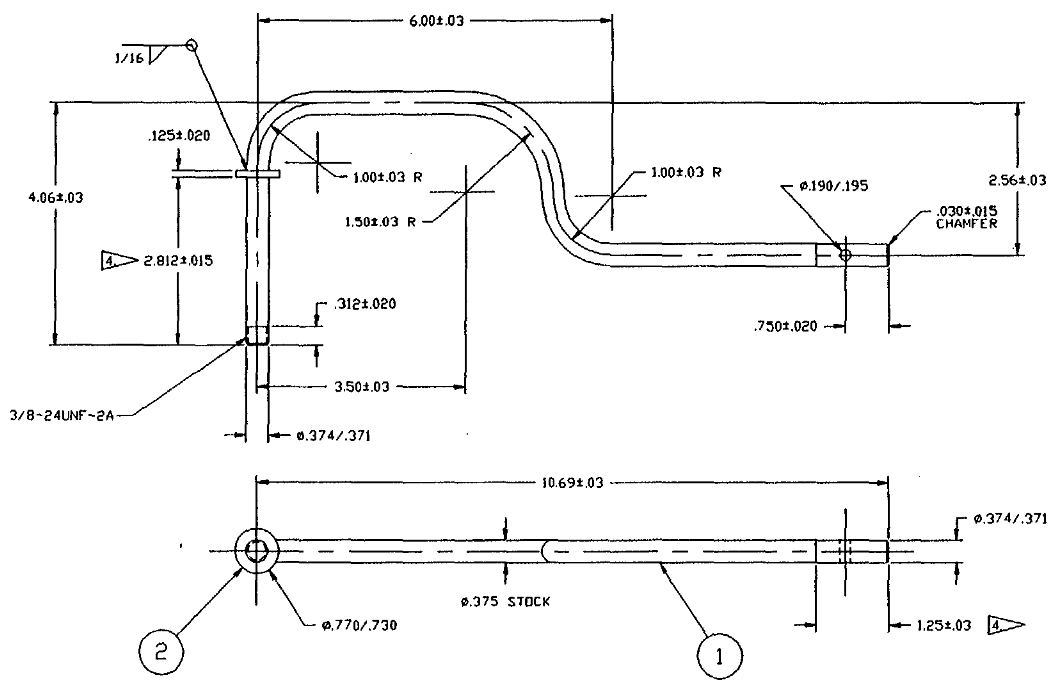
REVISIONS						
ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211		11/15/97		

PART OR CONTROL NUMBER

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.

4 MACHINE SHAFT TO DIAMETER SHOWN OVER THIS LENGTH ONLY.



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1	QQ-S-763	STAINLESS STL, TYPE 304, RND, .375 DIA			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING, STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Shaft Wheel RFM205

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: SHAFT, WHEEL, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: D

DRAWING NUMBER: RFM-205

FSCM 4213 SCALE 1/1 SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2o

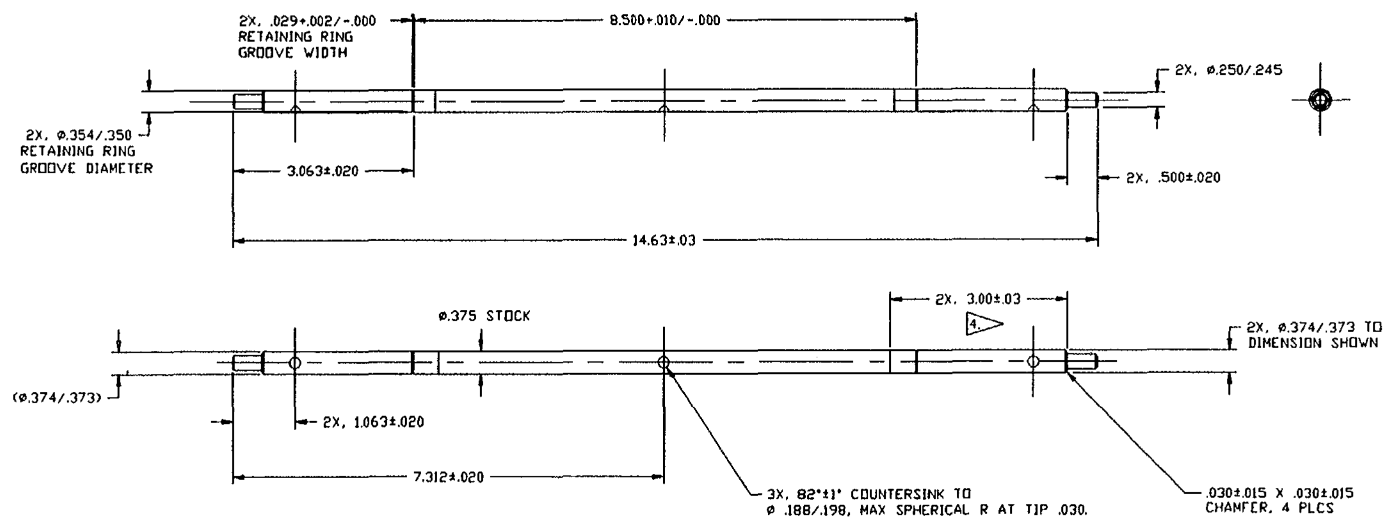
GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, ROD, TYPE 304 PER QQ-S-763.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.
4. MACHINE SHAFT TO DIAMETER SHOWN OVER THIS LENGTH ONLY.

PART OR CONTROL NUMBER

REVISIONS						
ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
B		GLOWKA/STALLER, 6211	9/18/96		
C		REMOVED FLATS, ADDED CSK 2 PLCS	9/24/96		



PART CODE	FILE NAME = Horizontal Shaft RFM206	
SHEET 1 2 3 4 5 6	TITLE	TITLE CLASSIFICATION
ISSUE C	HORIZONTAL SHAFT, RFM II	
PART CLASSIFICATION UNCLASSIFIED		
DRAWING CLASSIFICATION UNCLASSIFIED	SIZE D	DRAWING NUMBER RFM-206
FSCM 4213	SCALE 1/1	SHEET 1 OF 1
STATUS	ORIGIN SC-AN1-V1.2a	

GEOMETRIC PRECISION = .0001

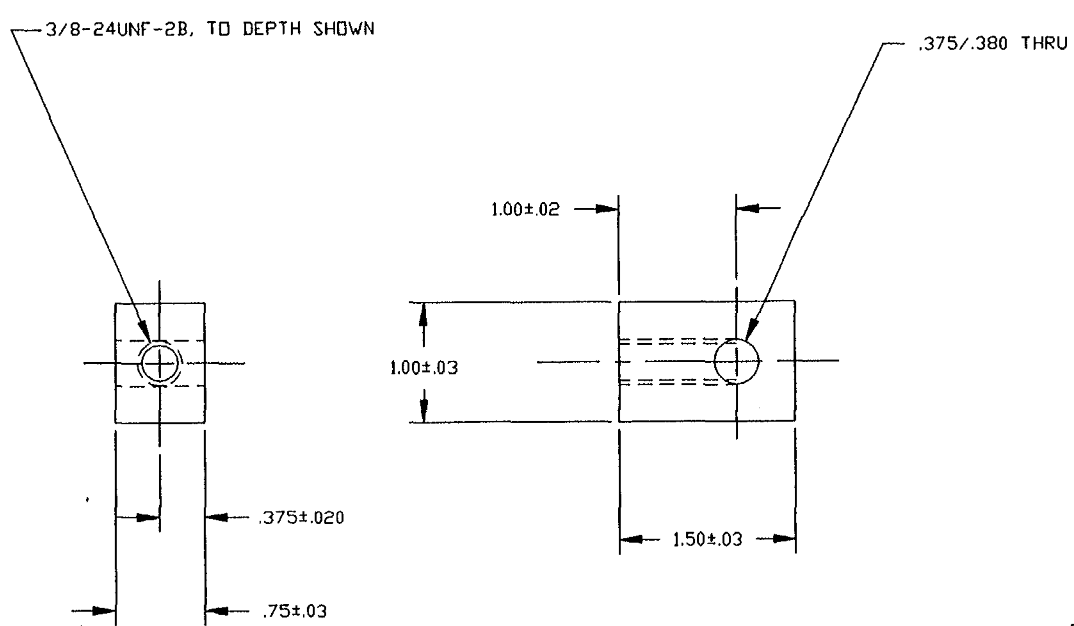
NOTES

1. GENERAL REQUIREMENTS PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304 PER QQ-S-763.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211			
B		DELEATED D-HOLE, 10-32 THD, AND R, EXTENDED 3/8-24 THD DEPTH, CHANGED LENGTH.	9/24/96		



PART CODE FILE NAME = Adapter CB Shaft RFM207							
SHEET	1	2	3	4	5	6	TITLE / TITLE CLASSIFICATION: ADAPTER, CB SHAFT RFM II
ISSUE	B						
PART CLASSIFICATION: UNCLASSIFIED							
DRAWING CLASSIFICATION: UNCLASSIFIED							SIZE: B; DRAWING NUMBER: RFM-207
							FSCM 14213; SCALE 1/1; SHEET 1 OF 1
STATUS							ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STEEL, ANGLE, BAR SIZE, ASTM-A36, 2X1.25X.25.
3. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E70XX ELECTRODES PER AWS A5.1-XX OR E70S-X ELECTRODES OR RODS PER AWS A5.18-XX.

PART OR CONTROL NUMBER

REVISIONS						
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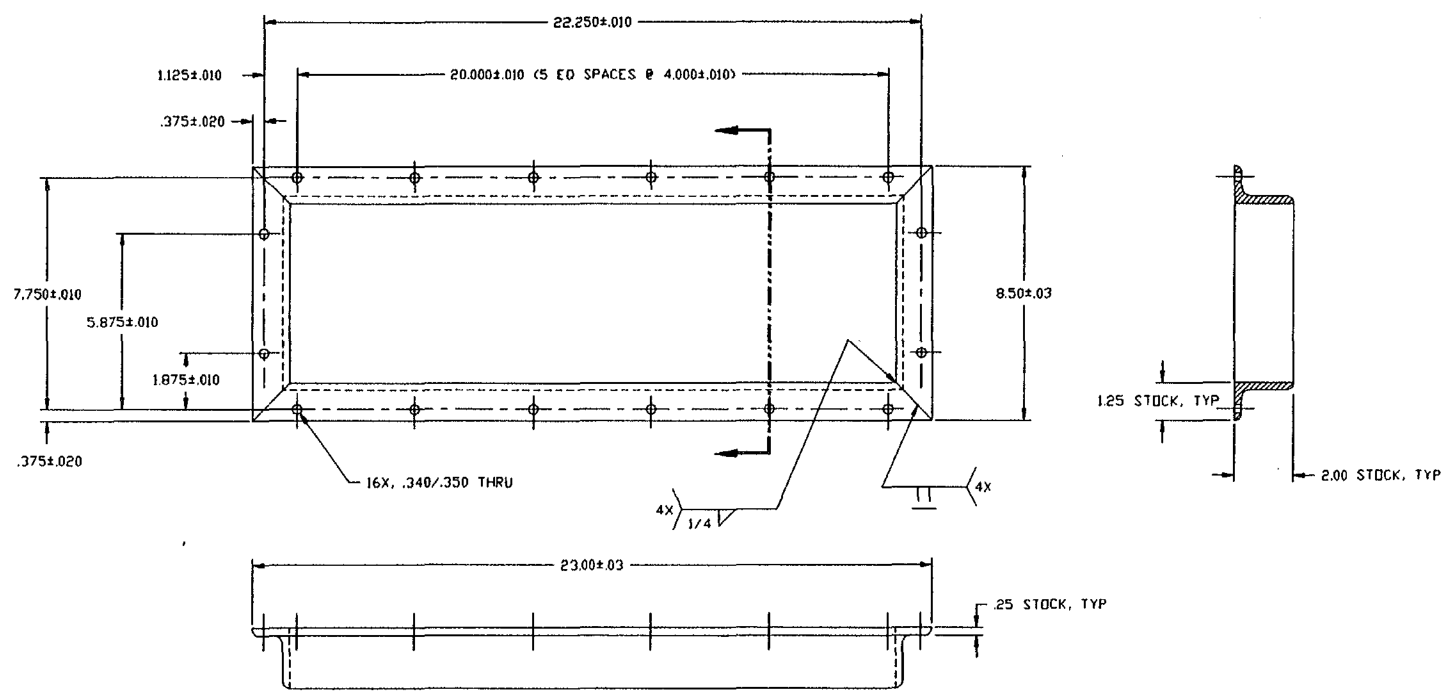

PART CODE FILE NAME = Mounting Flange RFM208

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ISSUE	A					

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TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: D | DRAWING NUMBER: RFM-208

FSCM 14213 | SCALE 1/2 | SHEET 1 OF 1

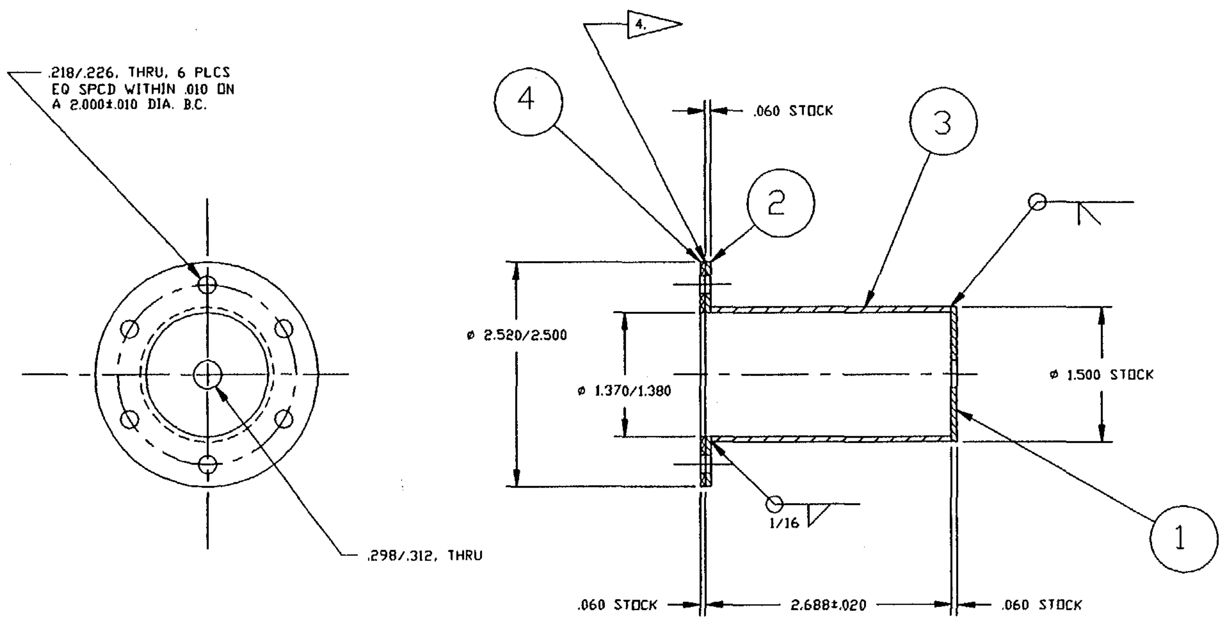
STATUS | ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRONES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.
4. BOND GASKET (ITEM 4) TO COVER FLANGE (ITEM 2) USING ANY RUBBER BASED ADHESIVE, PER THE MANFACTURER'S INSTRUCTIONS.
5. ALTERNATE METHOD OF FABRICATION. ITEM 3 MAY BE ROLLED AND WELDED.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	B		GLOWKA/STALLER, 6211	9/18/96		



NO REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
1		RUBBER, SHEET, BUNA-N, 40 SHORE DUROMETER, .063 THK			4
1		STAINLESS STL, TYPE 304, TUBING, 1.5" OD X .065 WALL	5		3
1	QQ-S-766	STAINLESS STL, TYPE 304, SHT, 16 GA			2
1	QQ-S-766	STAINLESS STL, TYPE 304, SHT, 16 GA			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING, STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Cover Horizontal Shaft RFM209

SHEET 1 2 3 4 5 6 — ISSUE B

TITLE: COVER, HORIZONTAL SHAFT, RFM II — TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C — DRAWING NUMBER: RFM-209

FSCM14213 — SCALE: 1/1 — SHEET 1 OF 1

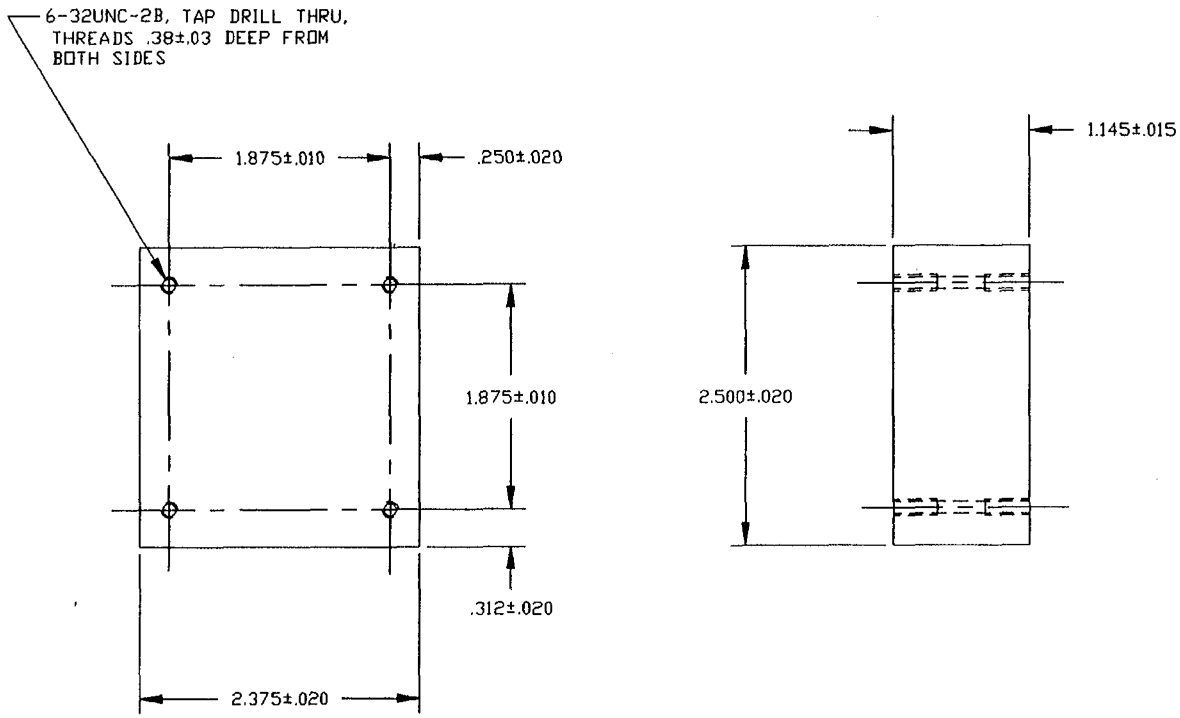
STATUS — ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: ALUMINUM, PLATE, 6061-T651, PER QQ-A-250/11.
3. ANODIZE PER SANDIA SPECIFICATION 9904102, TYPE II, CLASS II, DYE BLACK.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE FILE NAME = Spacer Gear Reducer RFM210

SHEET	1	2	3	4	5	6
ISSUE	A					

PART CLASSIFICATION UNCLASSIFIED

DRAWING CLASSIFICATION UNCLASSIFIED

TITLE: SPACER, GEAR REDUCER, RFM II

TITLE CLASSIFICATION

SIZE: B — DRAWING NUMBER: RFM-210

FSCM 14213 — SCALE: 1/1 — SHEET 1 OF 1

STATUS — ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

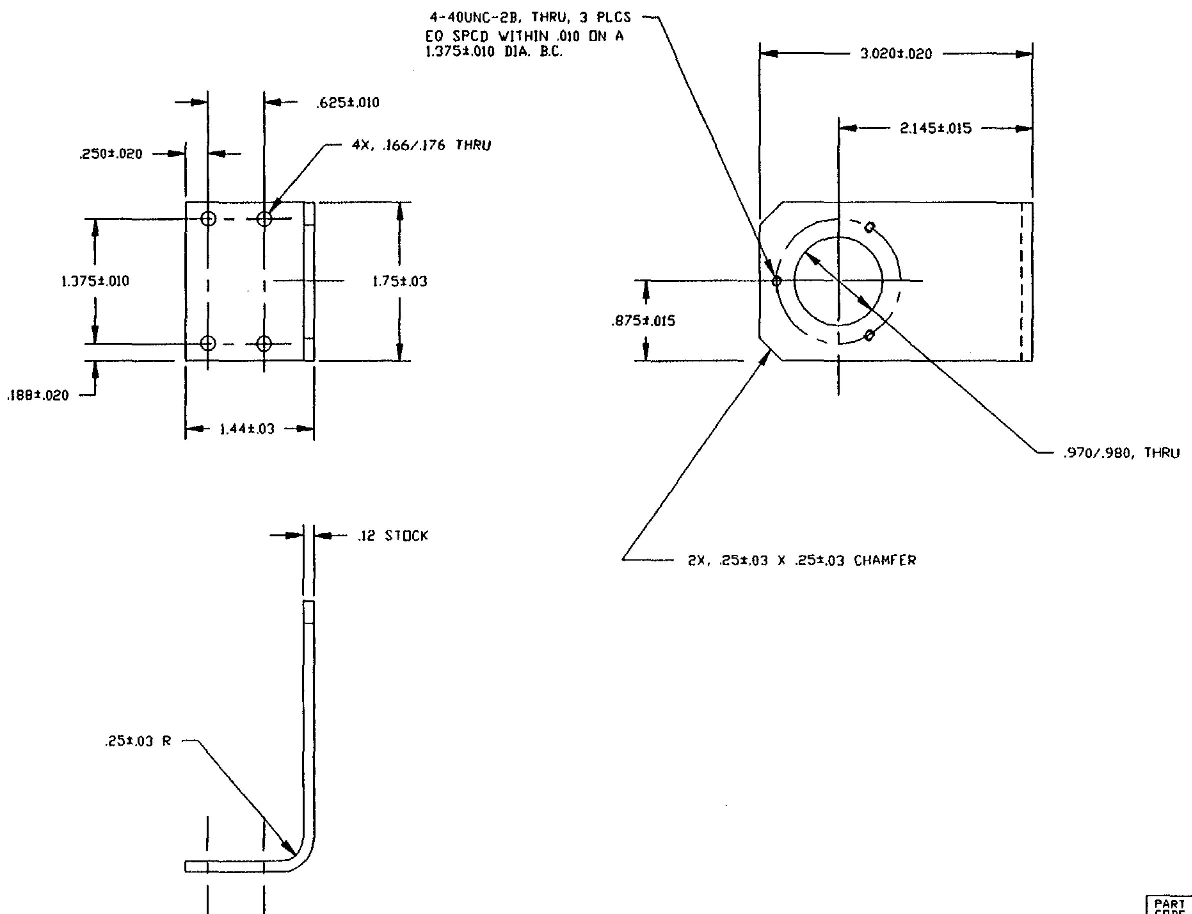
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304, SHEET, PER QQ-S-766, .12 THICK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE FILE NAME = Bracket Gr Rdcr Pot RFM211								
SHEET	1	2	3	4	5	6	TITLE	TITLE CLASSIFICATION
ISSUE	A						BRACKET, GEAR REDUCER POT, RFM II	
PART CLASSIFICATION UNCLASSIFIED								
DRAWING CLASSIFICATION UNCLASSIFIED							SIZE C	DRAWING NUMBER RFM-211
							FSCM 14213	SCALE: 1/1 — SHEET 1 OF 1
STATUS							ORIGIN SC-AN1-V1.2a	

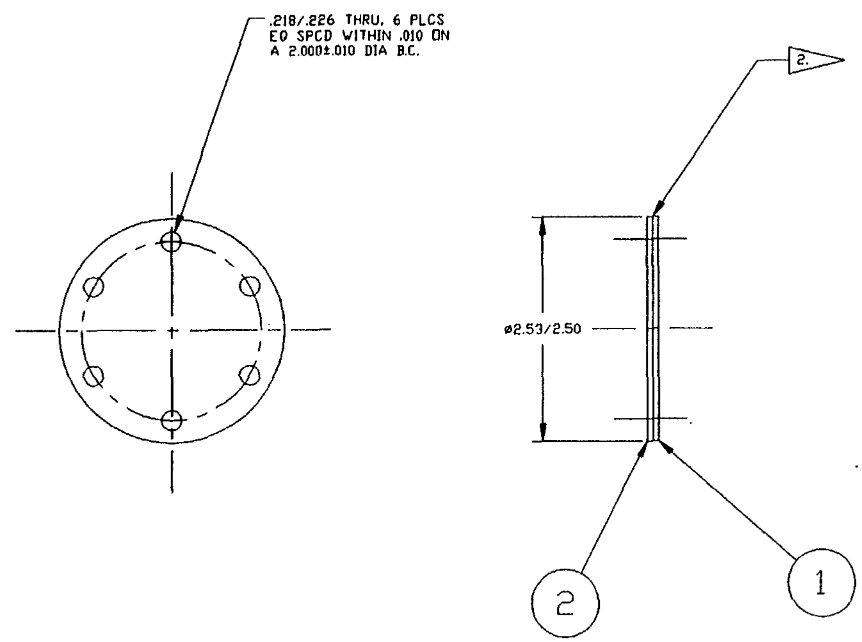
GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.

2. BOND GASKET (ITEM 2) TO COVER (ITEM 1) USING ANY RUBBER BASED ADHESIVE PER THE MANFACTURER'S INSTRUCTIONS.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



NO REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
1		RUBBER, SHEET, BUNA-N, 40 SHORE DUROMETER, .063 THK			2
1	QQ-S-766	STAINLESS STL, TYPE 304, SHT, .06 THK			1
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = CB Box Cover RFM213

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: COVER, CB BOX, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C

DRAWING NUMBER: RFM-213

FSCM 14213 SCALE: 1/1 SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

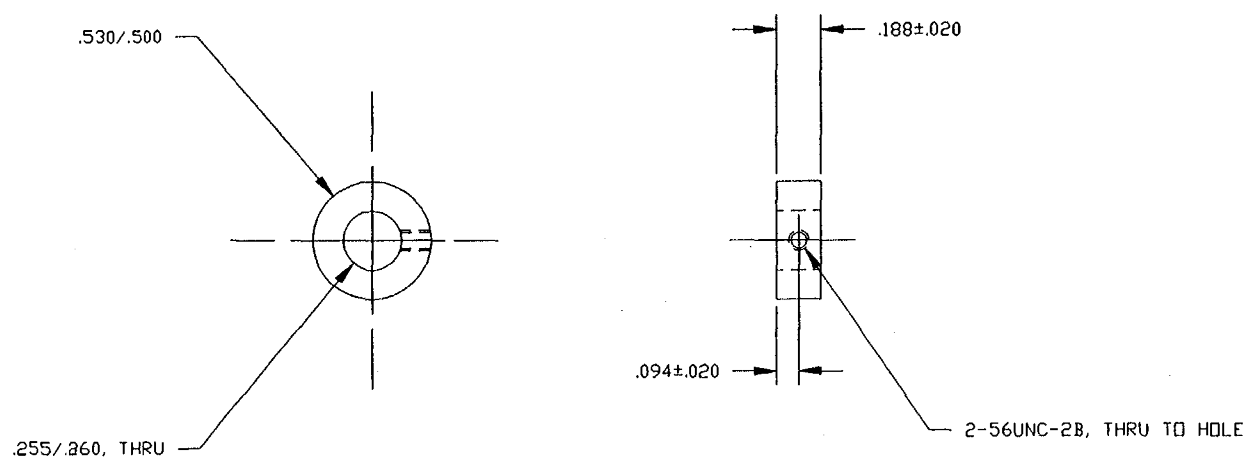
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304 PER QQ-S-763.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
		GLOWKA/STALLER, 6211		11/15/97		



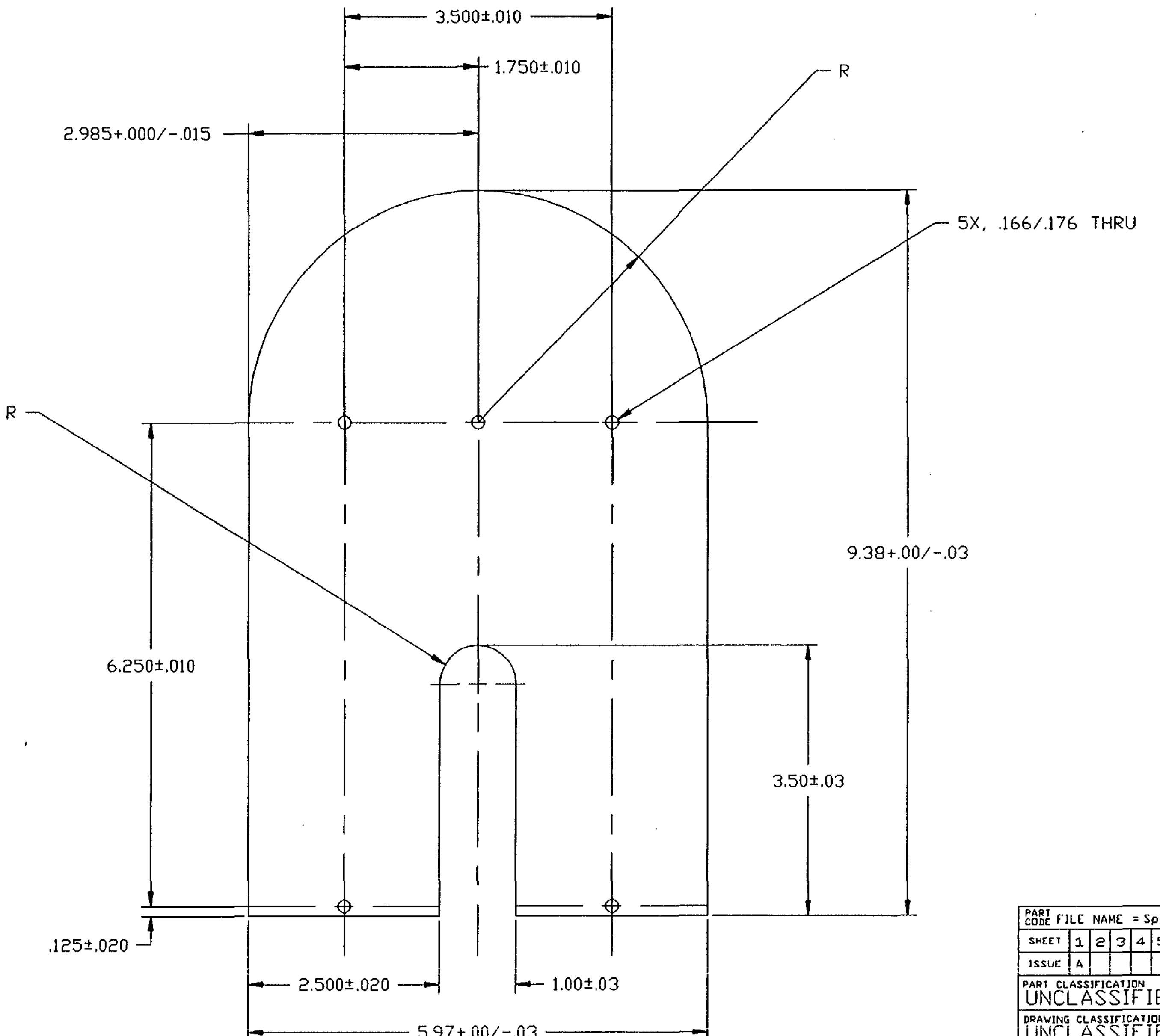
PART CODE	FILE NAME = Ring Horz Shaft Pointer RFM214						
SHEET	1	2	3	4	5	6	TITLE / TITLE CLASSIFICATION: RING, HORZ SHAFT POINTER, RFM II
ISSUE	A						
PART CLASSIFICATION: UNCLASSIFIED							
DRAWING CLASSIFICATION: UNCLASSIFIED	SIZE: B	DRAWING NUMBER: RFM-214					
	FSCM 14213	SCALE 2/1	SHEET 1 OF 1				
STATUS	ORIGIN SC-AN1-V1.2a						

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304, SHEET, PER QQ-S-766, .060" THK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



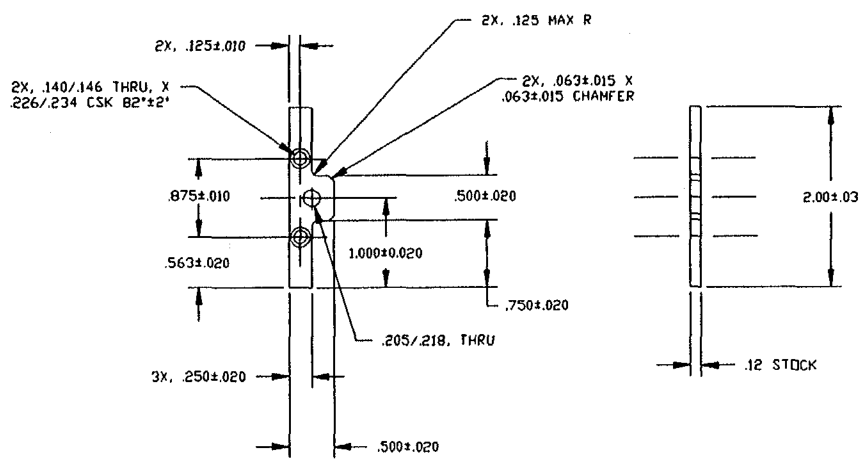
GEOMETRIC PRECISION = .0001

PART CODE	FILE NAME = Splash Plate RFM216
SHEET 1 2 3 4 5 6; ISSUE A	TITLE: SPLASH PLATE, RFM II — TITLE CLASSIFICATION
PART CLASSIFICATION	UNCLASSIFIED
DRAWING CLASSIFICATION	UNCLASSIFIED
SIZE	C
DRAWING NUMBER	RFM-216
FSCM14213	SCALE: 1/1 — SHEET 1 OF 1
STATUS	ORIGIN SC-AN1-V1.2a

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304, SHEET, PER QQ-S-766, .120 THK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



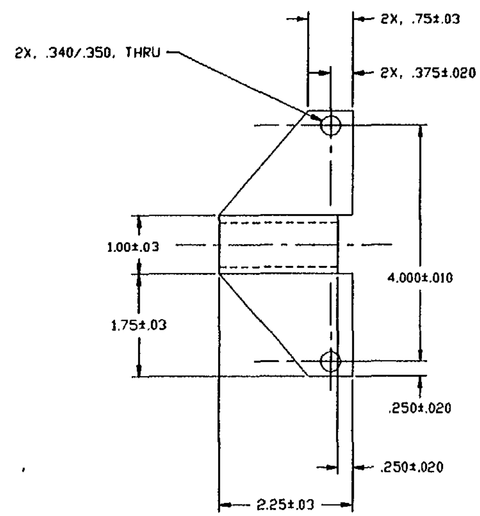
PART CODE	FILE NAME = Adjusting Tab RFM217
SHEET	1 2 3 4 5 6
ISSUE	A
TITLE	ADJUSTING TAB, STOP PLATE, RFM II
TITLE CLASSIFICATION	
PART CLASSIFICATION	UNCLASSIFIED
DRAWING CLASSIFICATION	UNCLASSIFIED
SIZE	C
DRAWING NUMBER	RFM-217
FSCM	14213
SCALE	1/1
SHEET	1 OF 1
STATUS	
ORIGIN	SC-ANI-V1.2o

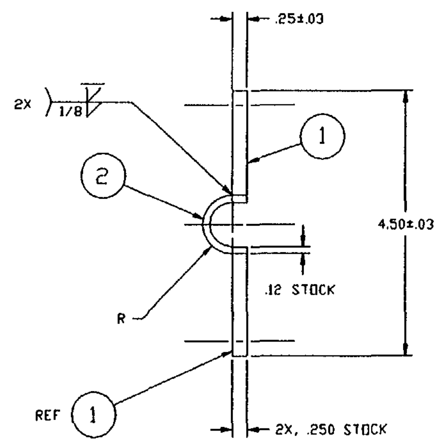
GEOMETRIC PRECISION = .0001

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E302 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.





NO REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
1	QQ-S-766	STAINLESS STL, TYPE 304, SHT, .12 THK			2
2	QQ-S-766	STAINLESS STL, TYPE 304, PLT, .25 THK			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Shield Adj Screw RFM218

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: SHIELD, ADJUSTING SCREW, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE D — DRAWING NUMBER RFM-218

FSCM 4213 — SCALE: 1/1 — SHEET 1 OF 1

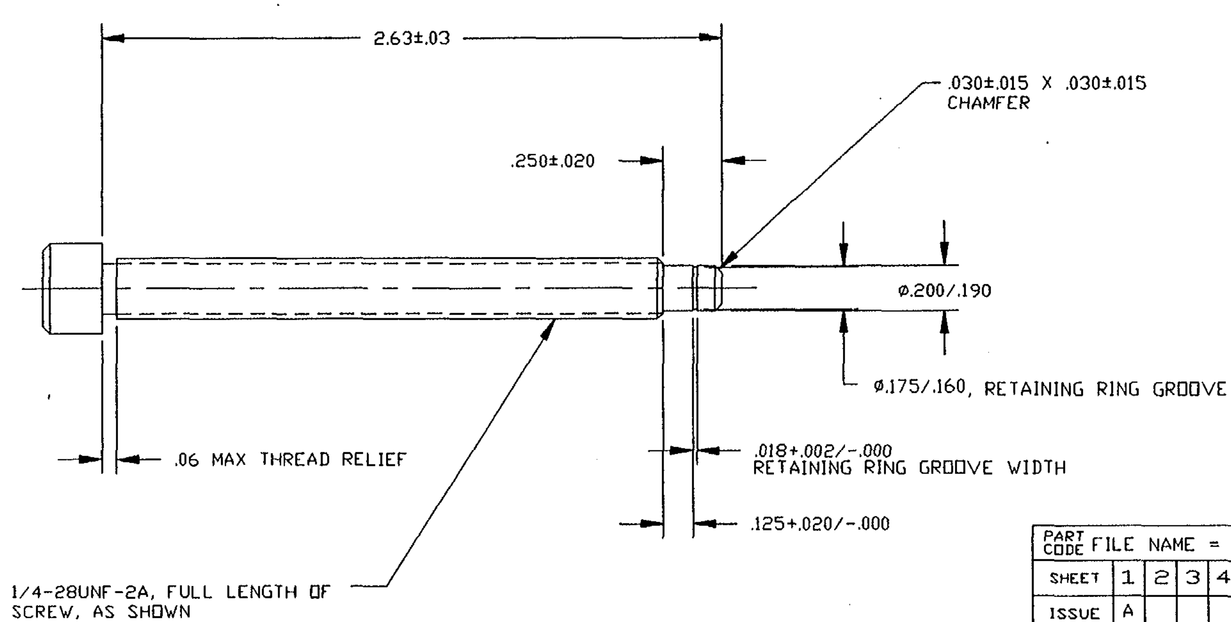
STATUS — ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: SOCKET HEAD CAP SCREW, STAINLESS STEEL, HEX DRIVE, 1/4-28UNF, MODIFIED AS SHOWN.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER	REVISIONS						
	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE FILE NAME = Adjusting Screw RFM 219

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: ADJUSTING SCREW, STOP PLATE, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B | DRAWING NUMBER: RFM-219

FSCM 14213 | SCALE: 2/1 | SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2a

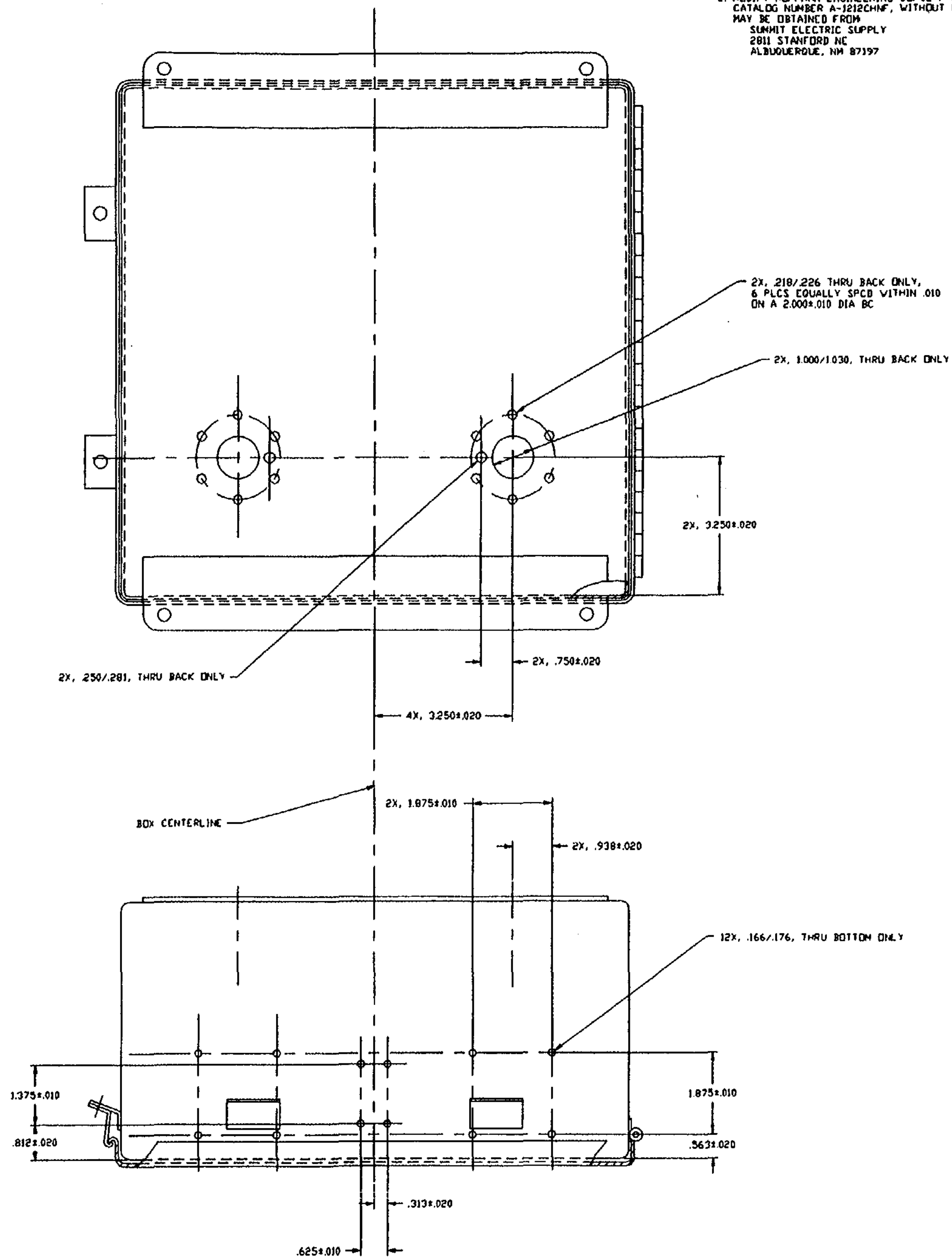
GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MODIFY HOFFMAN ENGINEERING CO. 12 X 12 X 6 TYPE 4 'CHNF' BOX, CATALOG NUMBER A-1212CHNF, WITHOUT PANEL, AS SHOWN.
   MAY BE OBTAINED FROM
   SUMMIT ELECTRIC SUPPLY
   2811 STANFORD NE
   ALBUQUERQUE, NM 87197

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		

(REVISIONS)



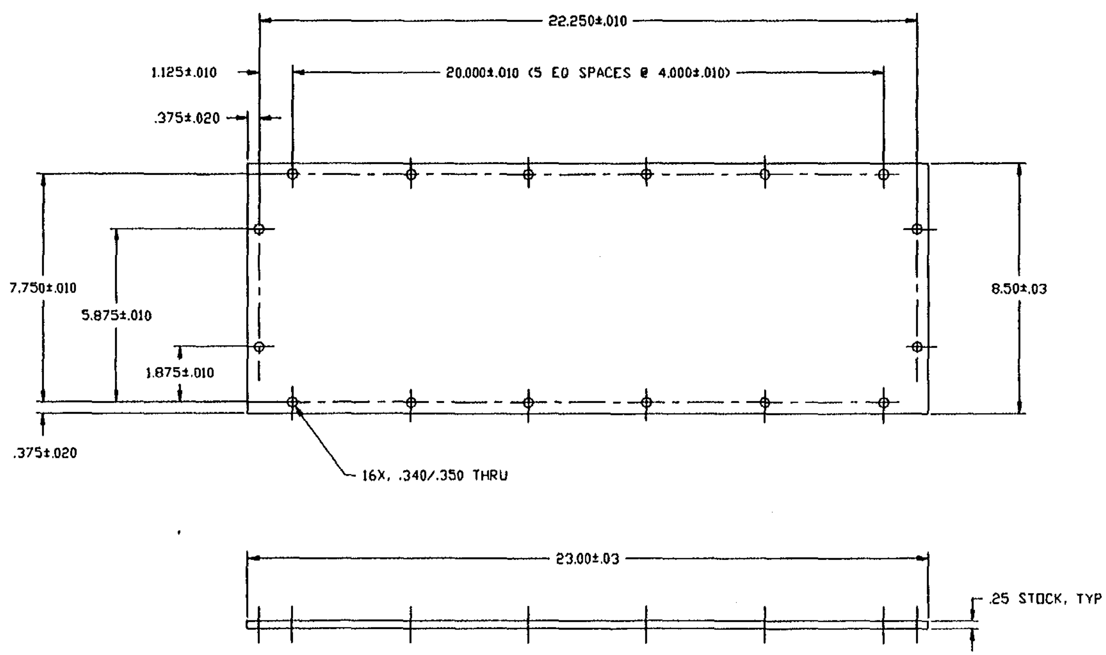
PART CODE	FILE NAME = Counter Balance Box RFM220
SHEET	1 2 3 4 5 6
ISSUE	A
TITLE	COUNTER BALANCE BOX, RFM II
PART CLASSIFICATION	UNCLASSIFIED
DRAWING CLASSIFICATION	UNCLASSIFIED
SIZE	E
DRAWING NUMBER	RFM-220
FSCM	4213
SCALE	1/1
SHEET	1 OF 1
ORIGIN	SC-AN1-V1.2a
STATUS	

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STEEL, PLATE, PER ASTM-A36, .25 THICK.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE FILE NAME = Flange Cover RFM221

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: FLANGE COVER RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: D — DRAWING NUMBER: RFM-221

FSCM 4213 — SCALE 1/2 — SHEET 1 OF 1

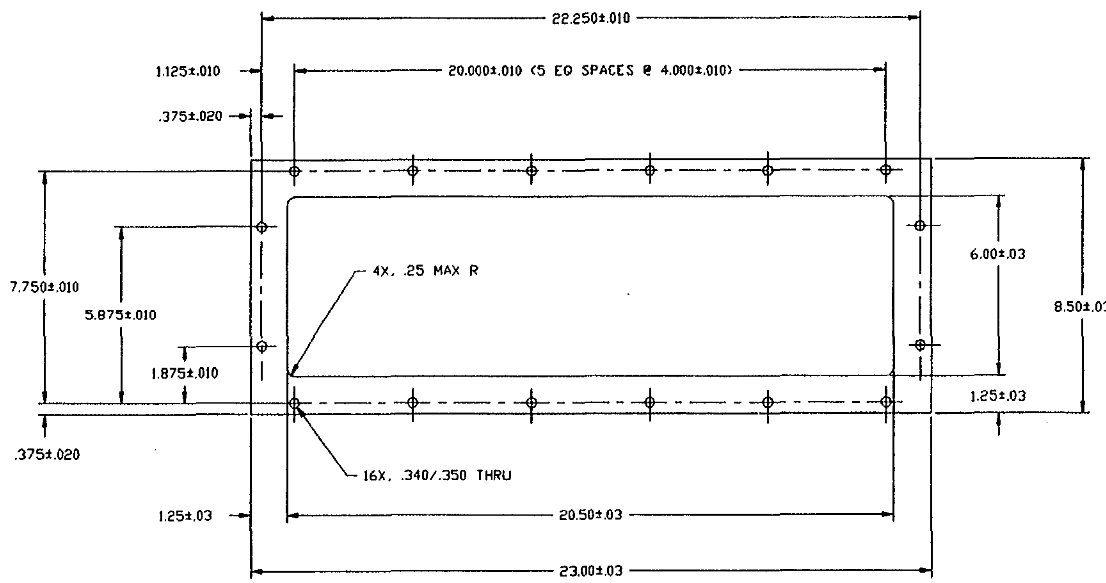
STATUS — ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: RUBBER, SHEET, BUNA-N, 40 SHORE DUROMETER, .06 THICK.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE	FILE NAME = Flange Gasket RFM222
SHEET 1 2 3 4 5 6 / ISSUE A	TITLE: FLANGE GASKET RFM II
PART CLASSIFICATION: UNCLASSIFIED	TITLE CLASSIFICATION
DRAWING CLASSIFICATION: UNCLASSIFIED	SIZE D / DRAWING NUMBER RFM-222
FSCM 14213	SCALE 1/2 / SHEET 1 OF 1
STATUS	ORIGIN SC-AN1-V1.2o

GEOMETRIC PRECISION = .0001

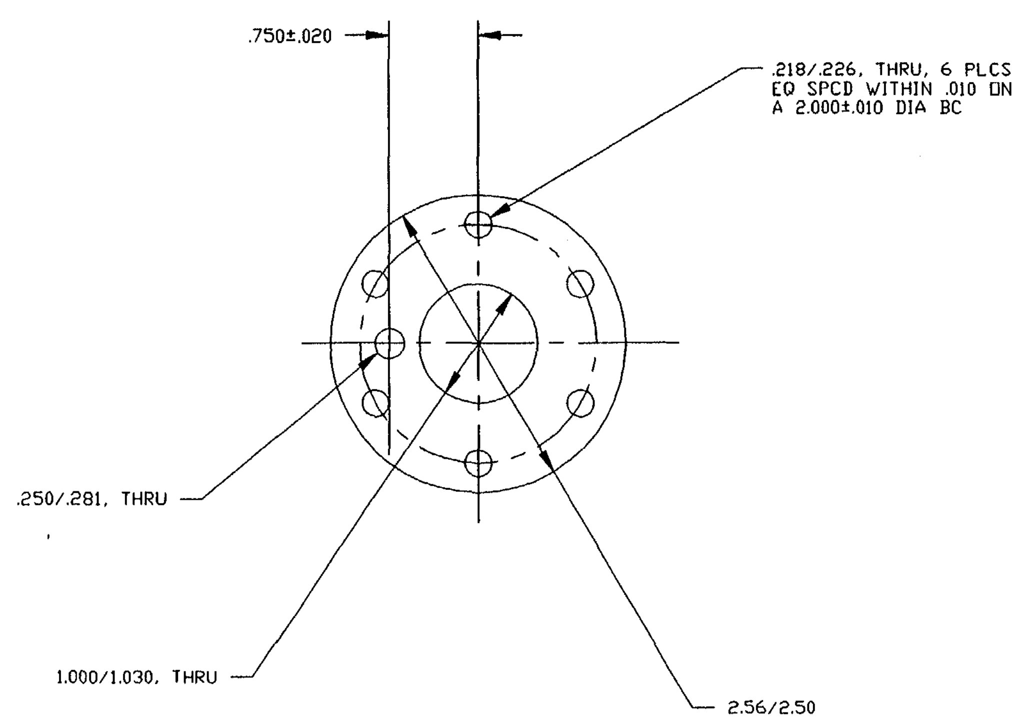
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: RUBBER, SHEET, BUNA-N, 40 SHORE DUROMETER, .06 THICK.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE	FILE NAME = CB Box Gasket RFM223						
SHEET	1	2	3	4	5	6	TITLE / TITLE CLASSIFICATION: CB BOX GASKET, RFM II
ISSUE	A						
PART CLASSIFICATION: UNCLASSIFIED							
DRAWING CLASSIFICATION: UNCLASSIFIED	SIZE: B	DRAWING NUMBER: RFM-223					
		FSCM 14213	SCALE: 1/1	SHEET 1 OF 1			
STATUS		ORIGIN SC-AN1-V1.2a					

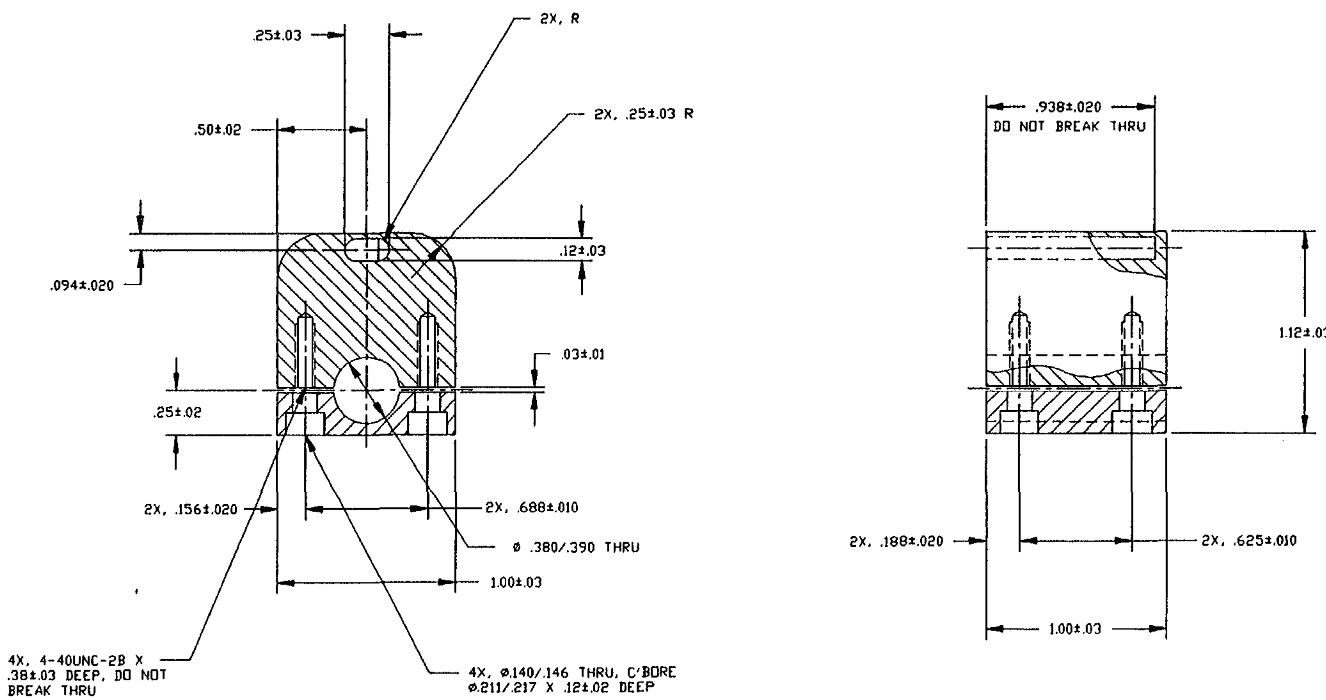
GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: ALUMINUM, PLATE, 6061-T651 PER QQ-A-250/11.
3. ANODIZE PER SANDIA SPECIFICATION 9904102, TYPE II, CLASS II, DYE BLACK.

PART OR CONTROL NUMBER

REVISIONS						
ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211		11/15/97		



FILE NAME = Housing Hall Eff Sensor RFM224

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: HOUSING, HALL EFFECT SENSOR, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C

DRAWING NUMBER: RFM-224

FSCM 14213 | SCALE: 2/1 | SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

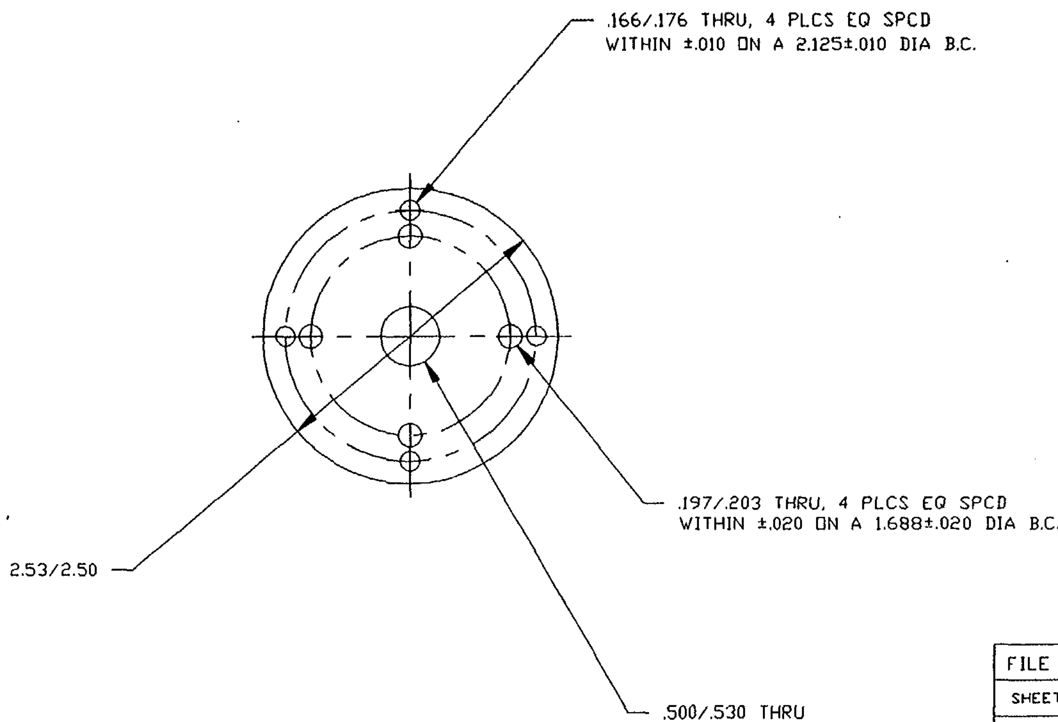
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, SHEET, TYPE 304 PER QQ-S-766, .060 THICK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211	11/15/97		



FILE NAME = Splash Guard Inside RFM225

SHEET	1	2	3	4	5	6	TITLE	TITLE CLASSIFICATION
ISSUE	A						SPLASH GUARD, INSIDE RFM II	

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B | DRAWING NUMBER: RFM-225

FSCM 14213 | SCALE: 1/1 | SHEET 1 OF 1

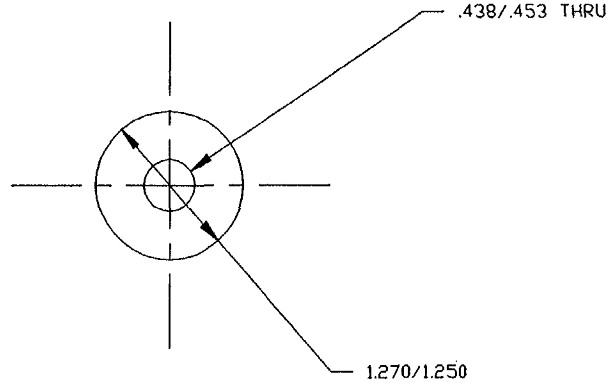
STATUS | ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, SHEET, TYPE 304 PER QQ-S-766, .060 THICK. MAY BE MADE FROM A 3/8" STAINLESS STEEL FENDER WASHER.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER							
	REVISIONS						
	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



FILE NAME = Splash Shield Internal RFM226

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: SPLASH SHIELD, INTERNAL, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B

DRAWING NUMBER: RFM-226

FSCM 14213 | SCALE: 1/1 | SHEET 1 OF 1

STATUS

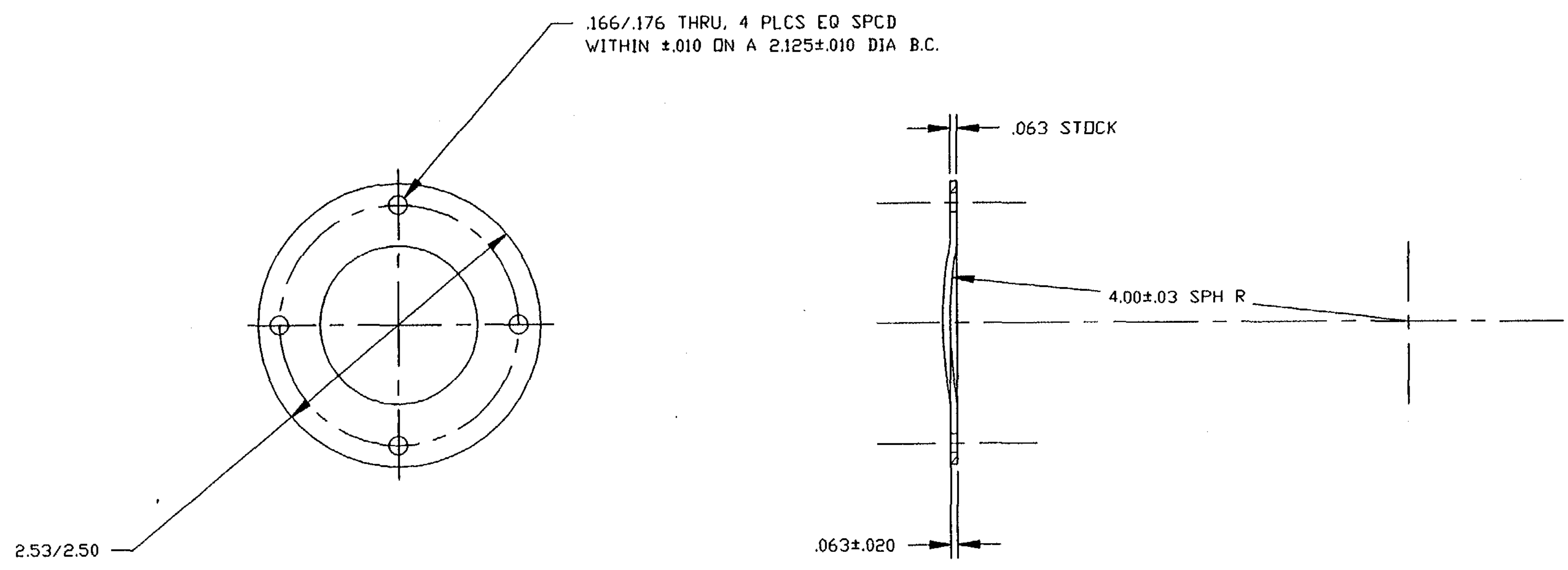
ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, SHEET, TYPE 304 PER QQ-S-766, .063 THICK.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



FILE NAME = Splash Guard Outside RFM227

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: SPLASH GUARD, OUTSIDE, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B

DRAWING NUMBER: RFM-227

FSCM 14213 SCALE: 1/1 SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2a

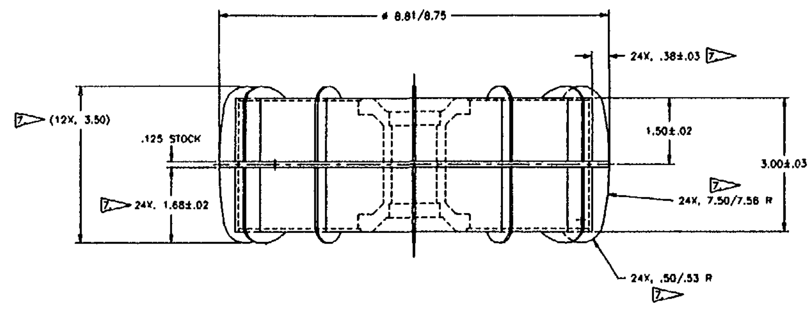
GEOMETRIC PRECISION = .0001

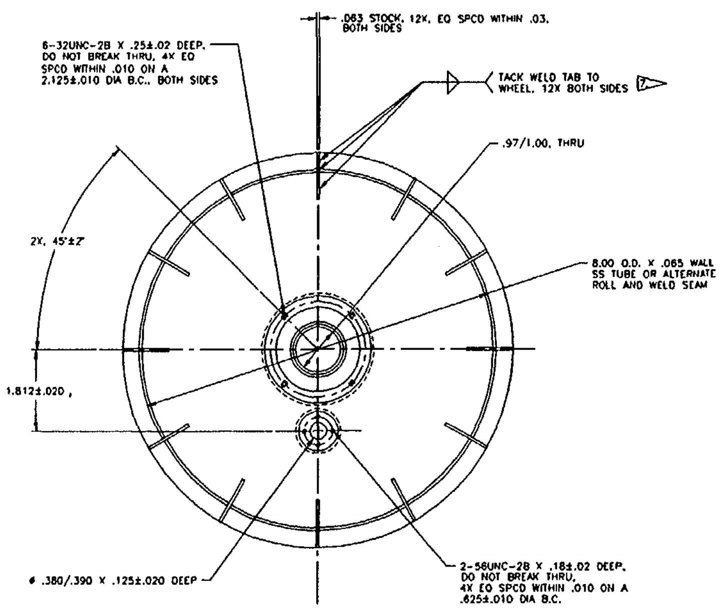
NOTES

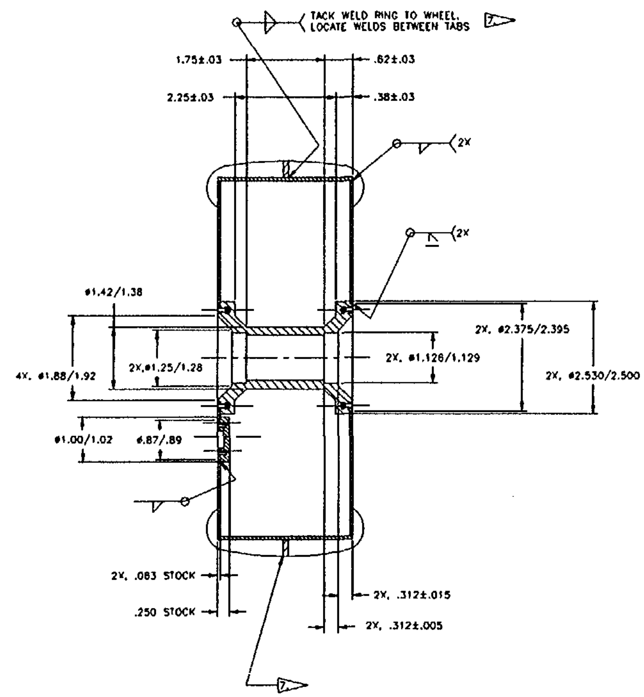
1. GENERAL REQUIREMENTS PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304 PER QQ-S-766.
3. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
4. WELDS SHALL BE WATER TIGHT.
5. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.
6. APPROXIMATE WEIGHT 2025g (4.5#).

7 TABS MAY BE ONE PIECE IF TABS AND RING ARE SLOTTED FOR LOCATING AND FIXTURING FOR WELDING.

PART OR CONTROL NUMBER	ISS	SHEET SIZE	PREPARED BY	REVISIONS DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 8211		10/24/98		







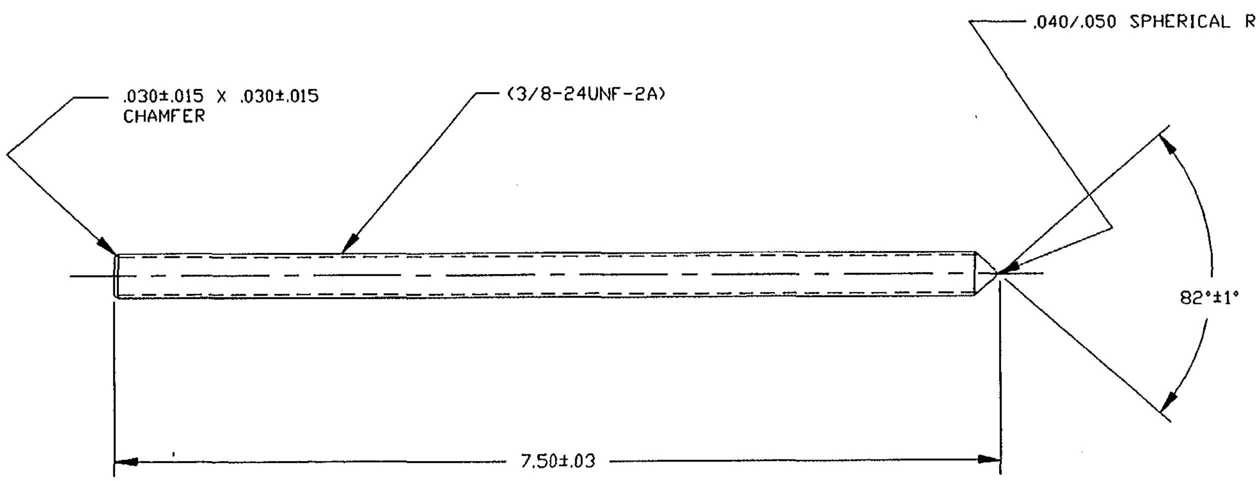
PART CODE	FILE NAME = 8 SS Wheel RFM228
SHEET	1 2 3 4 5 6
ISSUE	A
TITLE	8" SS WHEEL, RFM II
TITLE CLASSIFICATION	
PART CLASSIFICATION	UNCLASSIFIED
DRAWING CLASSIFICATION	UNCLASSIFIED
SIZE	E
DRAWING NUMBER	RFM-228
FSCM	4213
SCALE	1/1
SHEET	1 OF 1
STATUS	
ORIGIN	SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: THREADED ROD, STAINLESS STEEL, 3/8-24UNF.

PART OR CONTROL NUMBER	REVISIONS					
	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE FILE NAME = Shaft Counterbalance RFM229

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: SHAFT, COUNTERBALANCE, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B | DRAWING NUMBER: RFM-229

FSCM14213 | SCALE: 1/1 | SHEET 1 OF 1

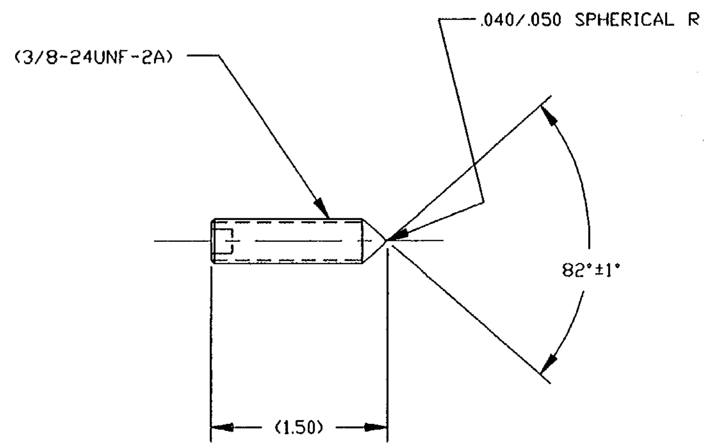
STATUS | ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: HEX SOCKET DRIVE SET SCREW, STAINLESS STEEL, 3/8-24UNF X 1.50" LONG, MODIFY AS SHOWN.

PART OR CONTROL NUMBER							
	REVISIONS						
	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



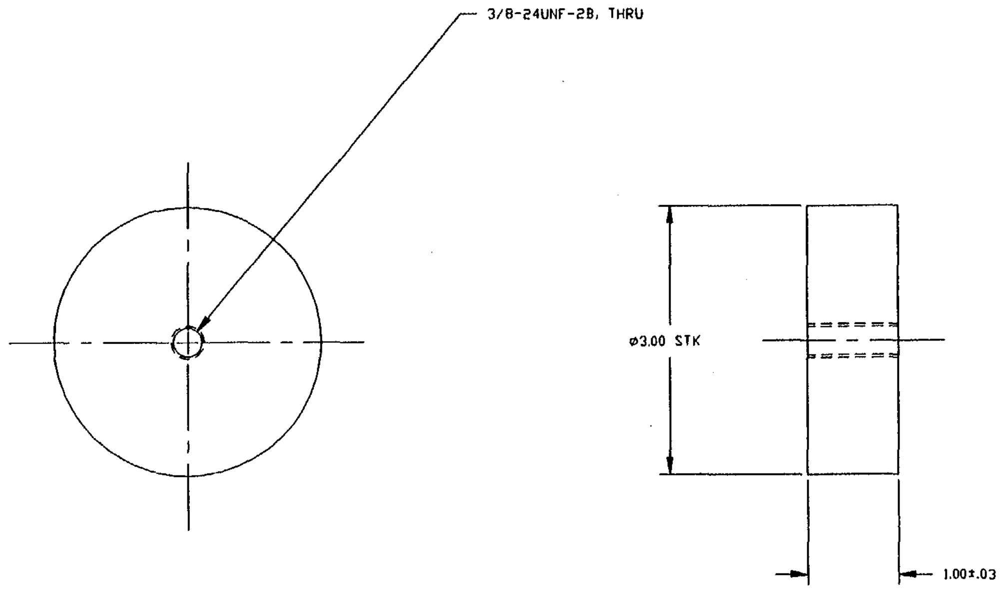
PART CODE	FILE NAME = Set Screw Pivot Bar RFM230						
SHEET	1	2	3	4	5	6	TITLE: SET SCREW, PIVOT BAR, RFM II (TITLE CLASSIFICATION)
ISSUE	A						
PART CLASSIFICATION: UNCLASSIFIED							
DRAWING CLASSIFICATION: UNCLASSIFIED							SIZE: B / DRAWING NUMBER: RFM-230
							FSCM14213 / SCALE: 1/1 / SHEET 1 OF 1
STATUS							ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: BRASS, ROD, TYPE C360 PER ASTM-B-16, HALF HARD, 3.00" DIA.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE FILE NAME = 962g Counterbalance RFM231

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: 962g COUNTERBALANCE RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C

DRAWING NUMBER: RFM-231

FSCM 14213 | SCALE 1/1 | SHEET 1 OF 1

STATUS

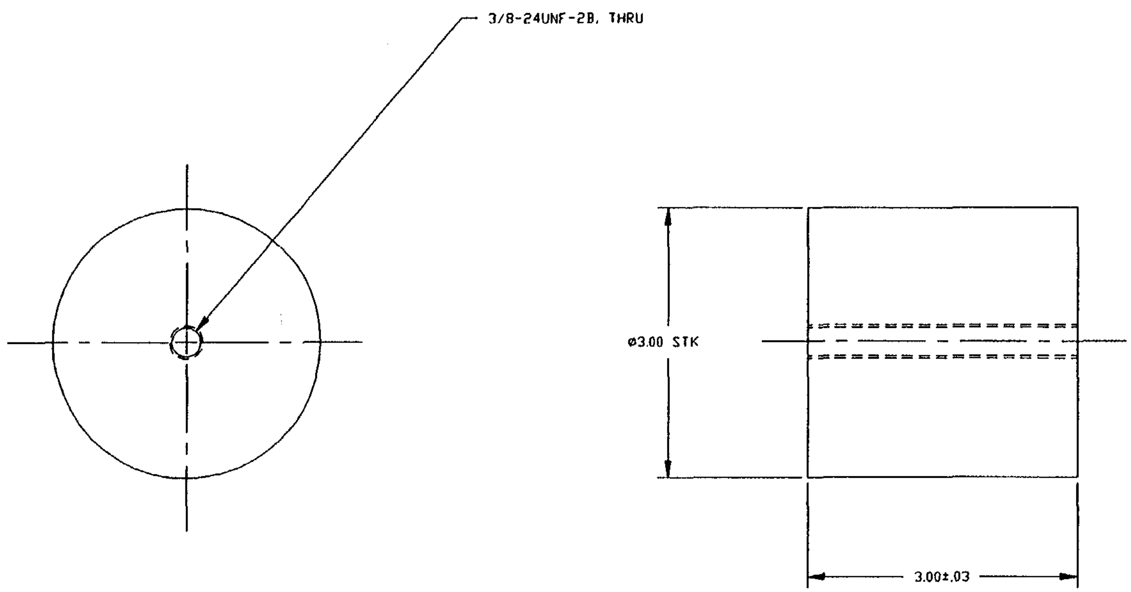
ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: BRASS, ROD, TYPE C360 PER ASTM-B-16, HALF HARD, 3.00" DIA.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211	11/15/97		



PART CODE FILE NAME = 2886g Counterbalance RFM232

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: 2886g COUNTERBALANCE RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: C | DRAWING NUMBER: RFM-232

FSCM 14213 | SCALE 1/1 | SHEET 1 OF 1

STATUS | ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

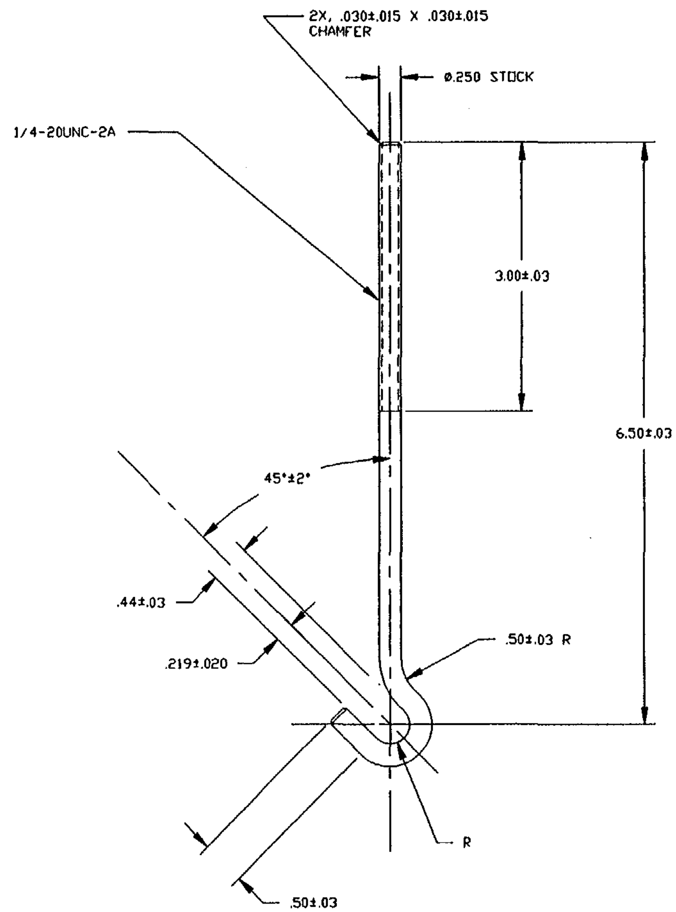
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, ROUND, TYPE 304 PER QQ-S-763, .250" DIAMETER.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211		11/15/97		



PART CODE	FILE NAME = Shipping Hook RFM233						
SHEET	1	2	3	4	5	6	TITLE: SHIPPING HOOK, RFM II (TITLE CLASSIFICATION)
ISSUE	A						
PART CLASSIFICATION: UNCLASSIFIED							
DRAWING CLASSIFICATION: UNCLASSIFIED	SIZE: C	DRAWING NUMBER: RFM-233					
		FSCM14213	SCALE: 1/1	SHEET 1 OF 1			
STATUS		ORIGIN SC-AN1-V1.2a					

GEOMETRIC PRECISION = .0001

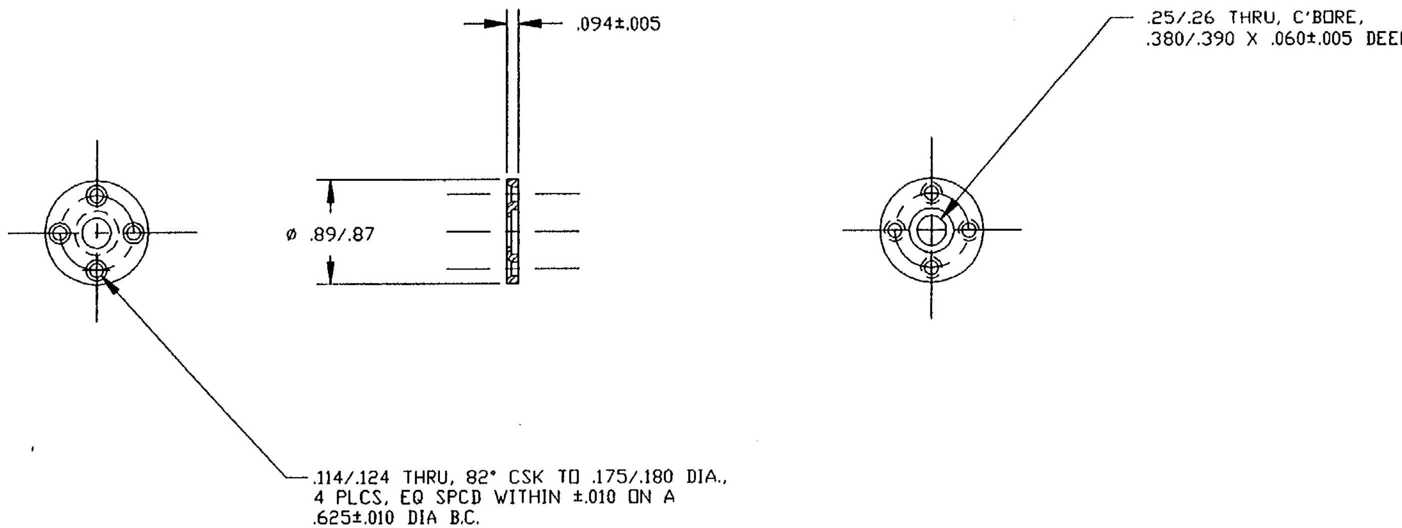
NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, SHEET, TYPE 304 PER QQ-S-766.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS

ISS	SHEET ZONE	PREPARED BY / DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211	11/15/97		



FILE NAME = Magnet Cover Plate RFM234

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE — TITLE CLASSIFICATION

MAGNET COVER PLATE, RFM II

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B | DRAWING NUMBER: RFM-234

FSCM14213 | SCALE: 1/1 | SHEET 1 OF 1

STATUS | ORIGIN SC-AN1-V1.2a

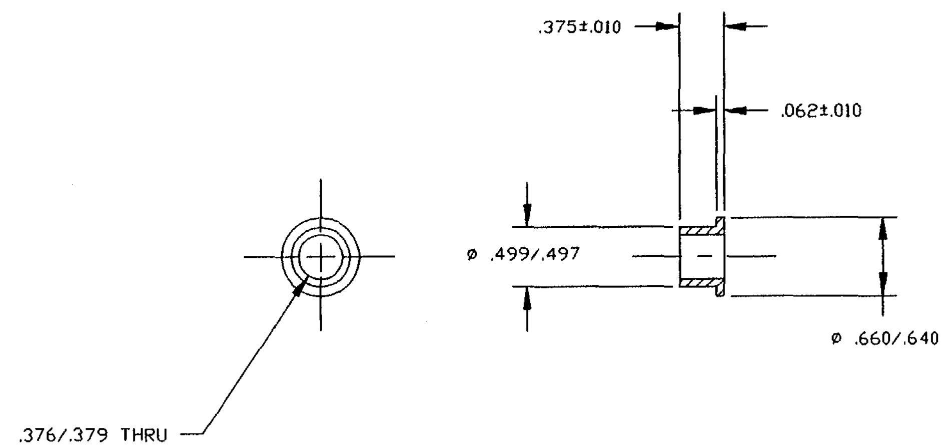
GEOMETRIC PRECISION = .0001

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. MATERIAL: STAINLESS STEEL, TYPE 304 PER QQ-S-763.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301.

PART OR CONTROL NUMBER

REVISIONS						
ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
A		GLOWKA/STALLER, 6211		11/15/97		



FILE NAME = Sleeve Wheel Bearing RFM235

SHEET	1	2	3	4	5	6
ISSUE	A					

TITLE: SLEEVE, WHEEL BEARING, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED

SIZE: B

DRAWING NUMBER: RFM-235

FSCM 14213 | SCALE: 1/1 | SHEET 1 OF 1

STATUS

ORIGIN SC-AN1-V1.2a

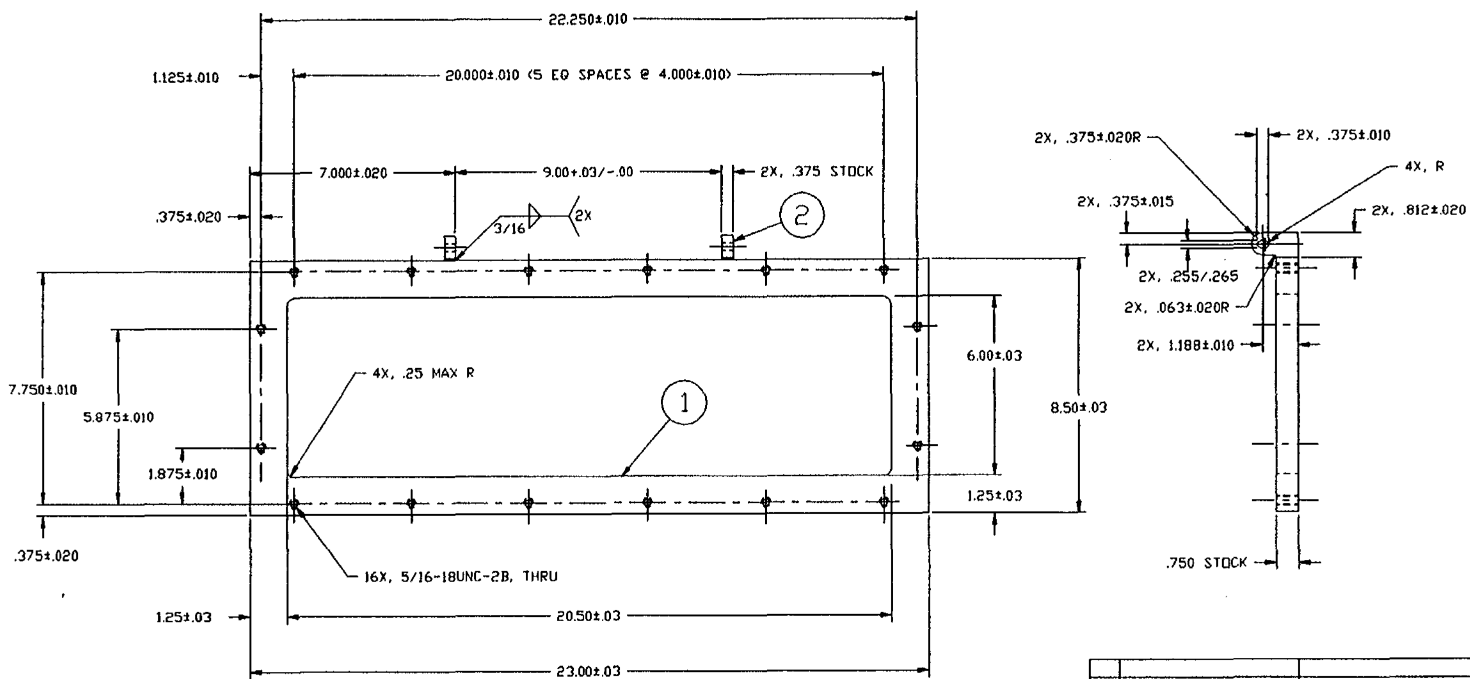
GEOMETRIC PRECISION = .0001

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOWKA/STALLER, 6211		11/15/97		

REVISIONS

NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.



NO REQD	PART/CONTROL NO.	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
2	QQ-S-766	STAINLESS STL, TYPE 304, PLT, .375 THK			2
1	QQ-S-766	STAINLESS STL, TYPE 304, PLT, .750 THK			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING, STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Hinge Spacer RFM236

SHEET 1 2 3 4 5 6 | ISSUE A

TITLE: HINGE SPACER, RFM II

TITLE CLASSIFICATION

PART CLASSIFICATION: UNCLASSIFIED

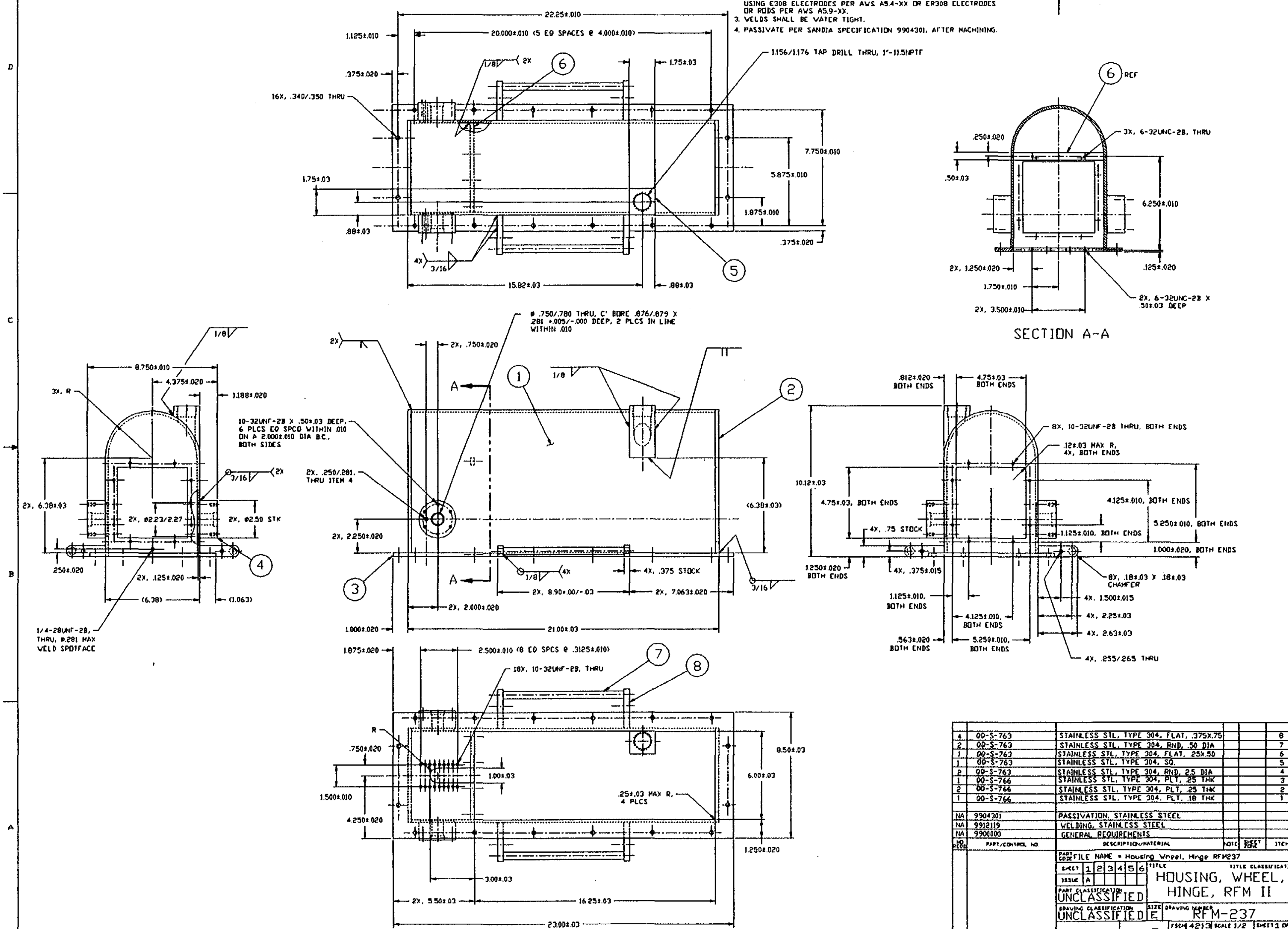
DRAWING CLASSIFICATION: UNCLASSIFIED | SIZE D | DRAWING NUMBER RFM-236

FSCM 4213 | SCALE 1/2 | SHEET 1 OF 1

STATUS | ORIGIN SC-AN1-V1.2a

GEOMETRIC PRECISION = .0001

D C B A 4 3 2 1



NOTES

1. GENERAL REQUIREMENTS ARE PER SANDIA SPECIFICATION 9900000.
2. WELD AND INSPECT PER SANDIA SPECIFICATION 9912119, CLASS II, USING E308 ELECTRODES PER AWS A5.4-XX OR ER308 ELECTRODES OR RODS PER AWS A5.9-XX.
3. WELDS SHALL BE WATER TIGHT.
4. PASSIVATE PER SANDIA SPECIFICATION 9904301, AFTER MACHINING.

PART OR CONTROL NUMBER	ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKR	APVD
	A		GLOVKA/STALLER, 6211				

NO. REQD	PART/CONTROL NO	DESCRIPTION/MATERIAL	NOTE	SHEET ZONE	ITEM
4	00-S-763	STAINLESS STL, TYPE 304, FLAT, .375X.75			8
2	00-S-763	STAINLESS STL, TYPE 304, RND, .50 DIA			7
1	00-S-763	STAINLESS STL, TYPE 304, FLAT, .25X.50			6
1	00-S-763	STAINLESS STL, TYPE 304, SQ.			5
2	00-S-763	STAINLESS STL, TYPE 304, RND, 2.5 DIA			4
1	00-S-766	STAINLESS STL, TYPE 304, PLT, .25 THK			3
2	00-S-766	STAINLESS STL, TYPE 304, PLT, .25 THK			2
1	00-S-766	STAINLESS STL, TYPE 304, PLT, .18 THK			1
NA	9904301	PASSIVATION, STAINLESS STEEL			
NA	9912119	WELDING, STAINLESS STEEL			
NA	9900000	GENERAL REQUIREMENTS			

PART CODE FILE NAME = Housing Wheel, Hinge RFM237

SHEET 1 2 3 4 5 6 — ISSUE A

TITLE: HOUSING, WHEEL, HINGE, RFM II

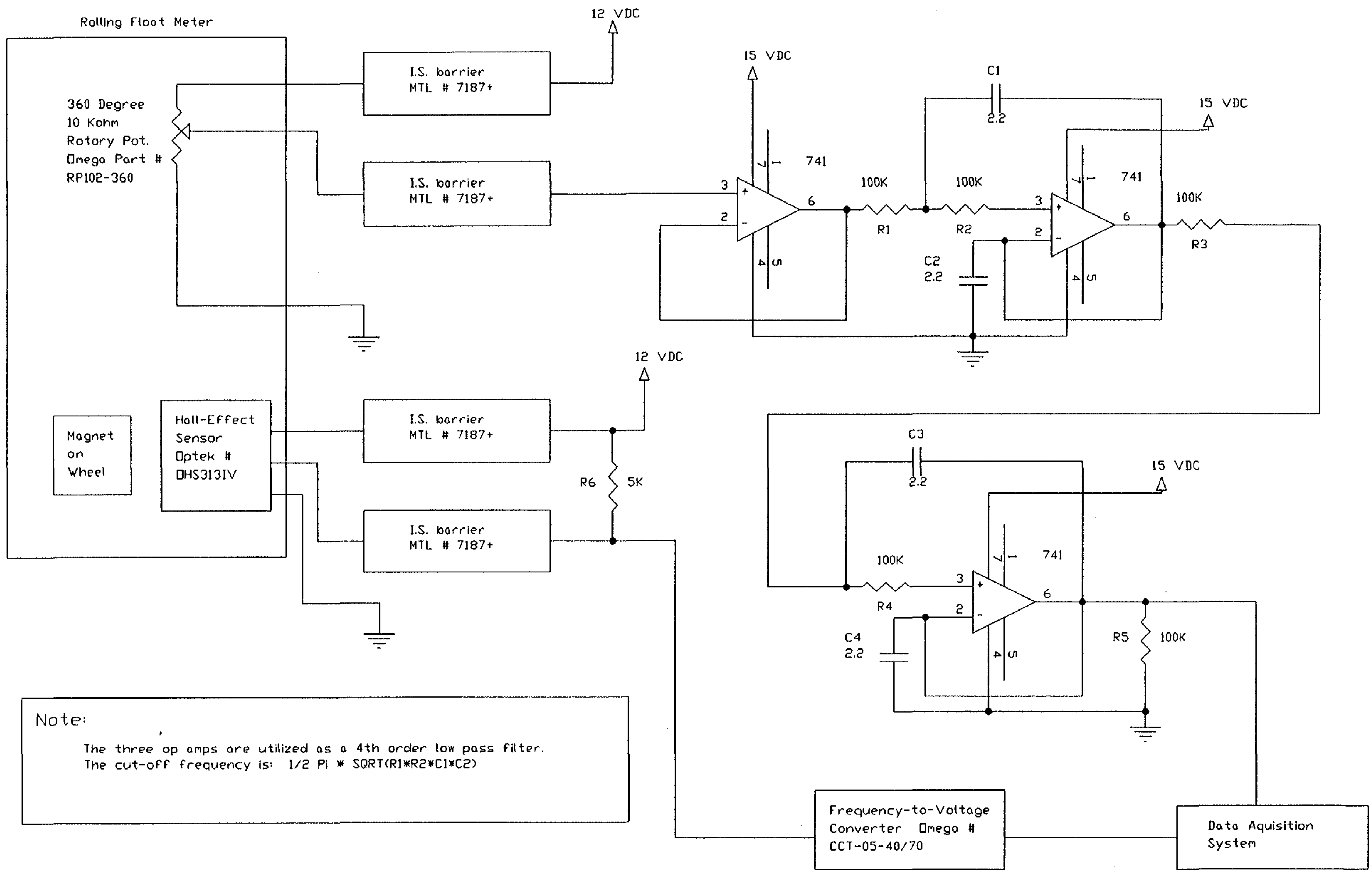
PART CLASSIFICATION: UNCLASSIFIED

DRAWING CLASSIFICATION: UNCLASSIFIED — SIZE E — DRAWING NUMBER RFM-237

FSCM 4213 — SCALE 1/2 — SHEET 1 OF 1

ORIGIN SC-AN1-V1.2o

GEOMETRIC PRECISION = .0001



Title		
System Schematic Diagram, RFM II		
Size: A	Document Number: SK-RFM-001	Rev: A
Date: Thursday, January 22, 1998	Sheet 1 of 1	

Appendix B

Recommended Procedures

Recommended Procedures for RFM Field Installation

1. Install RFM on top of drilling fluid return line pipe between pitcher/flow nipple on well mud riser and mud tank shaker box.

2. Downslope angle of return pipe needs to be between 2° and 15° (8° to 12° works best).

3. Return line pipe needs an opening for RFM mounting flange. Torch cutting is acceptable. Opening should be located on pipe for access to the RFM during installation and service (i.e.-proximity to a work deck or sub-floor).

4. Opening for mounting flange needs to be sized to outside perimeter of mounting flange, not inside perimeter.

5. Mounting flange needs to be positioned in the pipe cutout only far enough to be welded. Use continuous weld while maintaining same downslope angle as pipe and level side to side with a bubble level tool.

6. The RFM can be tilted 90° for maintenance or removal from the return pipe. The direction of rotation needs to be determined before the RFM and hinge spacer are installed. The direction of rotation will be dictated by the side of the pipe that offers the easiest access to the RFM. The hinge portion of the hinge spacer will be on the opposite side of the pipe from this established access. The RFM NEMA 4 enclosure and internal components need to be mounted on the access side of the RFM.

7. Install a rubber gasket and RFM hinge spacer on top of the mounting flange. Bolts are inserted through the mounting flange tabs into the hinge spacer. (thread lubricant, such as Loctite #771, should be used on all bolts during installation).

8. Ensure that j-hook is securing RFM wheel in full up-position inside RFM housing before mounting RFM.

9. Mount RFM and a rubber gasket on top of hinge spacer. Install pins between RFM hinges and hinge spacer hinges, then insert and tighten bolts to secure RFM to hinge spacer.

10. Release j-hook and lower wheel slowly into pipe.

11. While spinning the wheel by hand, adjust the RFM stop plate to raise the wheel just enough to not touch the bottom of the pipe I.D. The RFM can detect lower flow rates if the wheel is close to the pipe I.D. bottom.

12. Check wheel weight for approximately 750 grams of down-weight. Attach a weight scale through the top access port on the RFM housing to the wheel mounting shaft. This measurement needs to be taken when the wheel mounting shaft is parallel to the RFM housing flange. If the wheel weight is not 750 grams, adjust the counter balance weight, located inside the NEMA 4 enclosure, until the 750 gram wheel down-weight is obtained.

13. The signal/power cable connections at the RFM are made inside the NEMA 4 enclosure to a WAGO terminal strip. The electrical feed-through on the back of the box is sized for a 4-pair cable.

14. The other end of the signal/power cable is connected to a terminal block in the RFM instrumentation box. This box is normally located some distance from the RFM, in the area of the data-acquisition computer. Wiring the signal/power cable at the RFM and instrumentation box is done according to the associated RFM wiring schematics.

15. Signal/power checkout normally requires two people, one person to monitor the data acquisition computer and instrumentation box, the other to manually spin the RFM wheel to verify Hall-effect rotation sensor operation and pivot the wheel mounting shaft to verify that the angle potentiometer is working. One person can do the signal/power checkout if the data-acquisition computer is concurrently taking data while the RFM is manually exercised.

Recommended Procedures for RFM Field Maintenance

Normally problems with the RFM in the field are minimal. The table below can serve as a guide if problems do occur.

Caution: Care should be exercised when working on a RFM attached to a return-line pipe, since temperatures of the drilling fluid flowing in the return-line may be high enough to burn exposed skin.

TABLE I - TROUBLESHOOTING A RFM

PROBLEM	POSSIBLE CAUSE/FIX
1. NO ROTATION SIGNAL AND/OR ANGLE VOLTAGE	CHECK THAT ALL POWER SWITCHES ON THE RFM ELECTRICAL INSTRUMENTATION BOX ARE ON AND THAT THE BOX IS CONNECTED TO 110VAC POWER.
2. NO ROTATION SIGNAL	VERIFY THAT THE WHEEL IS ROTATING FREELY VIA THE WHEEL INSPECTION COVER ON THE RFM HOUSING.
3a. NO ROTATION SIGNAL & WHEEL IS ROTATING	THE HALL-EFFECT ROTATION SENSOR MAGNET MAY HAVE PIECES OF FERROUS MATERIAL MAGNETICALLY ATTACHED. USUALLY A SWIPE ACROSS THE MAGNET FACE IS SUFFICIENT TO CLEAN ANY FERROUS MATERIAL OFF THE MAGNET.
3b.	EROSION OF THE MAGNET FACE EXPOSED TO THE DRILLING FLUIDS CAN OCCUR IF IT DOES NOT HAVE A PROTECTIVE COATING. EPOXY COATINGS OR NICKEL PLATING OF THE MAGNET FACE WILL EXTEND THE MAGNET LIFE DRAMATICALLY.
3c.	VERIFY THAT THE FREQUENCY-TO-VOLTAGE CONVERTER IS RECEIVING SIGNAL PULSES FROM THE RFM AND CONVERTING THEM TO A VOLTAGE OUTPUT FOR THE DATA-ACQUISITION COMPUTER.
4. ANGLE VOLTAGE CHANGES (FROM INITIAL NO-FLOW SETTING)	CHECK ALL SHAFT COUPLINGS INSIDE THE RFM STEEL ENCLOSURE BOX FOR TIGHTNESS. IT IS RECOMMENDED TO MARK ALL COUPLINGS AND SHAFTS INSIDE THE STEEL ENCLOSURE BOX WITH A PERMANENT MARKER. ANY SLIPPAGE BETWEEN THE COUPLINGS AND SHAFTS THEN WILL BE READILY APPARENT.

Note: The RFM can be tilted 90° on its side for maintenance purposes or to remove it temporarily from the return-line pipe without affecting drilling operations.

Note: The wheel and pivot shaft bearings have not been a source of problems to date, but should be inspected and/or replaced between RFM applications.

<u>Recommended Procedures for RFM Post Field Reconditioning and/or Initial Checkout</u>

1. Clean RFM thoroughly inside and out with water.

2. Inspect and, if required, replace wheel bearings with identical stainless steel bearings. Preload on bearings should be approximately 1/8-turn tighter after initial freeplay is adjusted out. The 1/8-turn preload should not change how easily the wheel turns when spun by hand. If it does, then readjust preload as necessary.

3. Visually check wheel for bent fins or any irregularities and straighten if necessary.

4. Visually check Hall-effect sensor housing and cable for any deterioration.

5. Replace magnet paying attention to polarity, since the Hall-effect sensor only actuates on a North pulse. The replacement magnet needs to be epoxy coated or nickel plated for protection if a blank magnet retaining cover is not used. If an epoxy coating is used, apply the epoxy through the hole in the magnet retaining cover after the magnet and cover is installed and only thick enough to be flush with the top of the cover.

6. Check pivot-shaft bearings for any roughness, freeplay, or seal leakage. Again, if required, replace with identical stainless steel bearings.

7. Replace rotary potentiometer (approximate cost $130) if the RFM has been in service for 2 months or more. Potentiometer can be reused if it is adjusted to use a new internal operating area, but this is not recommended.

8. Use thread adhesive (i.e. Loctite #242) on all screws associated with the rotary potentiometer, magnet retaining cover screws, and wheel bearing cover screws.

9. Use thread lubricant (i.e. Loctite #771) on all other screws and bolts.

Recommended Procedures for Preparation and Installation of the RFM Hall-Effect Magnetic Sensor

1. The lead-in wires are 24-gauge, Teflon-coated, and are dipped in etching fluid (i.e. Gore tetra-etch) for better adhesion of coating materials to the Teflon.

2. A two-part synthetic-rubber polysulfide coating (i.e. Flame Master CS3100) is applied to the junction terminals of the wires and Hall-effect sensor to prevent the terminals from shorting to each other or to the housing.

3. The Hall-effect sensor is installed in the housing with its nomenclature (lettering) facing outward in the direction of the magnet and positioned approximately 1/16" from the bottom of the machined slot in the housing.

4. Aluminum oxide epoxy filler (i.e. Shell Epon 828, cured with Fisher diethanol amine) is used to pot the Hall-effect sensor and wires into the housing. A cure time of 24 hours is required.

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