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FINAL REPORT

Investigations to Determine Dust Concentrations and Characteristics inside Enclosed Work Areas and Equipment at Large Grain Terminals

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Federal Grain Inspection Service
Agricultural Marketing Service

ABSTRACT

Grain dust samples were collected at Cargill elevators in Savage, MN, Norfolk, VA, Reserve, LA, and Seattle, WA, to determine airborne concentrations in the enclosed work areas and inside the casings of bucket elevators, belt and drag conveyors, and scales. Many of the samples were later analyzed for particle size distribution and chemical composition. Work areas, generally, had concentrations below 0.1 grams per cubic meter (30 to 50 g/m^3 is considered to be the minimum explosive concentration), with highest measurements of 0.4 and 1.4 g/m^3 at conveyor transfer points in tunnels at Savage and Norfolk, respectively, 0.6 g/m^3 in the lower section of the "cleaning house" at Reserve, and 0.1 g/m^3 at Seattle. Sampling was also performed with dust systems disabled for a period of up to 15 minutes, showing no extreme changes in concentrations other than at truck receiving areas (0.4 - 1.3 g/m^3), except at the Reserve terminal, which is an atypical example. Concentrations inside bucket elevator enclosures were extremely high (10 - 1200 g/m^3) at both the head and the boot. Horizontal conveyors had concentrations of up to 40 g/m^3 at loading points and 20 - 85 g/m^3 inside the discharge chutes. Inside scales measured 9 - 40 g/m^3 in the upper garner. Supplementary tests were performed to evaluate the practice of returnding dust to bucket elevators and adding airflow to boots. Mass mean diameters for 39 work area samples averaged about 15 μm, for 44 equipment samples about 18 μm, and for 34 samples of settled dust about 20 μm. Chemical analysis (wet) measured moisture (5-11%), starch (30-70%), protein (6-20%), fat (1-3%), and ash (5-40%) for 76 samples. It is concluded that the minimum explosive concentration of grain dust is typically exceeded inside the feeding and discharge enclosures of bucket elevators and (to a lesser degree) of horizontal conveyors at grain terminals.

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INTRODUCTION

The concern for explosion protection at grain elevators and related facilities has become ouite intense and widespread among industry, labor, and government people throughout the world. Although grain dust explosions have been a problem perhaps as long as machines have been used to handle and process grain, the rapid growth of the grain industry in recent years has seemingly brought with it large increase in economic and human losses caused by these explosions. Also heightened by the ever-growing consideration by business, and by society overall, for the health and safety of its employees, the desire to eliminate grain elevator explosions is being reflected very stronly in the grain industry's efforts in research, engineering, policy and training.

Most notable and fundamentally important of these efforts have been two recent technical symposia on grain dust explosions. The first of these was sponsored by the Grain Elevator and Processing Society (1) and held in Kansas City, Missouri, in October, 1977, in which the goals were

> ". . . to identify existing valid research data and information relating to the causes and control techniques of (grain dust) explosions; bring together those people currently addressing this problem and provide a forum for the effective exchange of this information."(2)

Among the contents of the three-day conference were presentations summarizing past literature and statistics regarding dust explosions, current research in characterizing grain dust and its explosibility, and new and accepted practices in preventing or controlling the explosion of grain dust. The second symposium was held in Washington, D.C., in July, 1978, and sponsored by the National Academy of Sciences (3), for the purpose of providing "a common understanding of the state of the art and available course of action regarding the grain dust hazard"(4).

There were numerous contributions from U.S. government agencies (USDA, EPA, OSHA, NIOSH, and the Senate), labor unions, insurance companies, and grain industry spokesmen (both from the U.S. and abroad), in addition to technical presentations regarding grain dust's explosion behavior, measurement and control. These symposia have helped to give a uniform technical foundation and a broad explosure of opinion from which to assess current knowledge for remedial actions and to formulate futher research.

Combined with this search for answers is the increasing acceptance of guidelines for explosion protection from various experts and institutions. The National Fire Protection Association has published the following publications which treat this problem - the Fire Protection Codes (5), the National Electrical Code (6), and a 1922 text, Dust Explosions (7). The latter is to a great extent superseded by a 1973 text, Dust Explosions and Fires (8), written by K.N. Palmer of the Fire Research Station in Great Britain. Such sources prescribe to industry planners, builders, and managers a large variety of means to prevent or control explosions in their facilities, and in doing so act invaluably as references.

The pool of information regarding explosion protection is thus becoming fairly large - to the point that many alternative solutions have been developed and many more are soon to come. At the same time, the heightened awareness and urgency of dust explosions in elevators has resulted in much pressure to employ any and all possible measures for their solution. However, the cost of doing "everything possible" can be a severe drain in capital, hurting the efficiency of the marketing system. In order to optimize the solution, it has become necessary to know more about the actual elevator environment, so that areas of highest concern can be located and remedied. The survey of dust characteristics in elevators was conceived for this purpose.

After becoming familiar with various methods for measuring and collecting dust in elevator environments, the Grain Research Lab of Cargill, Inc. (Minneapolis) entered into Cooperative Agreement No. 12-25-A-2957 with the U.S. Department of Agriculture (the Federal Grain Inspection Service and the Agricultural Marketing Service) to conduct a study, titled "Determination of Dust Concentrations and Characteristics inside Enclosed Work Areas and Equipment at Large Terminals". Its objective has been to obtain a better understanding of dust, and the hazardous conditions resulting from its presence, in specific environments of various grain elevators. Beginning in November, 1978, sampling of dust inside work areas and enclosed grain handling equipment was conducted at four grain terminals owned by Cargill, Inc. (Savage, Norfolk, Reserve, and Seattle), which were selected on the basis of differences in geographical location and the type of grain being handled, as well as other factors (e.g., age, type of operation, dust control practices, etc.). From these samples mass concentrations, particle size distributions and chemical composition were determined. This report describes the sampling and analyses performed under this cooperative agreement and discusses some of the conclusions which can be drawn from its results.

A brief comment is appropriate at this point. The level of accuracy of the measurements made in this study probably will not satisfy the investigator trying to establish lack of compliance of regulations or the researcher interested in statistical inferences. Indeed, nothing is expected to be "proven". Grain terminal and elevator environments vary tremendously from one day to another, from place to place. The primary intent, rather, is to indicate types of locations and commonly used equipment in which explosible dust tends to accumulate to hazardous levels (concentrations) and to provide some data regarding the physical and chemical make-up of that dust. Thus, sampling errors which may be quite large are apt to be encountered that will nonetheless permit an adequate assessment of explosibility in overall terms. For example, concentrations were measured inside bucket elevators of 600 grams per cubic meter - a value of questionable accuracy and precision, given the technique by which the sample was collected. Yet, the probability that the minimum explosible concentration has been exceeded is hardly questionable. Also, the replication of samples and measurements has been avoided in the interest of getting the widest possible sampling of conditions within the six months or so allotted for this project. The successfulness of this approach is for the reader, the future researcher, and ultimately the grain industry and its employees to determine.

BACKGROUND

A survey of dust characteristics, by definition, must use one or several measurement processes. Cadle (9) has written an excellent text which describes how dust, as an airborne suspension of particles, can be measured to determine concentrations, sizes, shapes, surface area, etc. He catagorizes these methods into two groups: in-situ (on site) measurement and sampling combined with separate laboratory measurement. These two approaches are quite separate from each other; therefore, either or both must be selected before the survey can be carried out.

Instruments which make in-situ measurements of dust characteristics generally sense and evaluate the suspended dust's effects on light transmission - attenuation, reflection, or scattering. Such devices have a number of drawbacks which make their application to the study of grain dust in elevators inappropriate. First, these devices do not measure concentrations within the explosible range, and to develop one to do this would be time-consuming and very expensive. Many of the instruments available only count particles in a known volume of air or measure percent light extinction/reflection, both of which must then be converted to mass concentration on the basis of assumed information of the dust, itself (particle specific density, size distribution, or light diffusion coefficients). Second, the abundant presence of larger objects, such as grain kernels and moving machine components, can plug, obscure, or damage the sensing elements of in-situ instruments, or otherwise lower their accuracy and reliability. Third, most of these devices are not approved or acceptable for use in hazardous environments, according to codes of the National Fire Protection Association (5 & 6). Fourth, chemical composition of the dust is not ascertainable with any of these instruments in this group.

Sampling consists of extracting a portion, or sample, of the air from the environment in question and removing the dust from that air sample. The process is simple in concept and quite flexible in its application. Concentrations (in the desired units - grams per cubic meter) are determined directly by measuring the airflow through the sampler and weighing the extracted dust. Afterwards, the sampled dust is available for laboratory study of particle size, chemical composition, etc. There are some problems with sampling, though, which can lead to large errors in measurement and analytical results. First, the sample of air may not be representative of the particular environment from which it is taken. The suction of air into the sampler may not capture larger particles in the air because of settling or inertia. Methods for estimating these errors have been developed by Davies (10) and Belyaev and Levin (11), in which particle diameters, sampling head dimensions, sampling rates and "wind" velocities are taken into consideration. A second source of error in sampling is the time-averaging process, which ignores rapid variations inconcentration and other dynamic characteristics in the environment. Third, before lab tests can be performed on the dust sample, the particles may change characteristics (moisture, particle size, etc.) or become non-recoverable from their entrained state on the filter, in the impinger, or other sampler component. Some of these errors are controllable by proper sampler design, sampling execution, and dust sample packaging; others may be significant and, yet, quite difficult to estimate. These will be discussed more thoroughly later in the paper.

The sampling procedures for this survey were developed and tested between January and October of 1978 under actual elevator conditions. High-volume samplers (General Metal Works Model 2000H) were acquired and used in a number of trials for measuring concentrations in the elevator setting - inside a large storage building during emptying; in a headhouse basement over six months of eight-hour (day shift) sampling periods; and spot measurements in a variety of elevator work areas. Enclosed equipment sampling was adapted from the high-volume sampling method by, at first, making a simple housing for an explosion-proof fan (a type used in grain sampling applications) so that air would be drawn from a sampling port, through a hose, and through a filter supported across the fan intake (see Figure 1). Airflow was estimated by measuring the back pressure of the fan. After several trials in sampling dust from leg casings, the housing was refined to minimize dust accumulations at points other than the filter. Also, a separate housing was added to the fan exhaust which measures airflow across an orifice in the same fashion as the General Metal Works samplers. Sampling port locations for bucket elevator enclosures were selected on the basis of trial results from eight ports made in the shipping leg at Savage terminal.

Analytical procedures were selected which were standards or in common usage. Particle size analysis is possible by several techniques, according to Cadle (9). Another technique, which Cadle does not mention, is the electrolyte resistance technique. The Coulter Counter, an instrument employing this technique, has been described and evaluated by Deblois and Bean (12) and applied in grain dust studies by Parnell (13) and Martin (14). The Coulter Counter has the advantage over other counting techniques in that results are processed as percent volume rather than percent by number of particles for each size interval. This allows the data to be compared directly with seiving results in mass-basis analyses (assuming constant particle density). Seiving/ Coulter size distributions were performed by Donaldson, Inc's Particle Lab

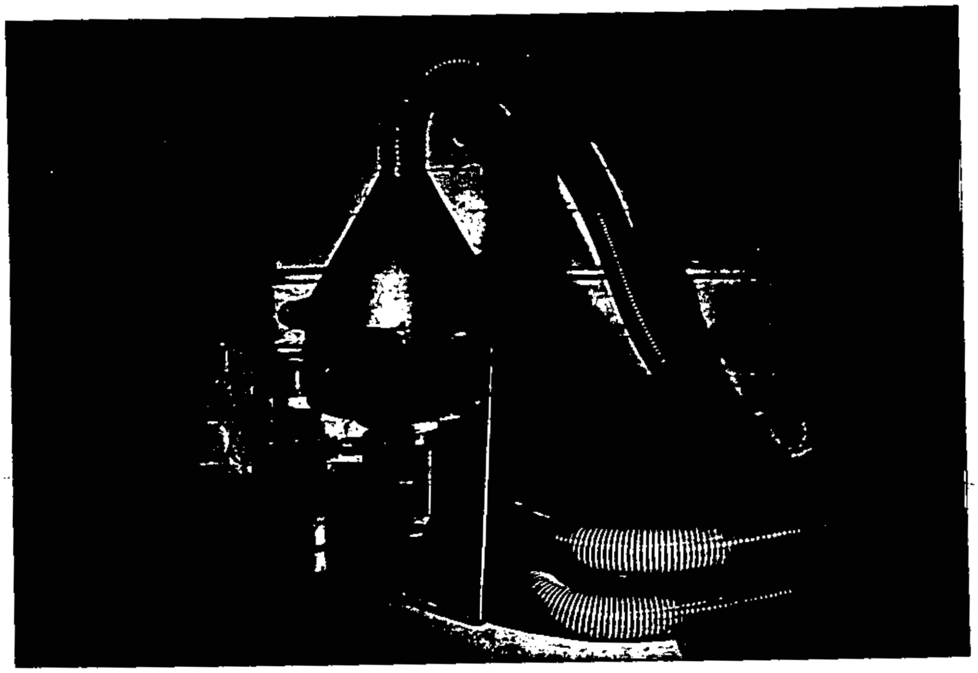


Figure 1. Early version of high volume air sampler for dust inside enclosed equipment.

on several preliminary samples to establish reporting formats before the elevator survey was underway. AOAC* standard procedures were specified for determination of moisture, starch, protein, oil, and ash contents of dust samples. Gas chromatography (GC) procedures were to be developed for grain dust analysis under a separate study for the National Grain and Feed Association of volatiles and fumigant residues in grain elevators. After Midwest Research Institute (Kansas City, MO) gained approval for that study, they agreed also to perform a number of GC analyses on samples from this survey.

Other background information which is considered pertinent for this study concerns the definitions for dust and explosible concentrations. Definitions for dust usually specify a range of particle diameters (Cadle, 9). In this study, the lower limit is reflected by the capturing capability of the filters used - the Gelman filters used for airborned dust and suspended dust inside equipment had specified capture efficiencies of 99.7% of particles above 0.3 m and 98% of those greater than 0.05 μm in diameter. Maximum particle size was chosen as 500 or 600 μm, as per results published by Dr. Bartnecht in the Precedings of the International Symposium on Grain Elevator Explosions (3). The subject of particle diameter, itself, is left to Cadle and other authorities. Explosible concentrations are defined as those within a range bounded by a minimum and maximum explosible concentrations established in laboratory test. For grain-type dusts the minimum explosible limit has been estimated to be between 20 and 50 grams per cubic meter, according to tests described by Palmer (8), while the maximum light exceeds that by several orders of magnitude - too high to be of current interest in controlling explosions.

* Association of Official Analytical Chemists (15).

SAMPLING AND CONCENTRATIONS IN WORK AREAS

Dust samples were collected from the work areas at four large grain terminals owned by Cargill, Inc. These terminals consisted in one inland (rail-and-barge-loading) facility at Savage, Minnesota, and three export (ship-loading) terminals at Norfolk, Virginia, Reserve, Louisiana, and Seattle, Washington. Samples for measuring the concentrations of airborne and respirable dust were collected at 14 to 20 sites within each terminal, including receiving sheds; samples of settled dust were collected at 10 sites each. The procedures and results from work area sampling are described in this section, while the data in more complete form is presented in Appendix A, in order to make the report more readable.

PROCEDURES

Airborne Dust. To collect samples of total dust (particulate matter less than 500 m in diameter) suspended in work areas, two conventional high-volume air samplers were used. Both samplers were GMW-2000H units, made by General Metal Works of Van Cleve, Ohio. The alumimum shelters which come with these samplers were not used. Instead, as shown in Figure 2, the filter bracket and fan housing of each sampler were placed on home-made, tubular stands for better portability throughout the elevator. The pressure tap on the fan housing was connected to a Dwyer 16-inch U-tube manometer by light-weight plastic tubing. After calibrating the orifice back pressure with a GMW-25 airflow calibration assembly (also made by General Metal Works), the pressure from the manometer could be used to determine airflow rate in cubic feet per minute. The filter media used with these samplers were Gelman Type A/E fiberglass filters, 200 mm by 250mm rectangular sheets, which resist hygroscopic effects during atmospheric sampling. The filter's collection efficiencies are 98% for particles larger than 0.05 μm and 99.7% for particles

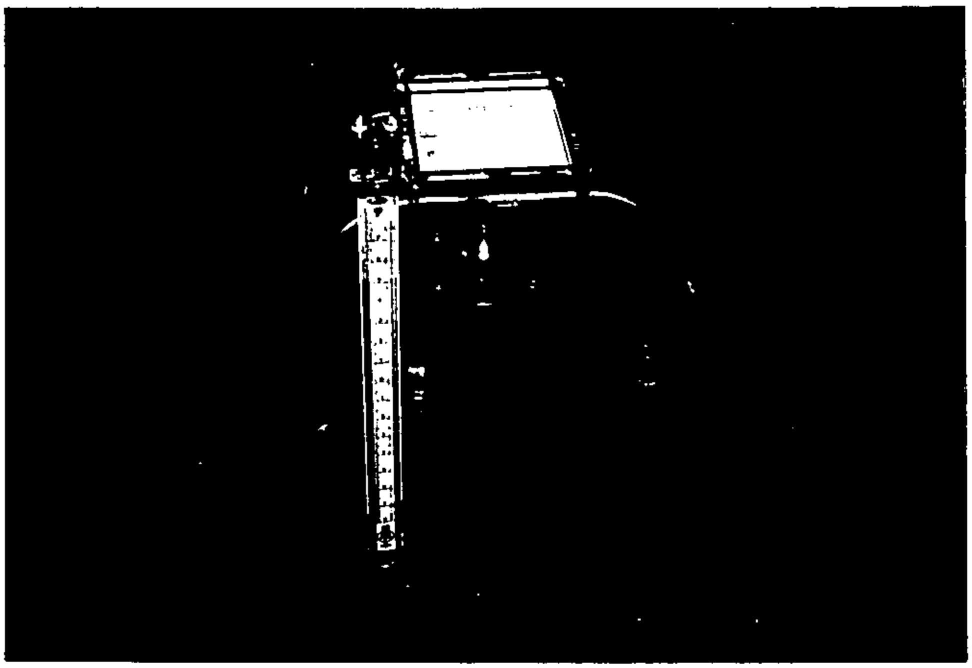


Figure 2. Conventional high volume air sampler, General Metal Works 2000H, in portable stand showing manometer for airflow measurement.

larger than 0.3μm.

The procedure for collecting airborne dust samples was as follows:

1. Filters were individually weighed on a digital electronic platform balance (Sartorius, model 3713) to within $\pm$ .01g. This tare weight was recorded on a manilla envelope kept with the filter for identification and later packaging.

2. The sampler was taken to the desired sampling site and placed in its stand. A pre-weighed filter was placed on the sampler's filter holder, and a gasketed bracket was placed over the filter and fastened down with 1/4 inch wing-nuts (finger-tight).

3. The descriptive data for the sample (date, time elevator, sampling site, sampler serial number, operating conditions, grain being handled, and obvious sources of dust suspension) were recorded on the envelope accompanying the filter.

4. The sampler was connected to a 110 volt explosion-proof outlet located in the terminal and turned on at that outlet (a safety measure). The time of sample collection, usually 15 minutes, was monitored with a stop-watch. The pressure inside the fan housing was measured with a manometer and recorded at 5 minute intervals, starting immediately after the sampler was turned on. (Figure 3 shows a sampling operation in progress). At the end of the sampling period, the pressure and time were recorded before turning the sampler off at the elevator's outlet.

5. After power had been disconnected, the filter bracket was removed and the

Figure 3. High volume air sampler during test to measure work area concentrations.

filter was folded across its narrow dimension, in a manner so that none of the sample was lost. It was then placed and sealed inside its accompanying envelope.

6. At the end of the day, the filter and dust were removed from the envelope and weighed on the balance described in Step 1. All information from the sample was recorded both on the envelope and on a separate data sheet (tabulated), after which the sample was repackaged and placed in a plastic speciman bag and heat-sealed for storage.

7. Air volume was determined from the calibration chart for the sampler and converted to units of cubic meters (1 cubic meter = 35.3 cubic feet). The net dust sample weight was then divided by air volume to determine mass concentration, grams per cubic meter (g/m^3).

The above procedure was used to collect dust samples at between 14 and 20 sites at each terminal. Where possible, a second sample was collected at the same site immediately after dust (emissions) control equipment in the area had been shut off. The purpose of this second sample was to give information on the dust system's effectiveness, and to indicate if hazardous concentrations would result from its temporary non-use.

<u>Settled Dust</u>. Samples of "layer" or settled dust were collected at ten sites at each terminal, roughly corresponding to some of the airborne sample discussed above. For each sample, a floor or other smooth horizontal surface was inspected to locate a region with typical or fairly high dust accumulation and few grain kernels. A plot was marked out and measured, after which the

dust from that area was diligently swept into a manila envelope using a soft-bristled 1-inch paint brush. This dust was then weighed and packaged similarly as the airborne samples in Step 6 above.

Respirable Dust. A kit containing five personal-type air sampler (Bendix Model 544, pictured in Figure 4) was acquired for the purpose of measuring worker's exposure to respirable dust. Rated by Factory Mutual for use in explosible atmospheres, these samplers are made to be fitted to and worn by individual workers so that their eight-hour exposure to dust particles smaller than 7 μm diameter (those which can become deposited in the lungs) can be determined. Each sampler consists of a battery-operated pump and a separate sampling head connected by light-weight plastic hose. The pump is small, can be clipped to the worker's belt, and contains a flowmeter to monitor sampling rate (maintained at 1.7 liters/minute, about the same as human respiration). The sampling head, which is usually carried near the worker's face, incorporates a nylon cyclone separator at the inlet and a plastic filter cartridge in which the small "respirable" dust is trapped for later measurement. In this survey, it was desired to determine workers' exposure at specific locations; therefore, each sampler was attached to stationery objects (not human subjects) and operated according to the following procedure:

1. Gelman type VM-1 filters were individually placed in small plastic envelopes, which were then weighed on a laboratory balance (Sartorius Model 2842) to within $\pm$ 0.1mg. This initial weight was recorded on a small tag which was inserted with the small bag into a heavier (.10mm) plastic envelope.

2. Each sampling pump was recharged for 16 hours during the night before

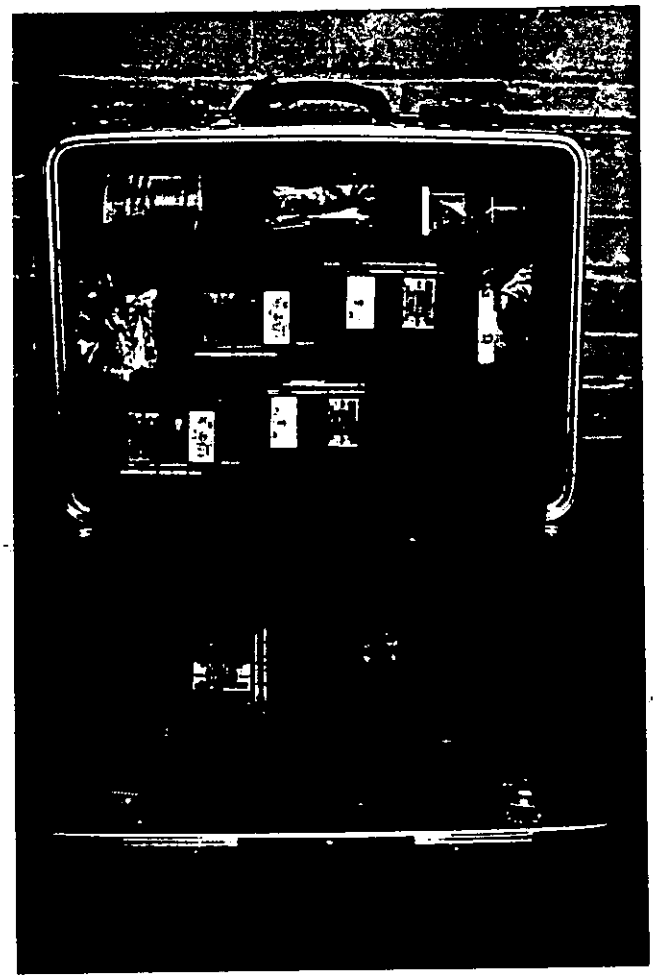


Figure 4. Bendix model 544 personal-type air samplers used to measure worker's exposure to respirable dust.

sampling was to be performed. The sampling head was cleaned and inspected for damage.

3. At the beginning of the work shift to be monitored, each sampler was assembled, a pre-weighed filter was inserted in the cartridge, and the pump was checked for operation and adjusted to a flow rate of 1.7 liters/minute. The pump's serial number and cycle count were recorded on the filter's weight tag, along with intended sampling site.

4. The sampler was then taken to its desired location and fastened to a suitable point (away from easy viewing and interference with people and equipment) with the sampling head at about face level.

5. The sampler was turned on and the flow rate checked again. It was then left to operate for the remainder of the shift with occasional inspections to check operation and sampling rate.

6. At the end of the shift, the sampler was turned off and removed to clean site (office). There, the final pump cycle count was recorded on the filter weight tag. The filter was removed from the head and placed back in its original envelope, which was repackaged with the weight tag into the second envelope. The sampler was cleaned off and put away.

7. Back at the laboratory, the filter and inner envelope were removed and weighed on the lab balance mentioned in Step 1. The final weight was recorded on the tag and later used to determine the weight of deposited dust. The total airflow was determined from the pump cycle counts (timed earlier, about 50/min). Concentration was then

calculated from this data and tabulated on a work sheet with other sampling information.

The above procedure was used in measuring respirable concentrations at nearly all the sites which were sampled for airborne dust (described earlier). The personal sampler was also used for measuring total airborned dust (cyclone deposit-combined with filtered dust) inside the meal storage building at the Norfolk terminal during a ship loading operation (described with results from airborne samples).

RESULTS

Data from all work area sampling is provided in this report under Appendix A, included with a simple plot plan of each terminal and the data from equipment sampling (to be discussed later) at that terminal. Sample indentification codes start with a letter (P=Savage, N=Norfolk, R=Reserve, S=Seattle) followed by a number which indicates the type of sample, according to the following system:

1 - 42	airborne dust samples
51 - 60	settled dust samples
71 - 90	respirable dust samples
100 -	equipment samples

Any sample codes in parentheses ( ) indicate a sample, usually of a different type, that was taken at the same site. (Example: under Savage work area samples, P1 is an airborne dust sample which was taken with a high-volume air sampler operated for 15 minutes inside the truck shed; sample P71 is a respirable dust sample which was also collected at the truck shed).

Airborne Dust. Concentrations measured during "typical" operations at the

TABLE 1. AIRBORNE DUST CONCENTRATIONS MEASURED INSIDE ELEVATOR WORK AREAS UNDER "TYPICAL" OPERATIONS

LOCATION	SAVAGE g/m3	NORFOLK g/m3	RESERVE ** g/m3	SEATTLE g/m3
Receiving Areas				
Truck rec. shed	.06	.07	---	.07
Rail rec. shed-hopper	--	.03	.002	.001
Rail rec. shed-boxcar	.07	--	---	.03
Conveyor Tunnels & Corridors				
Truck receiving	.05	.18	--	--
Rail receiving	.08	.04	.01*	.02
Rail receiving	--	--	.004*	.03
Rail receiving	--	--	---	.01
Beneath bins	.39	1.45*	.02*	.01
Beneath bins	.10	.13*	.004*	.003
Shipping	--	.02	.05	---
Shipping	--	--	.10	---
Headhouse/Workhouse Areas				
Leg boot area-rail rec.	.07	.01	.02R**	
Leg boot area-shipping			.24C	
Lower distribution area	.02	.04	.002W	.01
Lower distribution area	--	--	.55C	
Cleaner floor	.02	.01	.04C	.001
Cleaner floor	--	--	---	.01
Scale floor	.03	.01	.004W	--
Upper distribution area	.004	.02	.04/.48W	.002
Upper distribution area			.07C	.01
Leg head area-rail rec.	.01	.01	.01R	.01
Leg head area-shipping			.10C	--
Bin deck (trippers)	.04*	.02	.02	.04
Bin deck (trippers)	--	--	.01	--
Miscellaneous Areas				
Rail shipping shed	.08*			
Meal storage bldg. (during unloading)		.28*		

*No dust control installed in these areas

** At Reserve, three structures perform the functions that are usually performed in elevator headhouses. These are distinquishable by the letter following the concentration (R=Rail Receiving Tower, C=Cleaning House, and W= Weigh House).

four Cargill terminals are shown in Table 1, according to the type of sampling site. "Typical" means that in the area sampled, grain was at the same time being handled in a manner that was representative of normal operations for that area, to the extent possible. Most areas' concentrations did not exceed $0.10g/m^3$, none at Seattle. Those which did are as follows:

Savage	(P13)	conv. tunnel - east bins	$0.39g/m^3$
Norfolk	(N5)	conv. tunnel - truck rec.	0.18
Norfolk	(N9)	conv. tunnel - old bins	1.45
Norfolk	(N29)	meal storage bldg - unloading	0.29
Reserve	(R19)	cleaning house - ground floor	0.55
Reserve	(R21)	cleaning house - leg boot area	0.24
Reserve	(R15)	weigh house - below conv.	0.48

These concentrations still did not exceed the minimum explosible concentrations of these dusts (discussed earlier in "Background" section, page 8). However, they do show areas of concern from the stand point of worker's health and rapid dust accumulation on floors, which could contribute to an explosion if sufficiently disturbed. In all but samples N5 and N29, high concentrations were the result of one belt conveyor transfering to another. Peak concentrations inside the Norfolk Meal Shed actually exceeded $0.28g/m^3$, perhaps by several times, during the two hour sampling period. The lack of visibility and unpredictable movement of the tractor in the shed, made the use of the high-volume sampler unfeasable, however, such that maximum concentrations could not be measured.

In Table 2 is shown the airborne concentrations in the same areas as in Table 1, but without existing dust emissions control systems being used. (Starred values are the same as in Table 1). Receiving sheds were much affected, with concentrations increasing to as high as $1.34g/m^3$. Conveyor tunnels below bins at Savage had concentrations up to $0.44g/m^3$ and $1.38g/m^3$ at transfer points. Headhouse areas, besides those at Reserve, did not ex-

TABLE 2. AIRBORNE DUST CONCENTRATIONS MEASURED INSIDE ELEVATOR WORK AREAS WITHOUT DUST (EMISSIONS) CONTROL

LOCATION	SAVAGE g/m^3	NORFOLK g/m^3	RESERVE ** g/m^3	SEATTLE g/m^3
Receiving Areas				
Truck rec. shed	.43	.95	--	1.34
Rail rec. shed-hopper	--	.05	.28	.04
Rail rec. shed-boxcar	.09	--	--	.31
Conveyor Tunnels & Corridors				
Truck receiving	.06	.70	--	--
Rail receiving	.08	.05	.01*	.14
Rail receiving	--	--	.004*	.06
Rail receiving	--	--	---	.08
Beneath bins	1.38	1.45*	.02*	.003
Beneath bins	.44	.13	.04*	.003
Shipping	--	.02	.17	---
Shipping	--	--	.37	---
Headhouse Areas				
Leg boot area-rail rec.	.60	.03	.37R	
Leg boot area-shipping			1.43C	
Lower distribution area	.04	.01	.02W	.03
Lower distribution area	--	--	5.37C	
Scale floor	.006	.03	.01C	---
Cleaner floor	.07	.54	---	.002
Cleaner floor	--	--	---	.14
Upper distribution area	.003	.01	.06/.18W	.004
Upper distribution area	--	--	.14C	.01
Leg head area-rail rec.	.01	.006	.65R	.003
Leg head area-shipping			--	
Bin deck - trippers	.04	.06	.04	.03
Bin deck - trippers	--	--	.17	--
Bin deck - trippers	--	--	.11	--
Miscellaneous Areas				
Rail shipping shed	.08*			
Meal storage bldg. (during unloading)		.28*		

*No dust control installed in these areas

**See note at bottom of Table 1 (page 15) for Reserve Headhouse concentrations perience much change without dust control; exceptions were the leg boot area at Savage, where dust leaking out the shipping leg boot brought the concentration up to $0.60 g/m^3$ within 15 minutes, and the cleaner (garner) floor at Norfolk, where dust leaking from the rail receiving grain sampler caused that area's concentration to climb to $0.54 g/m^3$ with 15 minutes. The concentrations shown in Table 2 for the Reserve "headhouse" areas are much higher than those measured at similar locations at the other terminals. The two highest values - 5.4 and 1.4 g/m^3 - were measured during a period shortened to 1 minute because of the lack of visibility and the potential of exceeding the minimum explosible concentration. Other sampling in the Cleaning House was canceled, as it was recognized that operation of the dust system (suction) was essential. Several other areas, consisting mostly of the Rail Shed and Tower and certain conveyor discharge points, had concentrations that rose to between 0.10 to 0.65 g/m^3, such as would occur at only a few work area locations in other more conventional terminals. The main differences causing the higher concentrations with dust control shut off at Reserve are 1) much higher handling rates on conveyors and in legs (1500 to 3000 metric tons per hour per conveyor), 2) returning dust from dust control systems to conveyors and bucket elevators while suction is shut off, and 3) handling soybeans which seem to generate more suspended dust than other grains. It appears from these results that temporary interruptions of dust control cause serious risk of explosibility in a very limited number of elevator work areas.

<u>Settled Dust</u>. Data from the sampling of settled dust is provided in Appendix A, as explained at the beginning of this section on "Results". Although particle size and compositional information were the main objective of collecting these samples of settled dust, comparisons of sample weight and surface area can be

useful in a very general sense. Assuming concentrations greater than 30 grams per cubic meter to be explosive (see Background), samples exceeding 10 grams in weight at Savage, 13 grams at Norfolk, and 18 grams at Reserve and Seattle, indicate areas where sufficient dust is available, if suspended uniformly, to make a room with a three meter (10 ft.) high ceiling explosible. Comparing the number of such samplers may give a relative picture of the state of house-cleaning at each terminal, but such an evaluation might also be misleading, since little consideration was given to house-cleaning schedules when sampling was performed. This concept might be useful for prescribing house-cleaning schedules, however.

Respirable Dust. This data is included (in more or less complete form) in Appendix A. The concentrations which were measured are shown in Table 3, in a similar manner as those in Tables 1 and 2, except that values are in milligrams per cubic meter (mg/m^3) to simplify their presentation.

The measurements of respirable dust concentrations indicate worker's exposure to fine dust capable of penetrating lung tissue during a six to eight hour period (a normal work shift). According to our measurements, respirable dust concentrations did not exceed $5 mg/m^3$ at most locations. The exceptions were the truck receiving shed at Savage, where work exposure is likely to be very low, and several sites in Norfolk:

N72	Rail shed	13 mg/m^3
N73	Conveyor tunnel, truck receiving	20
N74	" " , below new bins	31
N75	" " , below old bins	7
N76	Headhouse, basement	6
N77	" , basement	12
N78	" , ground	17

TABLE 3. CONCENTRATIONS OF RESPIRABLE DUST IN ELEVATOR WORK AREAS MEASURED WITH BENDIX PERSONAL SAMPLERS

LOCATION	SAVAGE mg/m3	NORFOLK mg/m3	RESERVE* mg/m3	SEATTLE mg/m3
<u>Receiving Areas</u>				
Truck rec. shed	8	4	---	1
Rail rec. shed-hopper	2	13	0.2	0.4
Rail rec. shed-boxcar	2	--	---	0.4
<u>Conveyor Tunnels & Corridors</u>				
Truck receiving	3	20	---	---
Rail receiving	1	6	0.5	1
Rail receiving	-	--	1	3
Rail receiving	-	--	---	1
Beneath bins	2	31	0.2	1
Beneath bins	3	7	3	1
Shipping	--	5	1	-
Shipping	--	--	3	-
<u>Headhouse/Workhouse Areas</u>				
Leg boot area-rail rec.	1	12	1R*	
Leg boot area-shipping			0.2C	0.4
Lower distribution area	2	17	1W	
Lower distribution area	--	--	5C	
Cleaner floor	2	3	1C	0.3
Cleaner floor	--	--	---	---
Scale floor	0.1	1	3W	---
Upper distribution area	0.4	0.1	1W	0.5
Upper distribution area	--	---	1C	1
Leg head area-rail rec.	3	5	1R	1
Leg head area-shipping			2C	---
Bin deck (trippers)	2	1	1	1
Bin deck (trippers)	--	--	0.4	---
Bin deck (trippers)	--	--	0.2	---
<u>Miscellaneous Areas</u>				
Rail shipping shed	3	--	---	---
Inspection Office	--	--	---	2

* For notation of Reserve Headhouse samples see Tables 1 & 2.

The accuracy of these measurements seems somewhat questionable, particularly since some of them were made in well-ventilated areas (open doors) - N72, N74, N75, and N79. The conveyor tunnels are low exposure areas and, thus, are of less concern. (Workers are advised to wear respirators in these areas). The rail shed and headhouse areas, on the other hand, are work stations which require constant or frequent occupancy, such that wearing respirators or masks becomes a nuisance and are likely to be neglected.

A closer examination of the accuracy of personal sampler results is possible by checking concentration and size distribution of airborne dust samples (discussed later in this report) collected at the same site, although differences in sampling duration, analytical technique, and elevator environment at the time of sampling must also be considered. In Table 4, the respirable concentrations measured from airborne samples (collected during typical operations), which were analyzed for particle size, are compared with corresponding personal sampler concentrations. The high-volume sampler results were generally lower at the Norfolk terminal, yet averaged higher overall than corresponding personal sampler results.

The importance of measuring respirable dust concentrations might be questioned when total dust concentrations are much more likely to affect worker health and comfort (refer to Table 1, page 15). There appear to be certain situations, however, where total dust concentrations are low, while at the same time respirable concentrations are fairly high (e.g., the Norfolk headhouse leg head area, in which total concentration (N25) was $6 mg/m^3$ and the respirable concentration (N84) measured $5 mg/m^3$; also, the Savage headhouse leg head area, in which total concentration (P27) was $10 mg/m^3$ and respirable concentration was $3.2 mg/m^3$).

TABLE 4. COMPARISON OF RESPIRABLE DUST CONCENTRATIONS MEASURED BY PERSONAL SAMPLER* WITH THOSE DETERMINED FROM PARTICLE SIZE ANALYSIS** OF AIRBORNE DUST SAMPLES***

LOCATION	PERSONAL SAMPLER I.D.#	PERSONAL SAMPLER mg/m^3	HI-VOLUME SAMPLER I.D.#	HI-VOLUME SAMPLER mg/m^3
Norfolk - conv. tunnel	N75	7	N9	13
- basement	N76	6	N11	3
- scale floor	N80	1	N19	0
- garner floor	N81	3	N21	0
- leg heads	N83	5	N25	0
- bin deck	N84	1	N27	2
Reserve - conv. tunnel	R90	(3)	R41	(32)
- conv. tunnel	R88	3	R37	6
- W.H. 5th flr.	R77	1	R13	1
- C.H. leg head	R82	2	R25	9
- bin deck	R85	0	R31	0
Seattle - basement	S79	0	S17	0
- distr. floor	S81	1	S23	1
- bin deck	S84	1	S29	2
Average (excluding R90 & R41)		2.3		2.8

* Bendix model 44 w/model 99 sampling head and Gelman V-1 filters; 6 to 8 hours.

** Coulter model TA-II; percent at 7 μm diameter.

*** General Metal Works model GMW-2000H with Gelman A/E fiberglass filters; 15 minutes.

SAMPLING AND CONCENTRATIONS IN ENCLOSED EQUIPMENT

An experimental air sampler (shown in Figure 5) was developed at Cargill's Grain Lab in Minneapolis for the purpose of collecting and measuring the concentration of suspended dust inside enclosed conveyors, bucket elevators and other grain handling equipment. The early development of this sampler is described in the Background section of this paper. Its principle of operation consists of drawing air from the enclosed volume, removing all dust from the air with a replaceable glass-fiber filter, and measuring the discharged air with a calibrated flow meter (orifice-type). The sampling head, which attaches to the sampling port, contains a coarse screen to prevent grain from entering the sampler. The filter chamber is hinged to allow placement of a pre-weighed filter and to seal the filter with a gasket as it is tightened down. The exhaust of the explosion-proof 650 watt fan is directed through a General Metal Works 2000H air sampler fan housing, which measures airflow rates from 0.80 to 1.80m^3/min and is calibrated using a General Metal Works GMW-25 calibration kit. This sampler was used at the four Cargill terminals mentioned under work area sampling Savage, Norfolk, Reserve, and Seattle. Dust concentrations were measured at the feeding, the center, and the discharge sections of three conveyors and three bucket elevators at each terminal. In addition, compartments in bulk-weighing scales were sampled at the last two locations. This sampling scheme included an investigation of concentrations inside the equipment when dust (emissions) control systems were disconnected. After measurement of concentrations, the collected dust samples were analyzed for particle size distribution and chemical composition.

PROCEDURE

1. Sampling ports were located and cut into the casing of the conveyor,

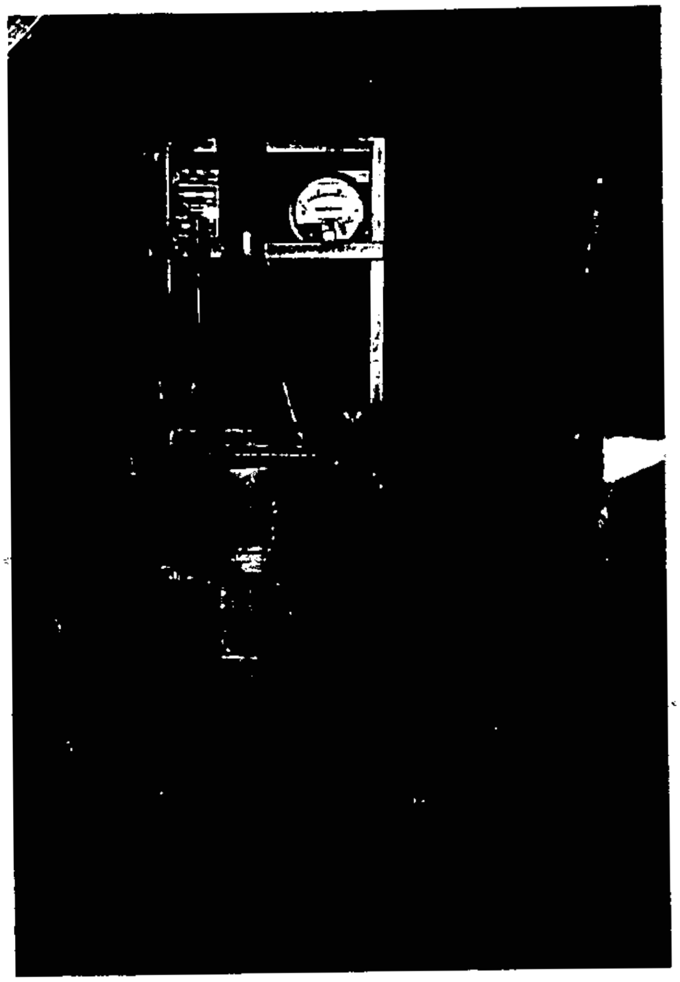


Figure 5. Experimental sampler for measuring dust inside enclosed equipment, such as bucket elevators, belt conveyors, and scales.

using a portable drill and a 63mm (2 1/4 inch) hole saw. A 100mm (4 inch) square metal plate was then mounted to cover the hole until the time of sampling. This operation required that the conveyor not be in use (locked out, electrically).

2. Gelman type A-E fiberglass filters, 200mm x 250mm, were weighed individually on a electronic balance (Sartorius model 3713) to within ± 0.01g. Each filter was placed with a manilla envelope on which was written the tare weight. (This step is indentical to Step 1 under the procedure for sampling airborne dust in work areas).

3. Grain flow conditions were monitored for the equipment to be sampled, and when conditions appeared favorable, the sampler and related equipment were positioned for collecting the first samples. The sampler was connected properly to the nearest 110 volt receptable in the terminal. The cover was removed from the sampling port and the sampling head of the experimental sampler was attached (using the port cover to clamp the sampling head in place) or held manually up to the port.

4. The time, date, location and conditions regarding the sample were recorded on the filter envelope. The pre-weighed filter was then placed in the filter chamber and the cover was tightened down.

5. With a stop-watch in hand, the operator started and timed the operation of the sampler for a period of up to 60 seconds. (Figure 6 shows sampling in progress.) The readings from the orifice pressure gauge (Dwyer Magnehelic, 0-15 inches w.g.) were noted at 20 second intervals.

Figure 6. Cargill's experimental sampler during sampling of dust inside a bucket elevator casing.

In cased where pressure dropped to 3 inches ($0.80m^3$/min before 60 seconds, the sampler was shut off immediately and the final time and pressure were noted.

6. The data from Step 5 were recorded on the filter envelope. The filter chamber was then opened and the filter was withdrawn, folded carefully, and placed inside the enevelope, along with dust stuck inside the filter chamber. The envelope was then sealed and placed inside a protective plastic bag.

7. The blast gate(s), or other means of disconnecting the dust control system to the equipment, was (were) shut off. Then a 5 minute intervals, Steps 4, 5, and 6 were repeated for three more samples. (When grain was not being handled continuously, as in a truck receiving operation, 5 minute intervals were not observed, but the time of sampling was recorded).

8. After sampling was completed at a given port, the dust control system was returned to normal, the sampling head was removed from the equipment, and the port cover was replaced and sealed with caulk. The sampler was then relocated to the next port and Steps 3 through 6 were repeated.

9. Within a day or two the samples were taken from their envelopes and weighed (with the filter) on the balance described in Step 2. The sample was then repackaged and sealed inside a plastic speciman bag. The data from the envelope was recorded on a separate sheet of paper. Refering to a calibration chart, the sample's pressure and time records were used to determine volume of sampled air. The net sample

weight was then divided by the air volume to calculate concentration in grams per cubic meter.

Some variations in the above procedure were used when grain flow was interrupted for long periods of time or when no dust system was attached to the particular handling equipment being sampled. These changes are recorded with the data for those samples which were affected.

RESULTS

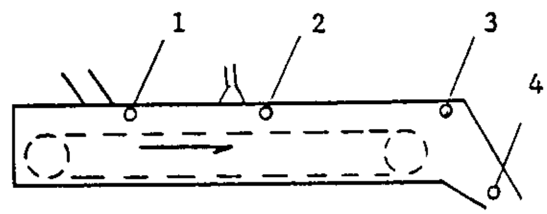
The data from the samples collected according to the above procedure are presented in Appendix A, under Equipment Samples. Sample numbers 1xx, 2xx, and 3xx are for conveyor samples, 4xx, 5xx, and 6xx are for bucket elevator samples, and 7xx are for samples from scales. The second digit corresponds to the port location and the last digit indicates the order in which the sample was taken at the particular port.

Conveyors. In Table 5 is presented a summary of the results from dust samples collected from belt and drag-type conveyors. At the top is a guide showing approximate locations of the sampling ports (flow direction is from left to right). Below each port number in the table are shown the highest concentrations measured at that port location in each of the twelve conveyors sampled. Port 4 was decided upon midway through the survey, which explains why no concentrations are listed for Savage or Norfolk. Conveyors in which grain flow was intermittent or no dust control was attached are indicated as such with footnotes. The conveyors at Reserve require some additional explanation: these are partially enclosed conveyors, exposed over considerable distance between ports 2 and 3; the bin deck conveyor has a mobile tripper which moves along rails; the shipping belt (sampled twice while handling dif-

TABLE 5. SAMPLING CONFIGURATION AND HIGHEST CONCENTRATIONS MEASURED AT EACH OF VARIOUS POINTS INSIDE ENCLOSED CONVEYORS

Sampling Location Guide

1 loading point
2 midway
3 discharge - top
4 discharge spout



Description	Grain	Sampling Location 1	2	3	4
		highest concentrations, g/m^3			
Savage, MN					
Truck rec. belt*	mixed	5	1	3	
Rail rec. belt*	corn	0.4	0.6	1.3	
Rail shipping belt**	corn	0.3	0.2	0.2	
Norfolk, VA					
Rail rec. belt	corn	2	3	3	
Shipping belt**	corn	3	0.3	4	
Bin full drag**	corn	9		1.2	
Reserve, LA					
Bin deck tripper belt**	soybeans	17	1	12	22
shipping belt	corn	11/20	4	3	80
Shipping belt	soybeans	41/9	4	10	85
Seattle, WA					
Truck rec. belt*	wheat	1	0.5		18
Rail rec. belt*	mixed	16	7		30
Shipping belt-transfer	wheat	18	1		21

* Intermittent grain flow
** No dust control feature

ferent grains) has two loading points, the first from a feeding conveyor and the second from a spout leading from the cleaners. This last conveyor contains dust control points at the first loader, at the end of the enclosure next to port 2, and at the garner into which the grain from this conveyor is discharged. Another significant feature is that dust from the Cleaning House dust system is returned at the beginning of the shipping belt.

The conveyor sample results from Savage and Norfolk, shown in Table 5, indicate concentrations well below the minimum explosible concentration. Those at Reserve and two of those at Seattle show concentrations at loading points (port 1) approaching the explosible range, while concentrations inside the discharge spout (port 4) appear to have reached or exceeded the minimum explosible concentration. There appear to be no significant variations for different grains being handled, although concentrations sometimes varied greatly from one sample to the next. The anticipated affect that concentrations would increase with time after dust control was disconnected was not observed with any regularity.

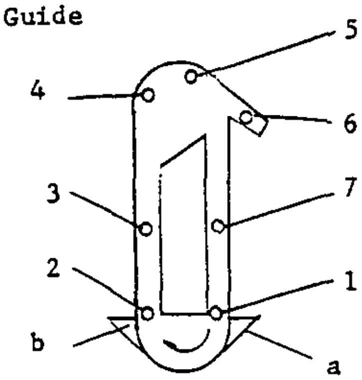
Bucket Elevators. The results from samples collected in bucket elevators are summarized in Table 6. Ports 1 and 2 are at the boot and 4, 5, 6 are at the head, with 3 and 7 midway up the casing (up and downside, respectively). The small letters a and b following each bucket elevator description indicate the feed location according to the guide. Bucket elevators varied in capacity from 400 to 1400 metric tons per hour. (See individual capacities in Appendix A). Truck receiving and two of the other bucket elevators were under intermittent load, due to small lot sizes or finishing operations (Norfolk shipping leg). All had dust control suction attached at the boot between up and downside casings except the Norfolk truck leg where it had been disconnected pre-

TABLE 6. SAMPLING CONFIGURATION AND HIGHEST CONCENTRATIONS MEASURED AT EACH OF VARIOUS POINTS IN BUCKET ELEVATORS

Sampling Location Guide

1 boot - downside
2 boot - upside
3 midway - upside
4 head - upside
5 head - top
6 discharge spout
7 midway - downside

a, b indicate feed location



Description	Grain	Sampling location 1	2	3	4	5	6	7
		highest concentrations, g/m^3						
Savage, MN								
Truck - receiving*(b)	mixed	12	27	3	15	48	370	
Rail - transfer (a)	oats	26	330	4	2	34	1200	
Shipping (a)	soybeans	37	110	2	15	12	370	
Norfolk, VA								
Truck - receiving*(b)	mixed	600	600	39	38	52	45	
Loft - rail rec. (a)	corn	230	78		120	140	150	31
Shipping* (a)	corn	112	450	7	123	32	95	
Reserve, LA								
Rail - receiving (a)	corn	127	500		79	67	110	89
Cleaner (a)	corn	78	260		32	150	220	110
Cleaner (a)	soybeans	220	87		61	91	123	93
Seattle, WA								
Truck - receiving*(b)	wheat	28	100		22	83	52	18
Rail - receiving* (b)	mixed	13	94		103	92	160	40
Shipping - transfer(b)	wheat	49	116		92	69	220	22

* Intermittent grain flow

viously. The Norfolk loft leg also had suction off the explosion vent at the head. Dust systems returned dust to the casings of the Norfolk truck leg (near port 1) and the Reserve rail leg (between ports 2 and 3), even while dust control suction was turned off.

Concentrations inside the boots and heads of bucket elevators were found to exceed 100g/m^3 and, in some cases, reached 600g/m^3 or more. These highest values were calculated from very short sampling times (the filter or the hose screen plugged, restricting airflow to less than 0.8m^3/min within a few seconds), and are, therefore, not ver accurate. They do, however, give strong indication that the minimum explosible concentration was exceeded at those points. No difference among the different types of grain was evident. As in the conveyor samples, no regular pattern was observed in which concentrations continued increasing after dust control was turned off. The high values seemingly caused by dust being returned to the casings of the Norfolk truck leg and the Reserve rail leg suggested a follow-up study, described in Appendix C, Supplement I, in which return and no-return modes were compared. Some evidence was obtained from the Norfolk truck leg that returning dust to bucket elevators increases the internal concentrations.

These extremely high concentrations measured in bucket elevators spotlights them as being a constant potential source of primary explosions, needing only an ignition source to be set off (a burning cigarette, hot material from rubbing belts, etc.). With the great number of bucket elevators in use, the need of better explosion protection for this equipment appears to be of utmost importance. A second auxiliary study, Supplement II in Appendix C, was performed to determine if additional suction at the boot of a bucket elevator would reduce concentrations. The results were not favorable, but further study of air purging in bucket elevators is currently being planned. A third supplemental study was conducted in August, 1979, in which concentrations in bucket elevators at a Canadian terminal were investigated before and after cleaning operations. The results indicated that concentrations were reduced in only one of three tests, although the absence of high concentrations in any of the tests suggest that either cleaning at previous locations or slower operation of bucket elevators at the Thunder Bay elevator was quite effective.

The findings of this survey give particular urgency to a concurrent study being conducted at Fenwal's Fire Protection Lab in Boston, Massachusetts, in which explosion suppression and venting techniques for bucket elevators are being investigated, under sponsorship of the National Grain and Feed Association.

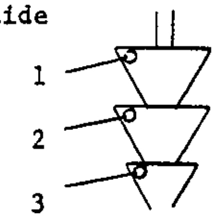
Scales. Dust samples were collected from inside compartments of Reserve shipping scale no. 4 and the Seattle hoppercar receiving scale, results of which are shown in Table 7. Although the data is much less complete than that of other equipment, concentrations in the scales appear to be maintained at or somewhat below the minimum explosible concentration. The results from the Reserve scale's upper garner paralleled those of the conveyor discharge spout leading into the garner (samples R24x and R34x, presented earlier). This data may suggest also the concentrations inside bins when being filled.

Sampling Error. Errors in the measurements from the experiment sampler have been of greater concern than those from other sampling methods for two reasons. First, the types of environments being sampled are quite turbulent and hostile (potentially damaging to the test equipment), with little information available or measurable regarding the causes of sampling and measure-

TABLE 7. SAMPLING CONFIGURATION AND CONCENTRATIONS MEASURED IN COMPARTMENTS OF BULK-WEIGHING SCALES

Sampling Location Guide

1 upper garner
2 scale compartment
3 lower garner



Description	Grain	Sampling Location 1	2	3
		highest concentration, g/m^3		
Reserve, LA				
Shipping (#4)	corn	18	-	-
Shipping (#4)	soybeans	40	-	-
Seattle, WA				
Rail-hopper	corn	9	5	2

ment errors. Second, traditional air sampling approaches require either an environment with a large volume of air and very little air movement for "source" sampling, or a fairly uniform flow of air through a duct of constant cross-section for "isokinetic" sampling (the velocity magnitude and direction of air entering the sampling probe is identical to that of the air moving through the duct). Neither of these criteria exist to any significant degree within elevator equipment. Also, isokinetic sampling is not very attractive because the presence of high concentrations and large particles makes probe plugging much too likely. The sampling process of the experimental sampler more closely resembles source sampling, of which some studies have been performed to determine sampling errors. The investigations of Davies (10), Belyaev and Levin (11) and Fuchs (17) have been reviewed quite closely, and the conclusions which can be deduced are that sampling efficiency drop rapidly for particles greater than 50 to 100 m and that transient velocities have a large effect in the loss of efficiency. Fuch's equation,

$$A = 1 - .8K + .08K \ldots$$

(where A = sampling efficiency and K = Stokes number, based on the settling velocity of the particle) predicts sampling errors of 0.5% for 50 m particles, 15% for 100 m particles, and 36% for 120 m particles. For particles 150 m and larger, the inertial effects far exceed the particles' ability to be drawn by suction. Fortunately, their settling velocities are also quite high, reducing their likelihood of being in suspension.

PARTICLE SIZE DISTRIBUTION

Analyses for particle size distribution were performed for 117 dust samples selected from work area and equipment samples discussed in earlier sections of this report and listed in Appendix A. Two techniques were used for these analyses - sieving, with US standard sieves in a Ro-Tap device (shown in Figure 7); and the Coulter Counter, Model TA II (pictured in Figure 8). This work was performed at Donaldson, Inc.'s Particle Laboratory in Minneapolis, Minnesota, under the direction of Bob Nicholson, Senior Project Engineer.

PROCEDURE

1. Samples collected on filter media were brushed (small, camel-hair paint brush) and lightly scraped from the filter, care taken not to remove the filter material.

2. Samples weighing greater than two grams were screened to determine amounts retained by US sieves #35 (500 μm), #100 (150 μm), and #170 (90 μm). Samples of less than two grams (mostly airborne, work areas samples) were screened with only the US #170 (90 μm) sieve. Weights of these fractions were measured to within 0.01 grams, with total sample weights of 0.5 grams to over 10 grams each.

3. The smallest fraction (<90 μm) of each sample was prepared to be processed by a Coulter Counter (electrolyte resistance pulse technique) instrument by diluting small (approximately 5 mg) portion of the fraction in 10 ml of dispersant (5% Triton x-100 in water), placing the dilution in a ultra-sonic cleanser for 5 - 10 seconds to deglommerate particles, then diluting the solution into 250 ml of electrolyte (2% NaCl in water).

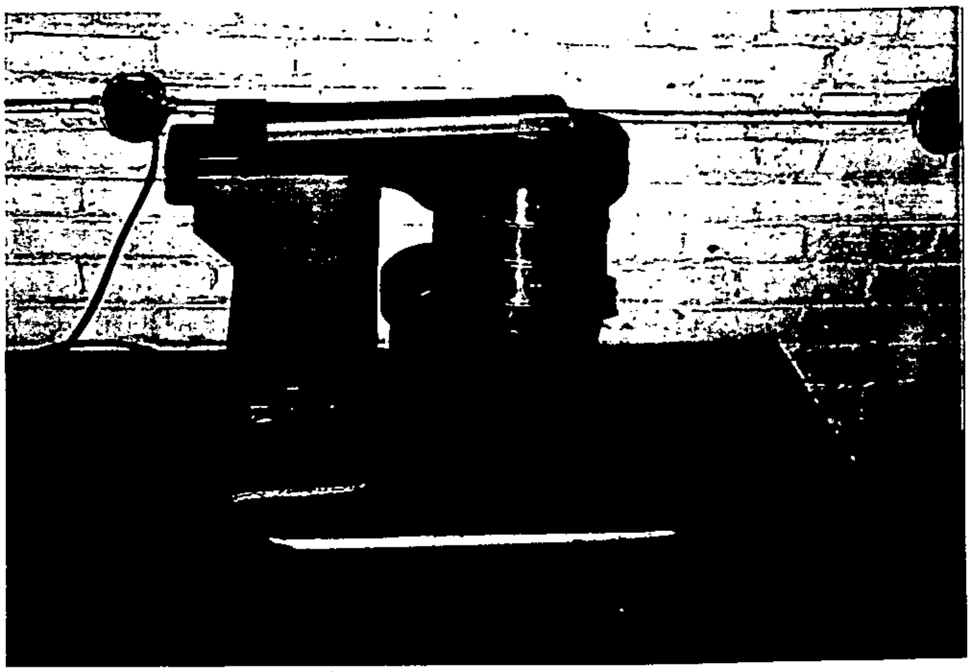


Figure 7. Ro-Tap device and 8 inch (200 mm) diameter sieves #35, #100, and #170 used for coarse particle size analysis.

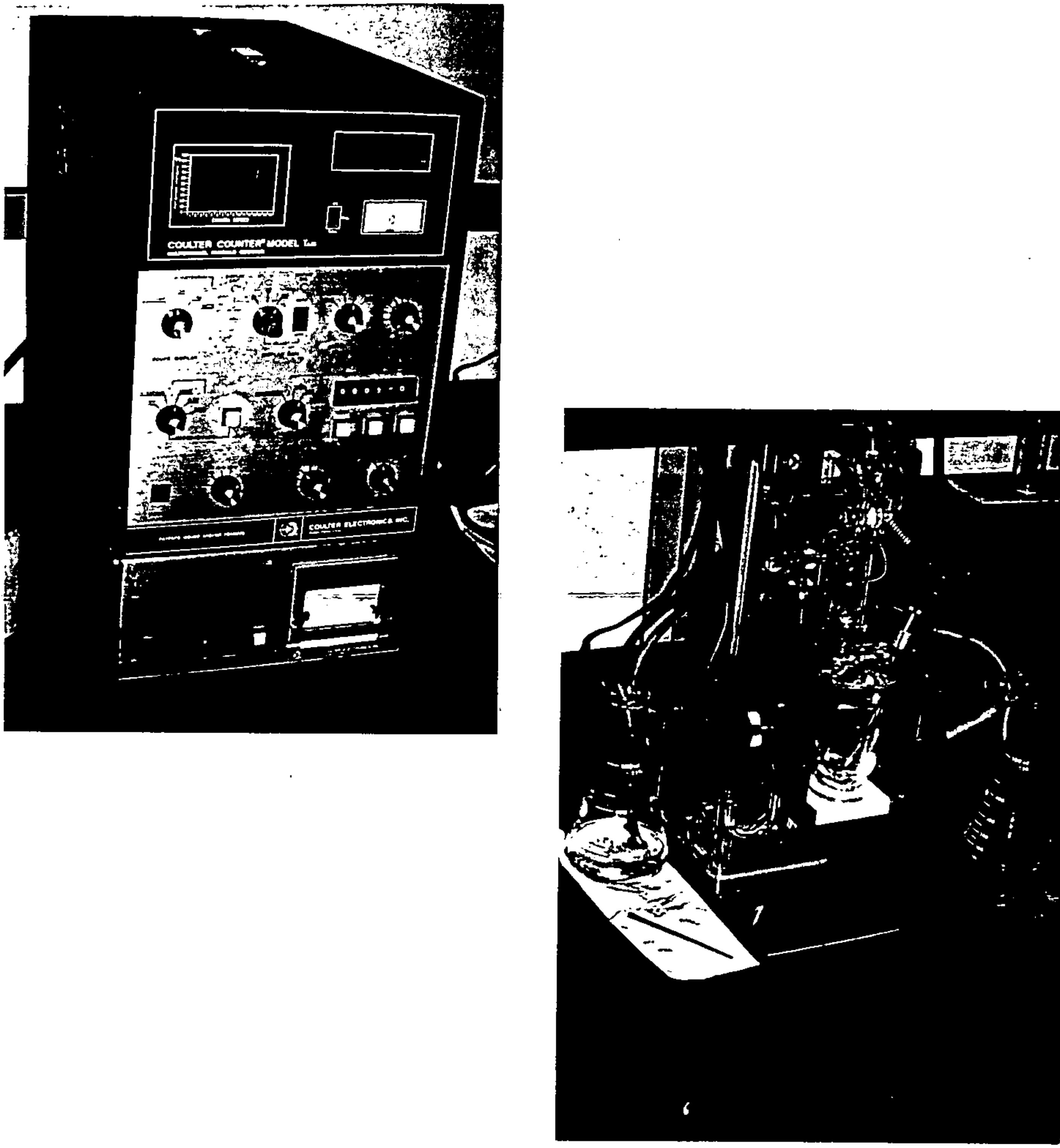


Figure 8. Coulter Counter Model TA-11 and electrolyte-orifice apparatus used in measuring particle sizes below 88 μm.

4. Three 30-second distributions were performed using a 280 μm diameter orifice at a meter reading less than "10". After sieving the electrolyte-dust solution (44 μm), three 30-second distributions were performed using a 100 μm orifice. The solution was then sieved again (20 μm) and three more 30-second distributions were performed using a 30 μm orifice.

5. Results were presented in the form of data sheets, showing the relative amount (volume) of particles in 26 size intervals - 0.3 to 88 μm (equivalent diameters by volume). Making the assumption that particles densities were uniform, a logarithmic - probability size distribution chart was then prepared incorporating the sieve and Coulter data for each sample. These charts were later adjusted so that material not passing the US #35 sieve would not be included in the analyses.

RESULTS

The charts prepared under step 5 above are presented in Appendix B, identified by and arranged in the order of the sample codes referenced in Appendix A (Sampling Data). Both the original and the adjusted distribution lines are shown in each chart, the later indicated by the dashed line.

To provide a means of comparing one particle analysis with another, certain values are read from each chart - percent volume (weight) less than 500 μm from original line; particle diameters along the adjusted line at 15.9, 50, and 84.1 percent less than stated size. The first of these is important because it indicates the amount of each sample that was explosible dust. The particle diameter at 50 percent is the mean mass (or volume) diameter, which

TABLE 8. PARTICLE SIZE DATA FROM WORK AREAS

Location	Number of samples	% under 500 μm	Mass Mean Diameter, μm	Multiplier (std. dev.)
		averages		
Airborne				
Savage*	9	99.5	15.5	2.64
Norfolk*	8	96.8	14.6	2.10
Reserve	10	99.5	13.7	2.71
Seattle	10	99.4	17.6	1.69
Total	37	98.9	15.4	2.29
Layer				
Savage*	9	95.5	26.1	2.35
Norfolk	10	89.7	17.8	2.28
Reserve	4	99.0	21.7	2.92
Seattle	10	96.2	22.1	2.13
Total	33	94.4	21.8	2.33

*Locations marked (*) each had one distribution not considered in the average because of large variation. At Reserve, ten layer samples were collected, but later were combined to form four composite samples.

is a frequently used indicator of particle size distributions. Particle diameters at 15.9 and 84.1 percent are each one standard deviation away from the mean mass diameter; the square root of their ratio is a multiplier used to find the geometric mean diameters one standard deviation above and below the mean mass diameter. Plotting these three values on the log-probability chart and connecting them gives a straight-line (uniform) distribution equivalent to that actually measured. In truth, the samples analyzed in this study are (or can be approximated more accurately as) combinations of two (bi-modal) or more uniformly distributed sets of particles, which give each line its curved features. Such an analysis is more rigorous than was determined necessary for this study, however, and is left to the reader to carry out at his volition.

A summary of the data described above is shown for airborne and layer samples from work areas in Table 8. Note particularly that 98.9 percent of airborne samples and 94.4 percent of layer samples were composed of dust as defined early in this paper. Thus, little or no correction of the concentration data presented earlier is needed from a practical perspective. Also, mean mass diameters for airborne samples are lower than those for layer samples, but not so much as to suggest that large airborne particles or small settled dust particles were significantly missed by the respective sampling techniques. The variation of multipliers among the four terminals probably reflect the different types of grains handled at each - Savage (various grains), Norfolk (mostly corn), Reserve (mostly soybeans), and Seattle (mostly wheat).

The particle size data for equipment samples are summarized in Table 9. In comparing the amount of dust (less than 500 μm) in these samples, the percentages for bucket elevator samples are noticeably lower and more varied

TABLE 9. PARTICLE SIZE DATA FROM EQUIPMENT SAMPLES

Type of Samples	Number of Samples	% under 500 μm	Mass Mean Diameter, μm	Multiplier (std. dev.)
		----------averages	----------------	----------------
Conveyors (belt and drag)				
Corn	6	97.9	15.6	1.86
Soybeans	3	98.8	16.2	3.72
Wheat	3	93.4	60.3	2.60
Total	12	97.0	26.9	2.51
Bucket Elevators				
Corn	15	92.2	16.7	2.26
Soybeans	5	79.9	45.3	3.43
Wheat	5	82.5	71.8	2.83
Oats	2	76.4	122.5	2.90
Sorghum	1(boot)	59.5	31.0	3.67
Boot	12	85.8	38.6	2.89
Middle	6	87.9	17.6	2.29
Head	10	85.1	54.3	2.67
Total	28	86.0	39.7	2.67
Scales				
Total	4	99.2	16.4	2.32
Total	44	90.2	35.4	2.59

than other types of samples. This may be a clue that two types of sampling errors were incurred. First, with more larger material being sampled, a higher percentage of the larger particles might also have been left behind due to inertial and settling effects. Davies' (10) and Belyaev and Levin's (11) arguments suggest that this effect may result in a loss in sampling efficiency of 20 percent or more. Second, particles adhering to grain kernals may have been drawn into suspension by the higher velocity of the sampled air as grain approaches the sampling port. These effects oppose each other and one might guess that the first predominates, tending to make concentrations measured by the sampler lower than actual. Thus, correcting for excess sample weight from material larger than 500 μm would be unnecessary. Another possibly meaningful picture presented by this data is that larger mean mass diameters are found in bucket elevator boots and heads. Those particles which would settle out quickly in less turbulent environments, instead, are caused to have a much more important role in any explosion that might occur at these points.

CHEMICAL COMPOSITION

Two types of chemical analyses were to be performed on groups of samples selected from work area (airborne and layer) samples and equipment samples described in earlier sections of this report. The first type was the standard wet-chemical analysis to determine moisture, starch, protein, oil, and ash content. Gas chromatography analysis will be done in coming months on composites of layer samples - three from each terminal sampled - to determine the presence of explosible fumigant residues or volatiles from decomposition. The wet-chemical analyses were performed by Ingman Labs in Minneapolis and the gas chromatography work is being arranged through Midwest Research Institute of Kansas City, MO.

PROCEDURE

1. Dust samples collected to determine concentrations in work areas and inside equipment were preserved in heat-sealed plastic envelopes and stored at room temperature for up to four months.

2. Samples were organized according to origin and type of grain being handled. Many were selected for particle analysis (mentioned under section on Particle Size Distributions). The remainder were set aside for chemical analysis.

3. Each sample was removed from the packaging and lightly brushed from the filter media. Like samples were combined to form amounts of 5g to 30g, or more.

4. Analyses were performed using AOAC* procedures according to the following priority list:

*Association of Official Analytical Chemists (16)

starch
moisture
protein
fat (oil)
ash (mineral)

5. Portion of composite layer samples not used in the wet-chemical analyses were placed in small glass speciman bottles and are being stored in refrigerator freezer to await gas chromatgraphy analyses.

6. When gas chromatography procedures have been developed for grain and dust analysis, the bottles from Step 5 will be sent to Midwest Research Institute. There, they will be tested for the presence of fumigant residues and volatiles resulting from decomposition or contamination.

RESULTS

Procedural Steps 1 through 5 have been completed and the wet-chemical analyses are presented in Table 10 for work area samples and Table 11 for equipment samples.

The airborne sampling procedure did not collect large enough samples to provide good compositional information by themselves, and thus must be examined with layer samples for meaningful results (Table 10). Among all work area samples, moisture content (7 to 8 percent) was much lower than that of the grain being handled (usually 10 to 15 percent). Starch, protein and ash contents varied greatly, depending on the type of grain being handled at each terminal. Norfolk handles mostly corn, yielding high starch and low mineral (ash) contents. Reserve handles greater quantities of soybeans yielding less starch, more protein, and much more mineral content. Seattle was handling mostly wheat yielding high starch, low protein, and

TABLE 10.
COMPOSITION OF WORK AREA DUST SAMPLES

Location	Moisture %	Starch %	Protein %	Fat %	Ash %
Savage, MN					
Airborne-headhouse	6.9	84.5	----	---	----
" -rail shed, bin flr	7.9	52.7(2)	10.1	1.3	11.3
" -truck shed	---	58.8	----	---	----
Layer-headhouse, upper	7.1	58.3	8.0	1.5	8.2
" -headhouse, lower	7.1	50.3	10.0	1.5	11.3
" -boots, rail rec.	6.8	46.7	10.2	2.0	9.7
Total	7.2	58.5	9.6	1.6	10.1
Norfolk, VA					
Airborne-headhouse	---	68.6	----	---	----
" -truck, rail rec.	9.7	63.6	6.9	0.9	11.2
Layer-headhouse, upper	7.9	60.9	11.2	---	----
" -headhouse, middle	8.1	56.1	11.6	3.1	7.8
" -headhouse, grd flr	7.4	65.2	9.4	1.4	10.7
" -headhouse, basement	8.2	63.3	9.0	1.4	10.5
" -conveyor tunnels	8.0	64.4	7.8	1.4	4.2
Total	8.2	63.2	9.3	1.6	8.9
Reserve, LA					
Airborne-houses (soybeans)	6.4	21.8(2)	16.4	1.1	38.4
" -rail rec. (corn)	---	24.4	----	---	----
Layer-weigh house	7.8	50.1	9.7	1.4	14.8
" -cleaning house	6.0	25.0	12.2	1.2	38.3
" -bins	---	32.4	----	---	----
" -rail receiving	8.1	40.8	9.0	2.3	3.3
Total	7.0	30.9	11.8	1.5	33.7
Seattle, WA					
Airborne-combined	---	50.8	----	---	----
Layer-headhouse, upper	7.6	44.8	8.0	1.3	18.7
" -headhouse, lower	7.9	54.8	8.0	1.6	----
" -rail conveyor tunnel	8.4	67.6	6.5	1.3	7.4
Total	8.0	54.5	7.5	1.4	13.0

moderate mineral consituents. Fat content remained fairly uniform at 1 to 3 percent. Fibrous content, which can be estimated by summing the average contents shown and subtracting from 100 percent; amounts to between 10 and 15 percent.

Composition of samples from equipment are summarized in Table 11. The greater size and number of like samples allowed a more thorough analysis and better preservation of sample identity. Therefore, more distinct characteristics between types of grain are visible. Fiber content, not shown, is found to be much higher in these samples - up to nearly 40 percent in wheat dust, 30 percent in oats, 20 percent in sorghum, and 15 percent in corn and soybeans. These higher values reflect more bran and chaff in the corresponding samples. Moisture contents were still found to be lower than actual grain moistures to be expected at these facilities - 6 to 10 percent vs. 12 to 15 percent for corn 9 to 13 percent for other grains.

Gas chromatography analyses are awaiting technical developments, which is soon to be completed by Midwest Research Institute under a grant from the National Grain and Feed Association. Results from these tests along with a brief description of the analytical technique will be issued as soon as possible (expected before September, 1978).

TABLE 11.
COMPOSITION OF DUST SAMPLES FROM EQUIPMENT

Location/Grain	Number of samples	Moisture	Starch	Protein	Fat	Ash
		%	%	%	%	%
Savage, MN						
corn	3	7.5	47.3	9.4	2.0	7.5
soybeans	3	7.5	29.9	18.0	2.5	22.2
wheat	1	---	50.1	----	---	----
oats	3	7.5	34.4	11.8	2.6	18.1
mixed*	3	9.4	35.8	8.5	---	----
Norfolk, VA						
corn	9	9.7	67.4	7.0	1.2	3.7
soybeans	3	8.3	52.3	10.3	1.1	22.4
Reserve, LA						
corn	8	10.2	62.1	6.6	1.2	2.9
soybeans	7	6.1	20.8	16.2	1.5	35.7
Seattle, WA						
corn	2	8.7	62.4	6.6	2.0	6.4
wheat	9	7.2	33.3	8.4	1.9	9.4
sorghum	1	8.1	47.6	6.2	5.9	10.0
Totals						
corn	22	9.5	62.3	7.2	1.4	4.2
soybean	13	6.9	30.2	15.2	1.6	29.5
wheat	10	7.2	35.0	8.4	1.9	9.4
oats	3	7.5	29.9	11.8	2.6	18.1
sorghum	1	8.1	47.6	6.2	5.9	10.0

*corn and sugar beet pellets

SUMMARY AND CONCLUSIONS

The collection and analysis of dust samples from Cargill grain terminals at Savage, MN, Norfolk, VA, Reserve, LA, and Seattle, WA, have provided the following results:

1. Work areas during typical operations contained concentrations far below the accepted minimum explosible concentration ($30g/m^3$). Most areas had $0.10g/m^3$ or less. Higher work area concentrations occurred at transfer points between conveyor belts, particularly if no dust control is used. The highest concentration measured during typical operations was $1.45g/m^3$.

2. Shutting off existing dust control systems yielded higher concentrations in receiving areas, conveyor transfer points, and near dust leaks in grain handling equipment. Savage, Norfolk, and Seattle still did not have concentrations that were explosible, but those at the Reserve Cleaning House rose to over $5g/m^3$ in less than one minute - an indication that they might have become explosible.

3. Settled dust accumulated to potentially hazardous amounts in several work areas. Respirable dust appeared to be a problem only in the Norfolk headhouse and rail receiving areas.

4. Concentrations were found to be extremely high, up to $600g/m^3$ or more, in the boot and head enclosures of bucket elevators. These were indicated as points where better explosion protection design and research are necessary.

5. Conveyor and scale garner enclosures had concentrations up to $80g/m^3$. These types of equipment need improved explosion protection, but

perhaps on a selective basis using conventional design techniques.

6. Particle size and chemical compositions were determined from numerous grain dust samples. These were presented according to the type of environment and the grain from which they originated. Differences between terminals were evident, resulting from the different grain types being handled.

The results from this study should be helpful to people in several areas of interest. First, they inform those with a general interest of the state of explosion hazards at grain elevators. Second, plant superintendents and supervisors are advised of specific hazards to be aware of in improving the safety of their facilities. Third, they point out locations in the elevator where improved designs of dust control and explosion protection may be necessary. Fourth, they provide information about the problems and characteristics of dust in grain elevator environments to assist people who are planning and conducting related research. To these ends we sincerely hope the product of our efforts and of the efforts of the many contributors is successful and well received, leading to a safer, healthier and more productive grain handling and merchandizing industry.

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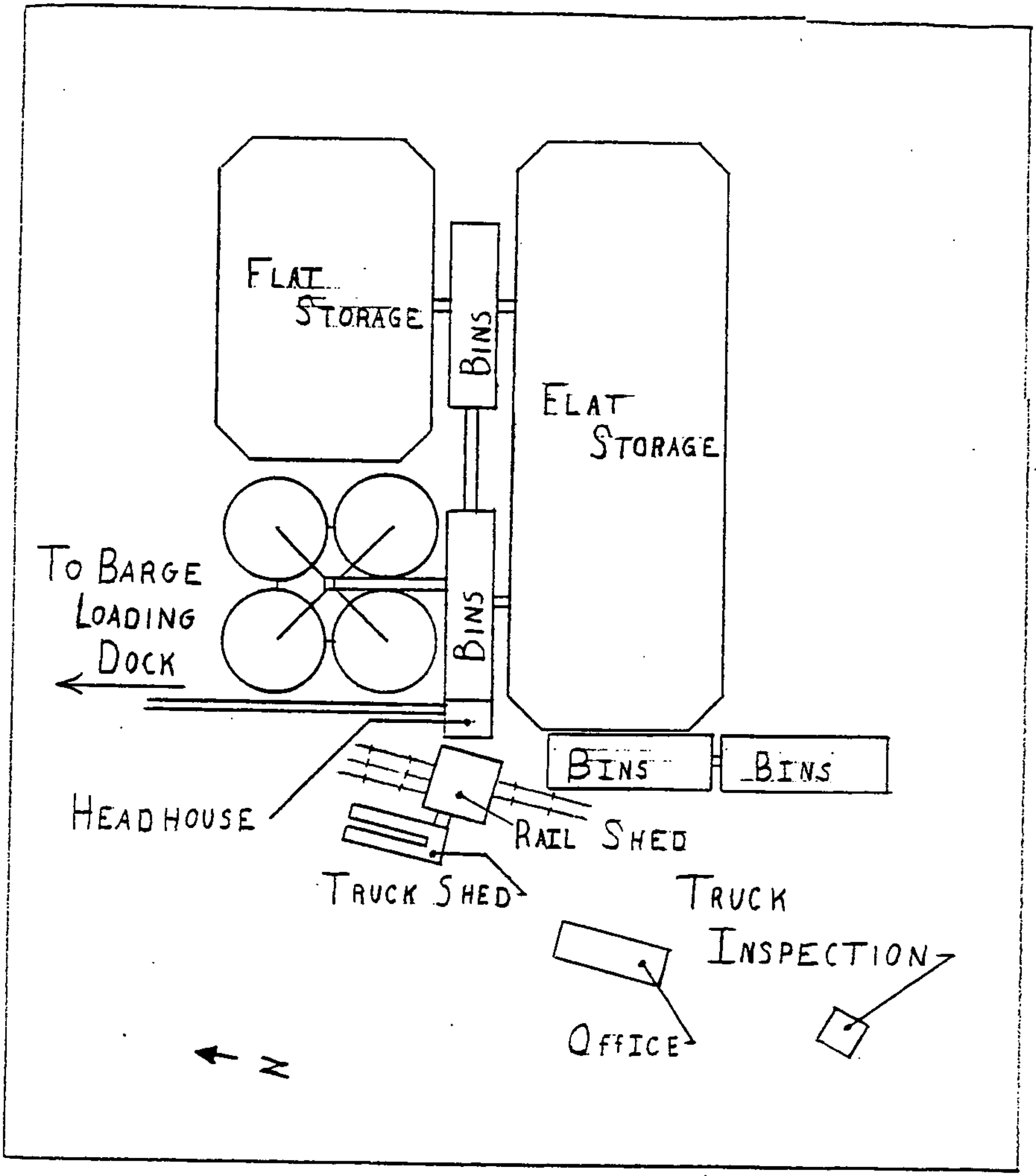
APPENDIX A. SAMPLING DATA

Procedures and discussion of results are in the main body of the report. This section contains detailed information ona sample-by-sample basis. All data is grouped according to its terminal of origin, then assigned an identification code by which it is organized. The code for each sample consists of a letter indicating the terminal, followed by a number which indicates the type of sample and the order in which it was taken.

Code Letter	Terminal
P	Savage, MN (Port Cargill)
N	Cheasapeake, VA (Norfolk)
R	Reserve, LA
S	Seattle, WA

Contents (for each terminal)

- Plot plan
- Work area samples
    - airborne (nos. 1 - 42)
    - layer/settled (nos. 51 - 60)
    - respirable (nos. 71 - 90)
- Equipment samples
    - conveyors - belt or drag (nos. 101 - 344)
    - bucket elevators (nos. 401 - 674)
    - scales (nos. 701 - 732)



DIVISION	GRAIN LAB.				
PLANT LOCATION	SAVAGE MN.				
GENERAL PLOT PLAN					
REV.	BY	DATE	SCALE		JOB NO.
			DRAWN KLS	DATE 7/2/79	SK. NO.

FORM N-469 A

SAVAGE, MN (Port Cargill)

WORKAREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Truck receiving shed-east side beside trailer, doors closed (P71)
P1 11/6/78 10:40am 15min 1.26g 20.8m^3 .061g/m^3
unloading hopper truck - wheat
P2 11/6/78 11:00am 15min 8.43g 19.4m^3 .435g/m^3
unloading hopper truck - wheat (truck dust system off)

Rail shed - next to boxcar unloader doors open (P72)
P3 11/6/78 1:10pm 10min 0.92g 13.6m^3 .068g/m^3
unloading boxcar - wheat
P4 11/6/78 2:00pm 15min 1.84g 19.8m^3 .093g/m^3
unloading boxcar - soybeans (rail dust system off)

Rail shed - next to hopper dump pit, doors open (P73)
P5 11/6/78 1:30pm 15min 0.07g 20.8m^3 .003g/m^3
unloading beet pulp pellets
P6 (could not be scheduled)

Rail shed - above and east of hopper car loading (P74)
P7 11/9/78 6:00pm 15min 2.12g 25.1m^3 .084g/m^3
loading corn
P8 (no dust system installed for this operation)

Conveyor tunnel - along truck receiving belt (P51) (P75)
P9 11/8/78 5:30pm 15min 1.17g 24.2m^3 .048g/m^3
unloading corn, wheat, and beet pulp pellets
P10 11/8/78 6:00pm 15min 1.43g 24.2m^3 .059g/m^3
(truck system blast gate off)

Conveyor tunnel - between rail and truck rec. belts (P52) (P76)
P11 11/8/78 11:00am 15min 1.82g 23.2m^3 .076g/m^3
truck & rail unloading - wheat, corn, beet pellets
P12 11/8/78 11:30am 15min 1.80g 23.6m^3 .076g/m^3
(dust systems 2 & 3 off)

Conveyor tunnel - beneath east tanks at transfer (P53) (P77)
P13 11/9/78 5:00pm 15min 9.29g 23.8m^3 .390g/m^3
corn to barge
P14 11/9/78 5:30pm 8min 20sec. 18.60g 13.5m^3 1.378g/m^3
corn to barge (dust system 2, 3, & 4 off)

Conveyor tunnel - beneath south tanks (400's) at transfer(P54) (P78)
P15 11/16/78 1:30pm 15min 2.75g 27.0m^3 .102g/m^3
wheat to barge
P16 11/16/78 1:45pm. 15min 9.41g 22.3m^3 .445g/m^3
wheat to barge

Headhouse - boot area - shipping, truck, and rail legs (P55) (P79)
P17 11/8/78 11:00am 15min 1.76g 24.2m^3 .073g/m^3
truck & rail unloading (see P11 & P12) beet pellets to barge
P18 11/8/78 11:30am 15min 13.69g 230m^3 .595g/m^3
(dust systems 2&3 off) - leak around ship leg bearings

Headhouse - basement north side of belt from east tanks (P56) (P80)
P19 11/9/78 5:00pm 15min 0.55g 26.8m^3 .021g/m^3
corn to ship
P20 11/9/78 5:30pm 5min 0.40g 8.9m^3 .045g/m^3
corn to ship (dust systems 2, 3, & 4 off)

SAVAGE, MN (Port Cargill)

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Headhouse - "cleaner" floor, center (P57) (P81)						
P21	11/10/78	9:20am	15min	0.67g	25.0m^3	.027g/m^3
	soybeans to barge					
P22	11/10/78	9:50am	15min	0.15g	24.6m^3	.006g/m^3
	(dust system #7 off)					
Headhouse, bin floor near shipping leg (P58) (P82)						
P23	11/27/78	1:00pm	15min	0.12g	27.3m^3	.004g/m^3
	corn from rail receiving					
P24	11/27/78	1:30pm	15min	0.09g	28.0m^3	.003g/m3
	(dust system #6 off)					
Headhouse, "vibrator" floor beneath cleaners (P59) (P83)						
P25	11/10/78	10:45am	15min	0.49g	28.7m^3	.017g/m^3
	shipping-soybeans; receiving - corn, wheat, pellets					
P26	11/10/78	11:10am	15min	2.08g	28.2m^3	.074g/m^3
	(dust systems 2 & 5 off) - leak from rail sampler at leg					
Headhouse, leg head area between truck and shipping legs (P60) (P84)						
P27	11/10/78	10:45am	15min	0.25g	24.0m^3	.010g/m^3
	(same time as P25 & P26)					
P28	11/10/78	11:10am	15min	0.22g	23.8m^3	.009g/m^3
	(dust systems 2 & 5 off) - see samples P25 & P26					
Bin deck, over east tanks next to rail conveyor tripper (P85)						
P29	11/27/78	1:00pm	15min	1.18g	26.3m^3	.045g/m^3
	(same time as P23 & P24)					
P30	(no dust system installed for this operation)					

WORK AREA SAMPLES - LAYER (SETTLED)

P51	Conveyor tunnel - truck receiving (P9 & P10)
	4.03g 0.15m^2 truck conveyor cover
P52	Conveyor tunnel - truck & rail rec. (P11 & P12)
	5.94g 0.15m^2 rail conveyor cover
P53	Conveyor tunnel - east bins (P13 & P14)
	14.89g 0.15m^2 floor next to basement conveyor
P54	Conveyor tunnel - south bins (P15 & P16)
	7.73g 0.15m^2 floor next to transfer to house conveyor
P55	Headhouse - boot area (P17 & P18)
	38.39g 0.15m^2 floor next to truck leg
P56	Headhouse - basement (P19 & P20)
	46.29g 0.15m^2 floor south of conveyor from east bins
P57	Headhouse - cleaner floor (P21 & P22)
	32.71g 0.15m^2 floor in center, west side
P58	Headhouse - bin floor (P23 & P24)
	3.81g 0.15m^2 floor next to conveyor to east bins
P59	Headhouse - vibrator floor (P25 & P26)
	14.45g 0.15m^2 floor beneath cleaners, northeast corner
P60	Headhouse - leg head area (P27 & P28)
	5.74g 0.15m^2 floor between truck & shipping legs

SAVAGE, MN (Port Cargill)

WORK AREA SAMPLES - PERSONAL SAMPLER (RESPIRABLE)

P71 Truck receiving shed - east side on ledge (P1)
11/21/78 unloading 20 trucks/hr - various grains .0085g/m^3
P72 Rail receiving shed (boxcar unloading) (P3)
11/27/78 unloading beet pellets, wheat .0016g/m^3
P73 Rail receiving shed (hopper unloading) (P5)
11/27/78 unloading wheat, soybeans, pellets .0018g/m^3
P74 Rail shed - shipping (loading hoppers & boxcars) (P7)
11/27/78 shipping corn .0032g/m^3
P75 Conveyor tunnel - truck rec. (P9)
11/21/78 unloading various grains .0030g/m^3
P76 Conveyor tunnel - rail/truck rec. (P11)
11/27/78 unloading various grains .0012g/m^3
P77 Conveyor tunnel - east tanks (P13)
11/21/78 shipping corn .0021g/m^3
P78 Conveyor tunnel - south tanks (P15)
11/21/78 transferring wheat .0029g/m^3
P79 Headhouse - boot area (P17)
11/27/78 unloading trucks & rail .0007g/m^3
P80 Headhouse - basement (P19)
11/21/78 shipping corn, unloading various grains .0021g/m^3
P81 Headhouse - cleaner floor (P21)
11/22/78 shipping corn, receiving trucks .0001g/m^3
P82 Headhouse - bin floor (P23)
11/22/78 shipping corn, receiving trucks .0004g/m^3
P83 Headhouse - vibrator floor (P25)
11/22/78 shipping corn, receiving trucks .0024g/m^3
P84 Headhouse - legheads (P27)
11/22/78 shipping corn, receiving trucks .0032g/m3
P85 Bin deck - east tanks (P29)
11/22/78 shipping corn, receiving trucks .0022g/m^3

SAVAGE, MN (Port Cargill)

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Belt conveyor, truck receiving - 15,000 bu/hr.
*dust systems - truck system at pts 1 & 2, system 3 at pt 3

Point 1 (loader) 11/14/78 2:30 - 2:45pm						
P111	on*	corn	60sec.	1.93g	1.37m^3	1.4g/m^3
P112	off-5min	corn	60	6.50	6.50	5.2
P113	-10min	corn	60	2.84	1.55	4.4
P114	-15min	corn	60	5.80	1.30	4.4
Point 2 (middle) 11/14/78 2:50 - 3:05pm						
P121	on*	wheat	60sec.	2.20g	1.63m^3	1.4g/m^3
P122	off-5min	wheat	60	1.00	1.63	0.6
P123	-10min	corn	60	1.13	1.67	0.7
P124	-15min	corn	60	0.64	1.70	0.4
Point 3 (discharge) 11/14/78 3:20 - 3:35pm						
P131	on*	wheat	60sec.	3.56g	1.32m^3	2.7g/m^3
P132	off-5min	s.b.pellets	60	2.56	1.60	1.6
P133	-10min	corn	60	3.00	1.68	1.8
P134	-15min	empty	60	0.69	1.68	0.4

Belt conveyor, rail receiving - 10,000 bu/hr.
*dust system #3 with pickups at pt 3

Point 1 (loader) 11/27/78 8:58 - 9:13am						
P211	on*	corn	60sec.	0.56g	1.42m^3	0.4g/m^3
P212	off-5min	corn	60	0.27	1.42	0.2
P213	-10min	corn	60	0.56	1.42	0.4
P214	-15min	corn	60	0.47	1.42	0.3
Point 2 (middle) 11/27/78 9:20 - 10:02am						
P221	on*	corn	60sec.	0.79g	1.42m^3	0.6g/m^3
P222	off-5min	corn	60	0.34	1.42	0.2
P223	-10min	corn	60	0.47	1.44	0.3
P224	-15min	corn	60	0.56	1.42	0.4
Point 3 (discharge) 11/27/78 10:14 - 10:29, 11:20am						
P231	on*	corn	60sec.	1.83g	1.40m^3	1.3g/m^3
P232	off-5min	corn	60	0.90	1.44	0.6
P233	-10min	corn	60	0.87	1.44	0.6
P234	-15min	corn	60	0.76	1.44	0.4

Belt conveyor, rail shipping 18,000 bu/hr.
*no dust system connected

Point 1 (loader) 11/15/78 3:00pm						
P311	*	corn	60sec.	0.46g	1.70m^3	0.3g/m^3
P312	*	corn	60	0.48	1.70	0.3
Point 2 (loader) 11/15/78 3:30pm						
P321	*	corn	60sec.	0.31g	1.70m^3	0.2g/m^3
P322	*	corn	60	0.31	1.70	0.2
Point 3 (discharge) 11/15/78 4:00pm						
P331	*	corn	60sec.	0.24g	1.70m^3	0.1g/m^3
P332	*	corn	60	0.36	1.70	0.2

SAVAGE, MN (Port Cargill)

EQUIPMENT SAMPLES - Cargill Experimental Sampler

Bucket elevator - truck receiving 15,000 bu/hr.
Intermittent load- corn, wheat, beet pellets, filter plugging
*dust system 2 - fan discharging to main system

Point 1 (boot - downside) 11/15/78 10:00 - 10:17 am						
P411	on*	wheat	16sec.	3.82g	$0.32m^3$	12 g/m^3
P412	off-5min	corn	18	2.23	0.38	6
P413	-10min	corn	60	2.43	1.23	2
P414	-15min	wheat	43	1.94	1.17	2
Point 2 (boot-upside) 11/15/78 10:30 - 10:45am						
P421	on*	wheat	4sec.	1.95g	$0.08m^3$	24 g/m^3
P422	off-5min	wheat	4	2.23	0.08	27
P423	-10min	wheat	4	1.85	0.08	23
P424	-15min	corn	9	3.28	0.18	18
Point 3 (middle-upside) 11/15/78 11:10 - 11:25am						
P431	on*	?	60sec.	0.44g	$1.83m^3$	0.3 g/m^3
P432	off-5min	?	60	0.58	1.81	0.3
P433	-10min	?	60	1.05	1.81	0.6
P434	-15min	?	60	4.33	1.69	2.6
Point 4 (head-upside) 11/15/78 1:25 - 1:40pm						
P441	on*	corn	16sec.	3.49g	$0.34m^3$	10 g/m^3
P442	off-5min	corn	8	1.74	0.16	11
P443	-10min	corn	16	5.11	0.35	15
P444	-15min	empty	4	0.45	0.08	6
Point 5 (head-top) 11/15/78 2:20 - 2:35pm						
P451	on*	?	10sec.	9.83g	$0.20m^3$	48 g/m^3
P452	off-5min	?	60	3.25	1.68	2
P453	-10min	?	25	15.84	0.54	29
P454	-15min	?	21	5.18	0.46	11
Point 6 (head-discharge) 11/15/78 1:54 - 2:11pm						
P461	on*	corn	30sec.	4.25g	$0.68m^3$	6 g/m^3
P462	off-5min	corn	14	11.42	0.30	38
P463	-10min	?	4	29.87	0.08	370
P464	-15min	corn	5	29.69	0.10	290

Bucket elevator - rail receiving leg 15,000 bu/hr.
transfer-constant load, plugging of nozzle caused short times
*dust system #2 - fan discharging to main system

Point 1 (boot-downside) 11/28/78 7:08 - 7:23pm						
P511	on*	oats	7sec.	1.38g	$0.13m^3$	10 g/m^3
P512	off-5min	oats	4	2.02	0.08	26
P513	-10min	oats	5	2.46	0.09	26
P514	-15min	oats	5	2.34	0.09	24
Point 2 (boot-upside) 11/28/78 7:33 - 7:51pm						
P521	on*	oats	2sec.	3.76g	$0.03m^3$	130 g/m^3
P522	off-5min	oats	6	3.53	0.04	80
P523	-10min	oats	4	4.03	0.04	100
P524	-15min	oats	3	4.72	0.01	330
Point 3 (middle-upside) 11/28/78 8:24 - 8:47pm						
P531	on*	oats	60sec.	3.15g	$1.45m^3$	2 g/m^3
P532	off-5min	oats	60	3.07	1.28	2
P533	-10min	oats	60	4.56	1.28	4
P534	-15min	oats	60	3.15	1.28	2

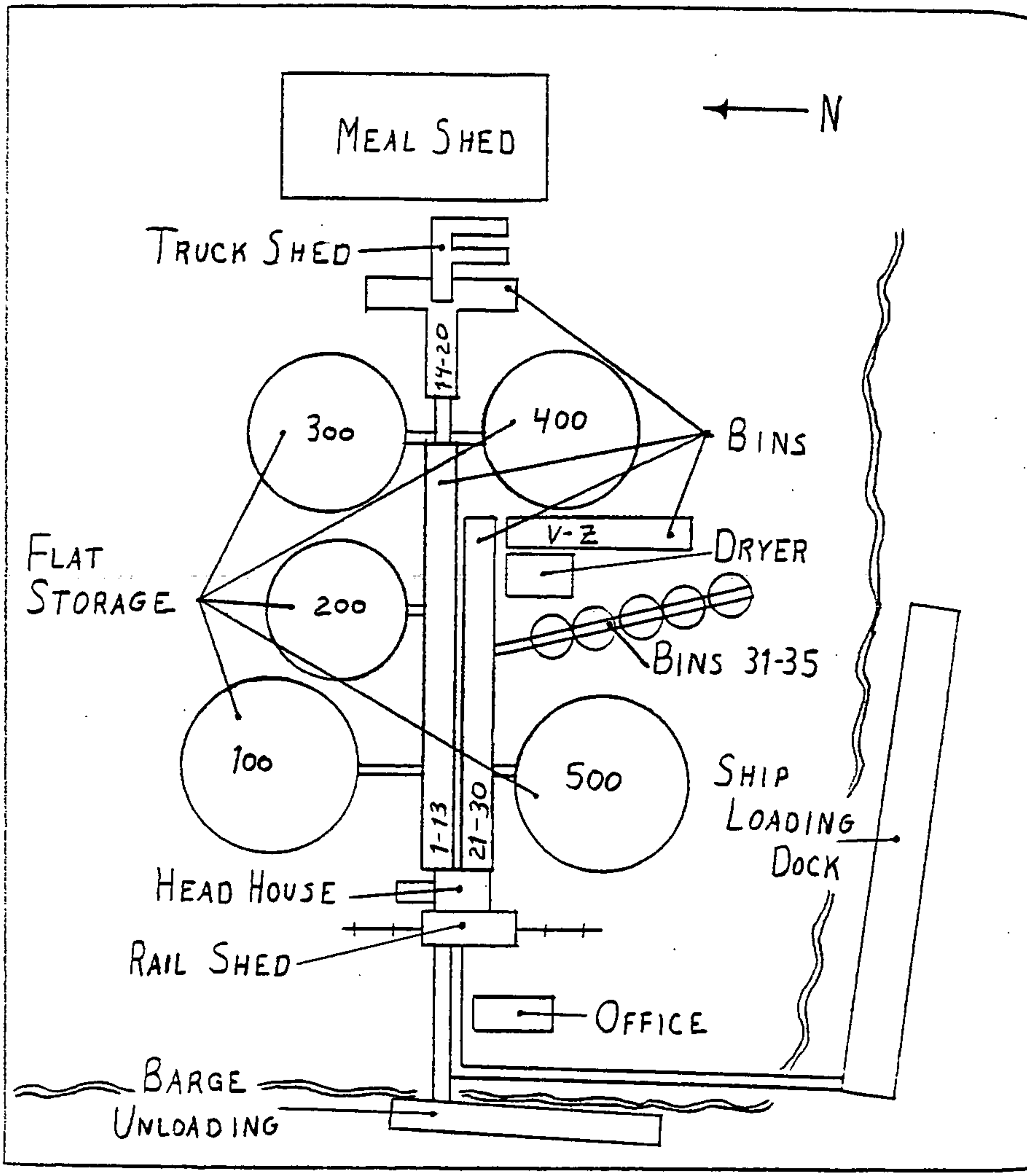
SAVAGE, MN (Port Cargill)

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - rail receiving leg (continued)						
Point 4 (head-upside) 11/28/78 9:40 - 10:00pm						
P541	on*	oats	30sec	1.07g	0.60m^3	2 g/m^3
P542	off-5min	oats	11	0.37	0.23	2
P543	-10min	oats	10	0.50	0.21	2
P544	-15min	oats	15	0.51	0.32	2
Point 5 (head-top) 11/28/78 10:20 - 10:50pm						
P551	on*	oats	7sec	3.60g	0.12m^3	30 g/m^3
P552	off-5min	oats	5	3.39	0.11	32
P553	-10min	oats	2½	1.68	0.05	32
P554	-15min	oats	4	2.90	0.08	34
Point 6 (head-discharge) 11/28/78 11:05 - 11:25pm						
P561	on*	oats	1½sec	13.04g	0.02m^3	600 g/m^3
P562	off-5min	oats	1½	22.88	0.02	1200
P563	-10min	oats	1	11.15	0.01	1200
P564	-15min	oats	1½	16.11	0.02	700

Bucket elevator - shipping leg 18,000 bu/hr.
loading barges for shipment
*dust system #2 - fan discharging to main system

Point 1 (boot-downside) 11/14/78 9:00 - 9:30am						
P611	on*	soybeans	9sec	1.88g	0.17m^3	11 g/m^3
P612	off-5min	soybeans	5	1.52	0.09	16
P613	-10min	soybeans	5	2.66	0.09	28
P614	-15min	soybeans	5	3.48	0.09	37
Point 2 (boot-upside) 11/14/78						
P621	on*	soybeans	3sec	3.32g	0.06m^3	60 g/m^3
P622	off-5min	soybeans	3	4.50	0.06	80
P623	-10min	soybeans	2½	5.06	0.05	110
P624	-15min	soybeans	2½	4.14	0.05	90
Point 3 (middle-upside) 11/14/78 12:00 - 12:15 pm						
P631	on*	soybeans	60sec	3.13g	1.50m^3	2.1 g/m^3
P632	off-5min	soybeans	60	2.15	1.41	1.5
P633	-10min	soybeans	60	1.90	1.44	1.3
P634	-15min	soybeans	60	2.00	1.39	1.4
Point 4 (head-upside) 11/17/78 2:40 - 2:56pm						
P641	on*	soybeans	13sec	3.25g	0.26m^3	12 g/m^3
P642	off-5min	soybeans	11	3.27	0.22	15
P643	-10min	soybeans	13	3.69	0.26	14
P644	-15min	soybeans	14	4.13	0.28	14
Point 5 (head-top) 11/17/78 3:15 - 3:32pm						
P651	on*	soybeans	26sec	6.48g	0.55m^3	12 g/m^3
P652	off-5min	soybeans	18	3.58	0.39	9
P653	-10min	soybeans	19	3.51	0.39	9
P654	-15min	soybeans	19	4.08	0.40	10
Point 6 (head-discharge) 11/17/78 3:40 - 4:00pm						
P661	on*	soybeans	5sec	8.67g	0.10m^3	80 g/m^3
P662	off-5min	soybeans	3	16.11	0.07	240
P663	-10min	soybeans	2½	15.03	0.05	300
P664	-15min	soybeans	2	14.98	0.04	370



DIVISION	GRAIN LAB.				
PLANT LOCATION	NORFOLK VA.				
GENERAL PLOT PLAN					
REV.	BY	DATE	SCALE	JOB NO.	
			DRAWN KLS	DATE 7/3/79	SK. NO.

FORM N-469 A

NORFOLK, VA

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Truck receiving shed - east stall, doors jammed open (N71)
N1 12/7/78 9:24am 15min 1.95g 27.2m^3 .072g/m^3
3 trucks - soybeans & corn
N2 12/7/78 9:28am 8min 13.26g 13.9m^3 .954g/m^3
2 trucks - soybeans & corn (truck dust system off)

Rail receiving shed - east side of track near dump operator (N72)
N3 12/4/78 9:56am 15min 0.89g 26.6m^3 .033g/m^3
unloading hopper cars - soybeans
N4 12/4/78 10:35am 11min 0.91g 19.6m^3 .046g/m^3
hoppercars - soybeans (dust system #1 off)

Conveyor tunnel - truck receiving (N73)
N5 12/7/78 9:10am 15min 4.44g 25.2m^3 .176g/m^3
(same time as N1)
N6 12/7/78 9:40am 15min 12.05g 17.2m^3 .701g/m^3
(same time as N2) (truck dust system off)

Conveyor tunnel - "new" east bins (conv.11) at bin 10 (N51) (N74)
N7 12/15/78 1:40am 15min 3.50g 26.4m^3 .133g/m^3
loading ship - corn;leak from open inspection doors
N8 (no dust system connected)

Conveyor tunnel - "old" east bins (conv.21) at transfer (N52) (N75)
N9 12/14/78 11:25pm 15min 30.88g 21.3m^3 1.450g/m^3
loading ship - corn; leak from open inspection door
N10 (no dust system connected)

Headhouse - basement next to rail rec. conv. (N53) (N76)
N11 12/15/78 9:35am 15min 0.97g 27.2m^3 .036g/m^3
unloading rail - corn, loading ship - corn
N12 12/15/78 10:18am 15min 1.37g 27.1m^3 .051g/m^3
(dust system #1 & 2 off)

Headhouse - basement next to shipping leg boot (N77)
N13 12/15/78 2:02pm 15min 0.26g 28.5m^3 .009g/m^3
loading ship - corn, unloading rail - corn
N14 12/15/78 11:43am 7min 30sec. 0.47g 15.0m^3 .031g/m^3
(dust systems #1 & 2 off), operations interrupted midway

Headhouse - basement next to shipping conv. (N54) (N78)
N15 12/15/78 9:34am 15min 0.43g 28.5m^3 .015g/m^3
unloading rail - corn, loading ship - corn
N16 12/15/78 10:18am 15min 0.65g 28.5m^3 .023g/m^3
(dust systems #1 & 2 off)

Headhouse - ground floor near loft leg, doors open (N55) (N79)
N17 12/15/78 11:15am 15min 1.25g 27.9m^3 .045g/m^3
unloading rail - corn, loading ship - corn
N18 12/15/78 11:45am 15min 0.33g 28.0m^3 .012g/m^3
(dust systems #1 & 2 off)

Headhouse - scale floor between rail and shipscales (N56) (N80)
N19 12/15/78 2:40pm 15min 0.21g 28.0m^3 .008g/m^3
unloading rail - corn, loading ship - corn
N20 12/15/78 3:10pm 15min 0.78g 28.0m^3 .028g/m^3
(dust systems #1 & 2)

NORFOLK, VA

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Headhouse - garner floor above rail rec. scale (N57) (N81)
N21 12/15/78 2:37pm 15min 0.16g 28.0m^3 .006g/m^3
unloading rail - corn, loading ship - corn
N22 12/15/78 3:10pm 15min 14.40g 26.6m^3 .541g/m^3
(dust systems #1 & 2 off) leak from rail spout sampler

Headhouse - bin floor, southeast corner (N58) (N82)
N23 12/15/78 3:40pm 15min 0.42g 26.8m^3 .016g/m^3
unloading rail - corn, loading ship - corn
N24 12/15/78 4:10pm 15min 0.34g 26.8m^3 .013g/m^3
(dust systems #1 & 2 off)

Headhouse - leg heads, west side between legs (N59) (N83)
N25 12/15/78 3:45pm 15min 0.16g 27.2m^3 .006g/m^3
unloading rail - corn, loading ship - corn
N26 12/15/78 4:15pm 15min 0.15g 27.2m^3 .006g/m^3
(dust systems #1 & 2)

Bin deck - "new" bins near tripper, rail receiving (N60) (N84)
N27 12/16/78 11:43am 15min 0.42g 27.6m^3 .015g/m^3
unloading unit-train - corn
N28 12/16/78 12:20pm 15min 1.74g 27.3m^3 .064g/m^3
(dust system #1 off)

Meal Storage Building - Bendix personal sampler mounted to cab of front-end loader (Michigan 175B) used to knock 40 ft. (12m) high pile of soybean meal and carry meal to conveyor draw-offs during ship loading operation. No dust control equipment in shed. "Total" dust measured (cyclone and filter combined). Instantantaneous levels fluctuated greatly (visibly) from the average
N29 4/13/79 3:00am 120min 0.056g 0.20m^3 .275g/m^3

WORK AREA SAMPLES - LAYER (SETTLED)

N51 Conveyor tunnel - "new" bins (conv.10) (N7)
20.29g 0.12m^2 top of conveyor cover
N52 Conveyor tunnel - "old" bins (conv.20) (N9)
155.23g 0.12m^2 floor, north side
N53 Headhouse - basement (N11 & N12)
20.35g 0.12m^2 floor next to lofting leg & rail conv.
N54 Headhouse - basement (N15 & N16)
8.68g 0.12m^2 floor, next to shipping conv. tail pulley
N55 Headhouse - ground floor (N17 & N18)
53.58g 0.12m^2 floor, next to lofting leg
N56 Headhouse - scale floor (N19 & N20)
17.00g 0.12m^2 floor, southeast corner
N57 Headhouse - garner floor (N21 & N22)
9.73g 0.12m^2 floor next to rail spout sampler
N58 Headhouse - bin floor (N23 & N24)
6.12g 0.12m^2 floor, southeast corner
N59 Headhouse - leg head area (N25 & N26)
6.21g 0.12m^2 floor west side between loft & ship legs
N60 Bin deck - over "new" bins (conv.#10) (N27 & N28)
5.89g 0.12m^2 top of metal box

NORFOLK, VA

WORK AREA SAMPLES - PERSONAL SAMPLER (RESPIRABLE)

N71	Truck receiving shed - west side next to office (N1)	
12/19/78	trucks - soybeans & corn	$.004 g/m^3$
N72	Rail rec. shed - east side ner operator (N3)	
12/19/78	rail unloading - soybeans	$.013 g/m^3$
N73	Conveyor tunnel - truck rec. (N5)	
12/19/78	trucks - soybeans & corn	$.020 g/m^3$
N74	Conveyor tunnel - "new" bins-bin #10 (N7)	
12/18/78	transfer - wheat	$.031 g/m^3$
N75	Conveyor tunnel - "old" bins- transfer from#31 (N9)	
12/17/78	ship loading - corn	$.007 g/m^3$
N76	Headhouse - basement, rail rec. conv. (N11)	
12/18/78	rail unloading - soybeans; transfer-wheat	$.006 g/m^3$
N77	Headhouse - basement, behind shipping leg (N13)	
12/19/78	rail unloading - shiploading-soybeans	$.012 g/m^3$
N78	Headhouse - basement, near shipping conv. (N15)	
12/17/78	ship loading, rail unloading - corn	$.005 g/m^3$
N79	Headhouse - ground floor, southeast corner (N17)	
12/18/78	rail unloading - soybeans, transfer-wheat	$.017 g/m^3$
N80	Headhouse - scale floor (N19)	
12/17/78	shiploading, rail unloading - corn	$.001 g/m^3$
N81	Headhouse - garner floor, near rail rec.sampler (N21)	
12/17/78	shiploading, rail unloading - corn	$.003 g/m^3$
N82	Headhouse - bin floor, near shipping leg (N23)	
12/18/78	rail unloading - soybeans; transfer-wheat	$.0001 g/m^3$
N83	Headhouse - leghead area (N25)	
12/17/78	ship loading, rail unloading - corn	$.005 g/m^3$
N84	Bin deck - "new" bins at conveyor tripper (N27)	
12/18/78	rail unloading - soybeans	$.001 g/m^3$
N85	Meal shed not measured (see N29)	

NORFOLK, VA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Belt conveyor - rail receiving (conv.10A) 15,000 bu/hr.
* blast gate at discharge only

Point 1 (loader) 12/13/78 4:00 - 4:16pm						
N111	on*	corn	60sec.	2.87g	$1.50m^3$	$1.9g/m^3$
N112	off-5min	corn	60	3.01	1.47	2.0
N113	-10min	corn	60	3.10	1.50	2.1
N114	-15min	corn	60	0.48	1.56	0.3
Point 2 (middle) 12/13/78 4:25 - 4:41pm						
N121	on*	corn	60sec.	2.43g	$1.50m^3$	$1.6g/m^3$
N122	off-5min	corn	60	2.85	1.50	1.9
N123	-10min	corn	60	2.85	1.61	1.8
N124	-15min	corn	60	4.29	1.59	2.7
Point 3 (discharge) 12/13/78 4:48 - 5:06pm						
N131	on*	corn	60sec.	4.04g	$1.27m^3$	$3.2g/m^3$
N132	off-5min	corn	60	1.53	1.49	1.0
N133	-10min	corn	60	0.90	1.40	0.6
N134	-15min	corn	60	0.92	1.40	0.7

Drag conveyor (Buhler) - over bins #31-5 10,000 bu/hr?
* no dust system

Point 1 (loader from feeding Buhler) 12/10/78 3:00 - 3:35pm						
N211	*	corn	60sec.	10.29g	$1.42m^3$	$7g/m^3$
N212	*	corn	60	11.99	1.45	8
N213	*	corn	60	12.52	1.42	9
Point 3 (discharge into bin 32) 12/10/78 2:35 - 2:45						
N231	*	corn	60sec.	2.15g	$1.40m^3$	$1.5g/m^3$
N232	*	corn	60	0.57	1.57	0.4
N233	*	corn	60	0.29	1.58	0.2

Belt conveyor - shipping (conv.51) 40,000 bu/hr
* no dust system

Point 1 (loader from sampler) 12/14/78 9:45 - 10:00pm						
N311	*	corn	60sec.	4.89g	$1.56m^3$	$3.1g/m^3$
N312	*	corn	60	1.17	1.69	0.7
N313	*	corn	60	0.62	1.71	0.4
Point 2 (middle) 12/14/78 9:15 - 9:30pm						
N321	*	corn	60sec.	0.52g	$1.74m^3$	$0.3g/m^3$
N322	*	corn	60	0.38	1.76	0.2
N323	*	corn	60	0.25	1.76	0.1
Point 3 (discharge) 12/14/78 8:50 - 9:00pm						
N331	*	corn	60sec.	5.26g	$1.65m^3$	$3.2g/m^3$
N332	*	corn	60	3.97	1.69	2.4
N333	*	corn	60	6.60	1.68	3.9

NORFOLK, VA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - truck receiving leg 15,000 bu/hr
intermittent loading - corn & soybeans
*dust system - no suction from leg; returns to leg at boot, downside

Point 1 (boot-downside) 12/7/78 2:00 - 2:20pm						
N411	on*	?	2½sec.	22.80g	0.04m^3	600g/m^3
N412	purge	?	4½	10.38	0.08	130
N413	purge	?	4½	11.50	0.08	140
N414	purge	?	4	13.30	0.06	200
Point 2 (boot-upside) 12/7/78 2:30 - 3:00pm						
N421	on*	?	10sec.	6.00g	0.17m^3	30g/m^3
N422	purge	?	1½	1.41	0.02	100
N423	purge	?	4½	30.78	0.08	400
N424	purge	?	2½	26.42	0.04	600
Point 3 (middle-upside) 12/7/78 3:30 - 4:00pm						
N431	on*	soybeans	5sec.	2.70g	0.09m^3	30g/m^3
N432	purge	soybeans	10	4.88	0.18	26
N433	purge	corn	9	4.68	0.16	30
N434	purge	corn	7	5.04	0.13	40
Point 4 (head-upside) 12/8/78 1:40 - 2:10pm						
N441	on*	soybeans	8sec.	2.06g	0.06m^3	40g/m^3
N442	purge	soybeans	3½	2.40	0.06	40
N443	purge	soybeans	9	2.33	0.17	14
N444	purge	corn	5	2.52	0.08	30
Point 5 (head-top) 12/8/78 2:25 - 2:45pm						
N451	on*	corn	5sec.	4.72g	0.09m^3	50g/m^3
N452	purge	soybeans	6½	5.46	0.11	50
N453	purge	soybeans	9	7.80	0.16	50
N454	purge	soybeans	10	6.20	0.18	30
Point 6 (head-discharge) 12/8/78 3:00 - 3:20pm						
N461	on*	soybeans	12sec.	8.99g	0.22m^3	40g/m^3
N462	purge	soybeans	14	9.58	0.25	40
N463	purge	soybeans	16	13.17	0.29	45
N464	purge	soybeans	11	6.40	0.19	30

Bucket elevator - lofting leg (rail receiving) 30,000 bu/hr.
loading somewhat constant; upside feed-corn from unit-train
* dust system - blast gates at boot and head (vent to roof)

Point 1 (boot-downside) 12/13/78 10:20 - 10:40am						
N511	on*	corn	3sec.	11.75g	0.05m^3	240g/m^3
N512	off-5min	corn	6½	17.57	0.11	150
N513	-10min	corn	5	9.78	0.09	110
N514	-15min	corn	5	9.42	0.08	110
Point 2 (boot-upside) 12/13/78 10:50 - 11:10am						
N521	on*	corn	10sec.	5.46g	0.18m^3	30g/m^3
N522	off-5min	corn	5	5.95	0.09	60
N523	-10min	corn	5	7.53	0.10	80
N524	-15min	corn	5½	6.97	0.10	70
Point 3 (head-upside) 12/13/78 11:30 - 11:50am						
N541	on*	corn	5sec.	6.69g	0.08m^3	80g/m^3
N542	off-5min	corn	4½	7.25	0.08	90
N543	-10min	corn	4	5.37	0.07	80
N544	-15min	corn	3	3.05	0.03	120

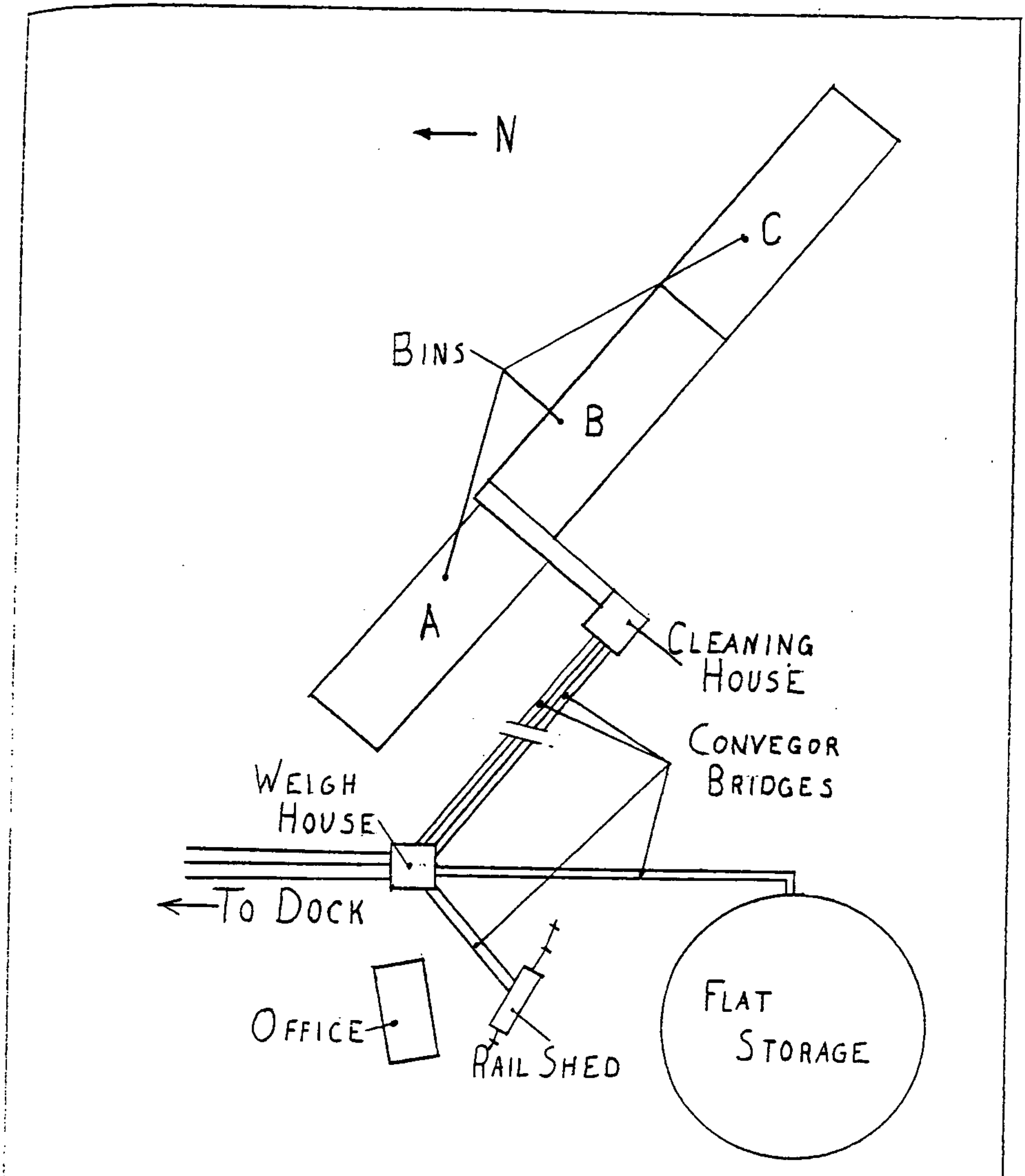
NORFOLK, VA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - lofting leg (continued)						
Point 5 (head-top) 12/13/78 12:40 - 1:00pm						
N551	on*	corn	2sec.	1.86g	0.02m^3	100g/m^3
N552	off-5min	corn	2	1.91	0.02	100
N553	-10min	corn	3½	8.52	0.06	140
N554	-15min	corn	2½	3.96	0.03	130
Point 6 (head-discharge) 12/13/78 1:10 - 1:30pm						
N561	on*	corn	3sec.	6.32g	0.05m^3	130g/m^3
N562	off-5min	corn	3½	6.20	0.06	110
N563	-10min	corn	4	9.10	0.07	130
N564	-15min	corn	3½	8.81	0.06	150
Point 7 (middle-downside) 12/13/78 11:30 - 11:50am						
N571	on*	corn	5sec.	2.85g	0.10m^3	30g/m^3
N572	off-5min	corn	8½	3.93	0.16	25
N573	-10min	corn	7½	4.18	0.13	30
N574	-15min	corn	7	3.98	0.13	30

Bucket elevator - shipping leg - 40,000 bu/hr.
continuous loading (except points 5 & 6) corn to ship.
* dust system - blast gate off upside casing, ground floor

Point 1 (boot-upside) 12/5/78 8:00 - 8:15pm						
N611	on*	corn	3sec.	3.23g	0.05m^3	60g/m^3
N612	off-5min	corn	3½	4.38	0.06	70
N613	-10min	corn	2½	4.89	0.04	110
N614	-15min	corn	3	5.16	0.06	80
Point 2 (boot-upside) 12/5/78 9:10 - 9:30pm						
N621	on*	corn	7sec.	5.32g	0.13m^3	40g/m^3
N622	off-5min	corn	1½	2.61	0.02	100
N623	-10min	corn	1½	2.34	0.01	200
N624	-15min	corn	1½	5.72	0.01	500
Point 3 (middle-upside) 12/5/78 9:45 - 10:00pm						
N631	on*	corn	34sec.	3.94g	0.72m^3	6g/m^3
N632	off-5min	corn	60	7.84	1.32	6
N633	-10min	corn	60	8.63	1.30	7
N634	-15min	corn	60	8.78	1.30	7
Point 4 (head-upside) 12/5/78 10:30 - 10:50pm						
N641	on*	corn	2sec.	1.55g	0.02m^3	90g/m^3
N642	off-5min	corn	2	1.98	0.02	120
N643	-10min	corn	22	7.49	0.43	18
N644	-15min	corn	3	2.91	0.03	110
Point 5 (head-top) 12/5/78 11:00 - 11:20pm						
N651	on*	corn	10sec.	5.81g	0.18m^3	32g/m^3
N652	off-5min	corn	10	5.69	0.20	28
N653	-10min	corn	10	3.49	0.19	19
N654	-15min	corn	60	4.42	1.44	3
Point 6 (head-discharge) 12/5/78 11:40 - 12:00am						
N661	on*	corn	5½sec.	5.74g	0.10m^3	60g/m^3
N662	off-5min	corn	4	4.31	0.06	70
N663	-10min	corn	3	4.84	0.05	100
N664	-15min	corn	60	7.92	1.43	6



DIVISION	GRAIN LAB
PLANT LOCATION	RESERVE LA.
	GENERAL PLOT PLAN

REV.	BY	DATE	SCALE		JOB NO.	
			DRAWN KLS	DATE 7/3/79		SK. NO.

FORM N-469 A

RESERVE, LA (Terre Haute)

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Rail receiving shed - near operator, doors open (R71)
R1 1/17/79 2:30pm 15min 0.07g 28.0m^3 .002g/m^3
unloading unit-train - corn
R2 1/17/79 2:55pm 10min 4.55g 16.0m^3 .280g/m^3
(rail dust system off) leak from 10in (250)opening in leg

Rail rec. shed - basement, below hoppers near leg boot (R51) (R72)
R3 1/17/79 2:37pm 15min 0.47g 27.8m^3 .020g/m^3
unloading unit-train - corn
R4 1/17/79 2:55pm 12min 8.60g 23.3m^3 .370g/m^3
(rail dust system off)

Rail leg head area - next to rail rec. conveyor (R52) (R73)
R5 1/17/79 3:47pm 15min 0.33g 25.1m^3 .010g/m^3
unloading unit-train - corn
R6 1/17/79 4:08pm 8min 12.41g 19.0m^3 .650g/m^3
(rail dust system off)

Conveyor tunnel - bridge from rail rec. leg to weigh house(R74)
R7 1/17/79 3:40pm 15min 0.23g 26.4m^3 .010g/m^3
unloading unit-train - corn, see definition of bridge in text
R8 (no dust system)

Weigh house - ground floor, next to shipping conveyors (R53) (R75)
R9 1/27/79 5:40pm 15min 0.06g 24.6m^3 .002g/m^3
unloading barges - soybeans; loading ship - soybeans
R10 1/27/79 6:50pm 15min 0.45g 23.8m^3 .020g/m^3
(dust systems off)

Weigh house - scale (3rd) floor, middle (R54) (R76)
R11 1/27/79 5:50pm 15min 0.09g 24.2m^3 .004g/m^3
barge rec. - soybeans; ship - soybeans (#4)
R12 1/27/79 6:50pm 15min 0.16g 25.0m^3 .010g/m^3
(dust systems off)

Weigh house - above garners, 5th floor (R55) (R77)
R13 1/27/79 7:20pm 15min 0.90g 22.9m^3 .040g/m^3
barge rec. - soybeans; ship - soybeans (#4)
R14 1/27/79 7:50pm 15min 1.35g 22.5m^3 .060g/m^3
(blast gates to upper garners shut off)

Weigh house - below conv. 49 head pulley, 5th floor
R15 1/26/79 3:00pm 15min 10.18g 22.2m^3 .460g/m^3
barge rec. - soybeans; ship - soybeans(#4)&screenings (#3)
R16 1/26/79 3:30pm 12½min 3.36g 18.4m^3 .180g/m^3
(blast gates to upper garners shut off)

Conveyor tunnel - bridge from weigh house to cleaning house (R78)
R17 1/27/79 4:40pm 15min 0.10g 23.1m^3 .004g/m^3
barge rec. - soybeans
R18 (no dust system)

Cleaning house - ground floor, near shipping conveyors (R56) (R79)
R19 1/17/79 9:15am 15min 11.92g 21.6m^3 .550g/m^3
shipping soybeans (#4) and wheat (#3)
R20 1/17/79 9:30am 1min 8.06g 1.5m^3 5.370g/m^3
(dust system off - see text)

RESERVE, LA

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Cleaning house - ground floor, leg boot area (R80)

R21 1/17/79 9:15am 15min 5.11g 21.7m^3 .240g/m^3
shipping soybeans (cleaners) and wheat

R22 1/17/79 9:30am 1min 2.14g 1.5m^3 1.400g/m^3
(dust system off)

Cleaning house - 3rd floor, cleaners (R57) (R81)

R23 1/17/79 3:00pm 15min 1.00g 28.0m^3 .040g/m^3
shipping soybeans (4cleaners)

R24 (no sample taken - see text)

Cleaning house - 5th floor, leg head area (R82)

R25 1/17/79 3:00pm 15min 2.42g 24.3m^3 .100g/m^3
shipping soybeans (cleaners)

R26 (no sample taken - see text)

Cleaning house - 6th floor, receiving conveyor transfers (R58) (R83)

R27 1/27/79 2:05pm 15min 1.64g 23.7m^3 .070g/m^3
barge rec. - soybeans; rail rec. - corn

R28 1/27/79 2:50pm 15min 3.26g 22.8m^3 .140g/m^3
(dust system off)

Conveyor tunnel - bridge, cleaning house to bins (R84)

R29 1/27/79 2:05pm 15min 0.48g 26.6m^3 .020g/m^3
barge rec. - soybeans; rail rec. - corn

R30 1/27/79 2:50pm 15min 1.08g 26.4m^3 .040g/m^3
(dust systems off) men sweeping nearby

Bin deck - "B section", at trippers to conveyors (R85)

R31 1/26/79 12:20pm 15min 0.29g 24.0m^3 .010g/m^3
barge rec. - soybeans on conv. 12

R32 1/26/79 1:30pm 15min 1.36g 7.8m^3 .170g/m^3
(dust systems off)

Bin deck - "C section", near tripper of conv. 12 (R59) (R86)

R33 1/26/79 12:20pm 15min 0.10g 23.4m^3 .004g/m^3
barge rec. - soybeans on conv. 12

R34 1/26/79 1:30pm 5min 0.84g 7.5m^3 .110g/m^3
(dust systems off) dust generated from tripper idler pulleys

Conveyor tunnel - below "C section" bins (R87)

R35 1/16/79 10:50am 15min 0.10g 25.1m^3 .004g/m^3
shipping soybeans

R36 (no dust system connected to equipment in this area)

Conveyor tunnel - below "B section" bins (R60) (R88)

R37 1/16/79 2:30pm 15min 0.59g 26.1m^3 .020g/m^3
shipping soybeans

R38 (no dust system connected)

Conveyor tunnel - below bins, transfer to cleaning house (R89)

R39 1/16/79 1:30pm 15min 1.31g 25.6m^3 .050g/m^3
shipping soybeans (#4) & wheat (#3)

R40 1/16/79 1:55pm 15min 2.44g 14.3m^3 .170g/m^3
(dust systems off)

Conveyor tunnel - from bins to cleaning house (see R39) (R90)

R41 1/16/79 1:30pm 15min 2.45g 25.1m^3 .100g/m^3
shipping soybeans and wheat

R42 1/16/79 1:55pm 7.5min 3.77g 10.1m^3 .370g/m^3
(dust system off) some dust from C.H. ground floor

RESERVE, LA

WORK AREA SAMPLES - LAYER (SETTLED)

R51 Rail leg boot area (R3)
1/27/79 9.4g $0.20m^2$ floor center of room
R52 Rail leg head area (R5)
1/27/79 157.0g $0.20m^2$ floor next to conv.
R53 Weigh house, ground floor (R9)
1/27/79 12.6g $0.20m^2$ floor beneath conv. to ship
R54 Weigh house, scale (4th) floor (R11)
1/27/79 15.0g $0.20m^2$ floor next scale #2 (rail)
R55 Weigh house, above garners (5th) floor (R13)
1/27/79 6.9g $0.20m^2$ floor near scale #4 (ship)
R56 Cleaning house, ground floor (R19 & R21)
1/27/79 13.1g $0.20m^2$ floor between conv. & leg
R57 Cleaning house, scale (3rd) floor (R23)
1/27/79 3.3g $0.20m^2$ floor south of cleaners
R58 Cleaning house, distribution (6th) floor (R27)
1/27/79 4.9g $0.20m^2$ floor near conveyors
R59 Bin deck, "C section" (R33)
1/27/79 3.9g $0.20m^2$ floor near conveyor
R60 Conveyor tunnel - below "B section" bins (R37)
1/27/79 5.9g $0.20m^2$ floor near conveyor

RESERVE, LA

WORK AREA SAMPLES - PERSONAL SAMPLER (RESPIRABLE)

R71	Rail receiving shed - near operator (R1)		
1/22/79	receiving corn	7½hr	.0002g/m3
R72	Rail leg boot area (R3)		
1/22/79	receiving corn	8hr	$.0014g/m^3$
R73	Rail leg head area (R5)		
1/22/79	receiving corn	73/4hr	$.0008g/m^3$
R74	Conveyor tunnel - rail rec. conveyor bridge (R7)		
1/17/79	receiving corn	8½hr	$.0005g/m^3$
R75	Weigh house - ground floor (R9)		
1/25/79	shipping soybeans	7½hr	$.0010g/m^3$
R76	Weigh house - scale floor (R11)		
1/25/79	soybeans,	6hr	$.0033g/m^3$
R77	Weigh house - floor above garners (R13)		
1/25/79	soybeans, screenings	73/4hr	$.0012g/m^3$
R78	Conveyor tunnel - bridge from W.H. to cleaning house (R17)		
1/25/79	rec. soybeans & corn	7½hr	$.0010g/m^3$
R79	Cleaning house - ground floor, near conveyors (R19)		
1/24/79	shipping soybeans	5½hr	$.0049g/m^3$
R80	Cleaning house - ground floor, near leg (R21)		
1/24/79	shipping soybeans	5½hr	$.0002g/m^3$
R81	Cleaning house - cleaner (3rd) floor (R23)		
1/24/79	shipping soybeans	4½hr	$.0013g/m^3$
R82	Cleaning house - leg head area (R25)		
1/24/79	shipping soybeans	53/4hr	$.0015g/m^3$
R83	Cleaning house - distribution (6th) floor (R27)		
1/27/79	receiving soybeans	5½hr	$.0006g/m^3$
R84	Conveyor tunnel - bridge, cleaning house to bins (R29)		
1/27/79	receiving soybeans	5hr	$.0006g/m^3$
R85	Bin deck - "B section" (R31)		
1/27/79	receiving soybeans	5½hr	$.0004g/m^3$
R86	Bin deck - "C section" (R33)		
1/27/79	receiving soybeans	5½hr	$.0002g/m^3$
R87	Conveyor tunnel - below "C section" bins (R35)		
1/17/79	shipping soybeans	73/4hr	$.0002g/m^3$
R88	Conveyor tunnel - below "B section" bins (R37)		
1/17/79	shipping soybeans	73/4hr	$.0034g/m^3$
R89	Conveyor tunnel - at transfer to cleaning house (R39)		
1/17/79	shipping soybeans	7hr	$.0011g/m^3$
R90	Conveyor tunnel - from bins to cleaning house (R41)		
1/17/79	shipping soybeans	73/4hr	$.0027g/m^3$

RESERVE, LA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Belt conveyor - bin deck (#12) 80,000 bu/hr
receiving soybeans by barge, continuous
*blast gate (pts 1 & 2); dust system for conv. 12 (pts3 &4)

Point 1 (loader from conv. 6) 1/26/79 4:45 - 5:00pm						
R111	on*	soybeans	24sec.	6.09g	$0.35m^3$	$17g/m^3$
R112	off-5min	soybeans	60	4.51	1.09	4
R113	-10min	soybeans	38	4.14	0.65	6
R114	-15min	soybeans	40	3.94	0.70	6
Point 2 (near dust pick up) 1/26/79 5:10 - 5:20am						
R121	on*	soybeans	60sec.	1.15g	$1.29m^3$	$0.9g/m^3$
R122	off-5min	soybeans	60	0.49	1.36	0.4
R123	-10min	soybeans	60	2.18	1.33	1.6
R124	(no grain on conveyor - 5:15pm)					
Point 3 (tripper - top of discharge) 1/26/79 5:45 - 6:10pm						
R131	on*	soybeans	60sec.	0.76g	$1.26m^3$	$0.5g/m^3$
R132	off-5min	soybeans	46	5.17	0.76	7
R133	-10min	soybeans	33	4.82	0.56	9
R134	-15min	soybeans	27	5.53	0.46	12
Point 4 (tripper - discharge spout) 1/26/79 1/26 1/27 12:45 - 1:00pm						
R141	on*	soybeans	53sec.	5.91g	$0.82m^3$	$7g/m^3$
R142	on	soybeans	18	4.42	0.28	16
R143	off-5min	soybeans	12	2.87	0.19	15
R144	-10min	soybeans	9	3.13	0.14	22

Belt conveyor - shipping (#49) 80,000 bu/hr
shipping corn, continuous from conv. 47 and cleaners
* blast gates (2) at loading end (pts 1a, 1b, & 2); blast gate on scale garner (pts 3&4). Dust system of C.H. returns to conveyor

Point 1a (loader from conv. 47) 1/20/79 5:20 - 5:50pm						
R211	on*	corn	60sec.	13.66g	$1.29m^3$	$11g/m^3$
R212	off-5min	corn	60	6.50	1.46	4
R213	-10min	corn	60	8.22	1.38	6
R214	-15min	corn	60	9.76	1.29	8
Point 1b (loader from cleaners) 1/20/79 6:10 - 6:30pm						
R215	on*	corn	60sec.	10.28g	$1.47m^3$	$7g/m^3$
R216	off-5min	corn	60	15.45	1.32	12
R217	-10min	corn	60	18.49	1.23	15
R218	-15min	corn	52	19.28	0.97	20
Point 2 (10m from pt. 1b, at dust hood) 1/20/79 6:50 - 7:10pm						
R221	on*	corn	60sec.	5.59g	$1.53m^3$	$3.6g/m^3$
R222	off-5min	corn	60	0.35	1.67	0.2
R223	-10min	corn	60	0.58	1.67	0.4
R224	-15min	corn	60	1.46	1.63	0.9
Point 3 (discharge-top) 1/20/79 8:20 - 8:40pm						
R231	on*	corn	60sec.	2.57g	$1.36m^3$	$2g/m^3$
R232	off-5min	corn	60	4.00	1.40	3
R233	-10min	corn	60	4.18	1.40	3
R234	-15min	corn	60	4.17	1.36	3
Point 4 (discharge chute) 1/20/79 9:00 - 9:15pm						
R241	on*	corn	60sec.	17.19g	$1.08m^3$	$16g/m^3$
R242	off-5min	corn	18	15.29	0.19	80
R243	-10min	corn	60	17.90	1.13	16
R244	-15min	corn	20	11.78	0.34	35

RESERVE, LA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Belt conveyor - shipping (#49) 60,000 bu/hr
shipping soybeans, continuous from conv. 47 and cleaners
* blast gates (2) at loading end (pts 1a, 1b, and 2); blast gate on scale garner (pts 3&4). Dust system of C.H. returns to conv.

Point 1a (loader from conv. 47) 1/25/79 4:15 - 4:30pm

R311	on*	soybeans	22sec.	7.67g	$0.39m^3$	$20g/m^3$
R312	off-5min	soybeans	14	7.36	0.24	31
R313	-10min	soybeans	14	8.36	0.24	35
R314	-15min	soybeans	11	7.37	0.18	41

Point 1b (loader from cleaners) 1/25/79 4:35 - 5:00pm

R315	on*	soybeans	29sec.	4.41g	$0.50m^3$	$9g/m^3$
R316	off-5min	soybeans	42	4.10	0.74	6
R317	-10min	soybeans	57	4.09	0.96	4
R318	-15min	soybeans	43	3.99	0.71	6

Point 2 (10m from pt. 1b, dust hood) 1/25/79 5:10 - 5:30pm

R321	on*	soybeans	60sec.	4.27g	$1.00m^3$	$4g/m^3$
R322	off-5min	soybeans	60	1.71	1.13	1.5
R323	-10min	soybeans	60	0.68	1.26	0.5
R324	-15min	soybeans	60	1.77	1.12	1.6

Point 3 (discharge-top) 1/25/79 6:45 - 7:00pm

R331	on*	soybeans	60sec.	1.60g	$1.07m^3$	$2g/m^3$
R332	off-5min	soybeans	46	2.79	0.79	4
R333	-10min	soybeans	44	3.19	0.71	4
R334	-15min	soybeans	36	3.71	0.37	10

Point 4 (discharge chute) 1/25/79 7:10 - 7:25pm

R341	on*	soybeans	15sec.	4.00g	$0.22m^3$	$20g/m^3$
R342	off-5min	soybeans	5	5.92	0.07	80
R343	-10min	soybeans	8	5.94	0.12	50
R344	-15min	soybeans	7	5.67	0.10	60

Bucket elevator - rail receiving leg 40,000 bu/hr
receiving unit-train - corn, continuous loading
* blast gate at boot; dust system returns to upside casing

Point 1 (boot-downside) 1/22/79 10:10 - 10:30am

R411	on*	corn	18sec.	15.61g	$0.32m^3$	$50g/m^3$
R412	off-5min	corn	8	8.56	0.13	70
R413	-10min	corn	7	16.10	0.13	120
R414	-15min	corn	6	14.01	0.11	130

Point 2 (boot-upside) 1/22/79 10:45 - 11:00am

R421	on*	corn	3sec.	8.72g	$0.05m^3$	$170g/m^3$
R422	off-5min	corn	2½	11.29	0.04	280
R423	-10min	corn	3½	20.89	0.06	350
R434	-15min	corn	3½	22.87	0.05	500

Point 4 (head-upside) 1/22/79 1:40 - 2:20pm

R441	on*	corn	5sec.	6.30g	$0.08m^3$	$80g/m^3$
R442	off-5min	corn	6	6.17	0.09	70
R443	-10min	corn	13	8.95	0.22	40
R444	-15min	corn	6	6.97	0.10	70

RESERVE, LA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - rail receiving leg (continued)						
Point 5 (head-top) 1/23/79 9:15 - 10:15am						
R451	on*	corn	8sec.	9.32g	$0.14m^3$	$70g/m^3$
R452	off-5min	corn	23	13.40	0.45	30
R453	-10min	corn	12	8.68	0.21	40
	(grain flow interrupted 9:30 - 10:10am)					
R454	-60min	corn	33	10.90	0.60	20
Point 6 (discharge spout) 1/24/79 10:40 - 11:00am						
R461	on*	corn	13sec.	14.09g	$0.21m^3$	$70g/m^3$
R462	off-5min	corn	8	8.52	0.13	70
R463	-10min	corn	5	8.87	0.08	110
R464	-15min	corn	5	8.47	0.08	110
Point 7 (middle-downside) 1/22/79 11:15 - 11:40pm						
R471	on*	corn	10sec.	11.27g	$0.18m^3$	$70g/m^3$
R742	off-5min	corn	9	12.29	0.16	80
R473	-10min	corn	16	15.28	0.29	50
R474	-15min	corn	8	11.60	0.13	90

Bucket elevator - cleaner leg 15,000 bu/hr (1 cleaner)
loading ship - corn, continuous from conv. 47
* blast gate at boot

Point 1 (boot-downside) 1/20/79 12:50 - 1:10pm						
R511	on*	corn	10sec.	11.05g	$0.19m^3$	$60g/m^3$
R512	off-5min	corn	12	13.18	0.21	70
R513	-10min	corn	9	11.69	0.15	80
R514	-15min	corn	10	11.50	0.16	70
Point 2 (boot-upside) 1/20/79 1:15 - 1:30pm						
R521	on*	corn	3sec.	3.97g	$0.04m^3$	$100g/m^3$
R522	off-5min	corn	3	11.12	0.05	220
R523	-10min	corn	2	7.71	0.03	260
R524	-15min	corn	2	3.91	0.03	130
Point 4 (head-upside) 1/20/79 2:30 - 2:50pm						
R541	on*	corn	60sec.	16.52g	$1.40m^3$	$12g/m^3$
R542	off-5min	corn	60	20.56	1.30	16
R543	-10min	corn	53	24.83	1.10	23
R544	-15min	corn	36	23.10	0.73	32
Point 5 (head-top) 1/20/79 3:00 - 3:15pm						
R551	on*	corn	5½sec.	14.68g	$0.11m^3$	$130g/m^3$
R552	off-5min	corn	5	12.64	0.09	140
R553	-10min	corn	2	3.52	0.03	120
R554	-15min	corn	2	4.55	0.03	150
Point 6 (head-discharge spout) 1/20/79 3:20 - 3:40pm						
R561	on*	corn	3½sec.	13.17g	$0.06m^3$	$220g/m^3$
R562	off-5min	corn	6½	18.23	0.12	150
R563	-10min	corn	6	16.48	0.12	140
R564	-15min	corn	6½	21.10	0.12	180
Point 7 (middle-downside) 1/20/79 1:45 - 2:05pm						
R571	on*	corn	15sec.	19.34g	$0.28m^3$	$70g/m^3$
R572	off-5min	corn	12	23.84	0.21	110
R573	-10min	corn	26	9.84	0.53	19
R574	-15min	corn	27	8.60	0.51	17

RESERVE, LA

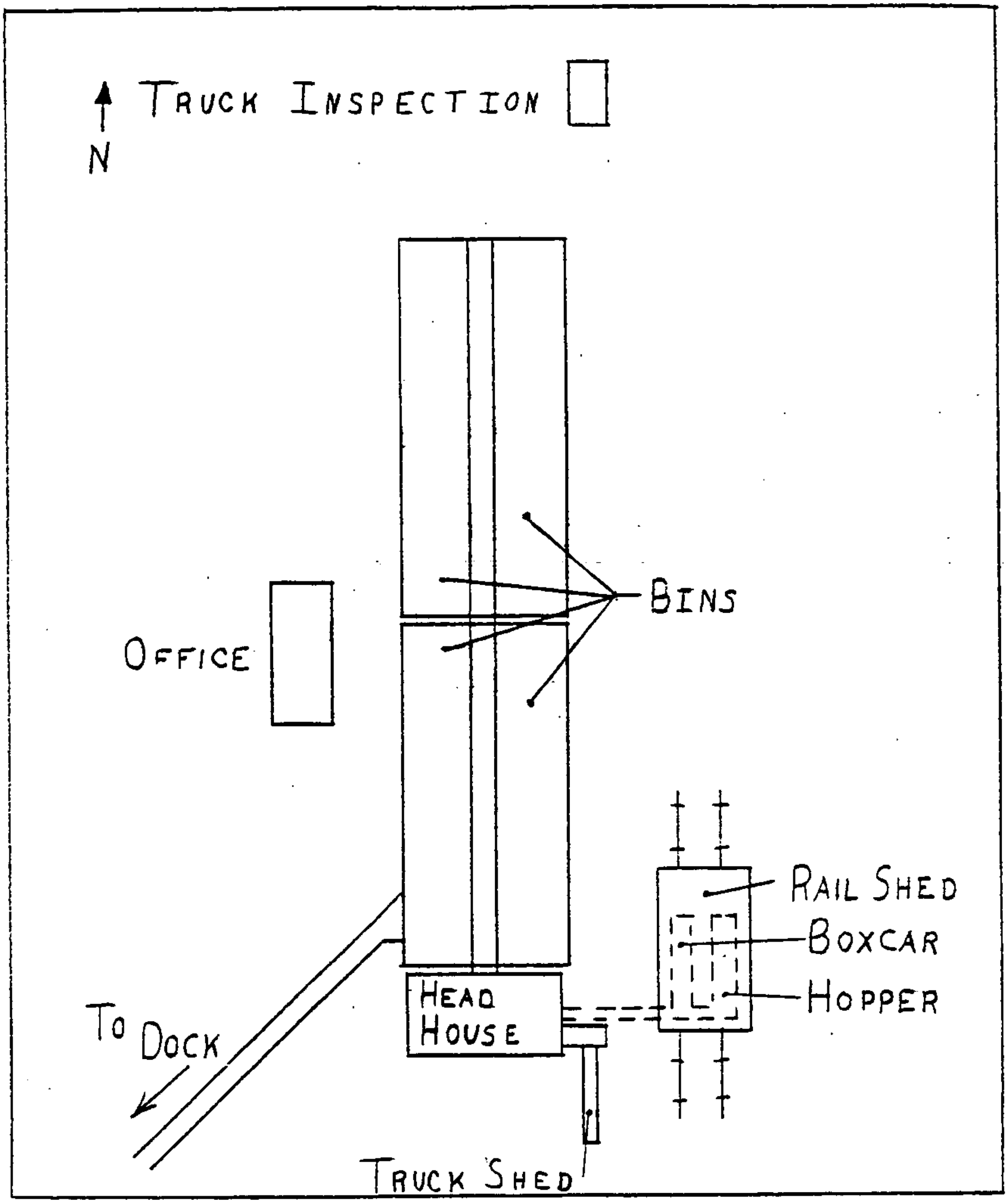
EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - cleaner leg 50,000 bu/hr (4 cleaners)
loading ship - soybeans, continuous from conv. 47
* blast gate at boot; pt.2 samples plugged w/hulls

Point 1 (boot-downside) 1/25/79 10:30 - 10:50am						
R611	on*	soybeans	3sec.	9.34g	0.05m^3	190g/m^3
R612	off-5min	soybeans	2	18.17	0.03	600
R613	-10mon	soybeans	3	10.52	0.05	210
R614	-15min	soybeans	3½	11.10	0.05	220
Point 2 (boot-upside) 1/25/79 10:50 - 11:10am						
R621	on*	soybeans	1sec.	0.87g	0.01m^3	90g/m^3
R622	off-5min	soybeans	2	0.50	0.02	30
R623	-10min	soybeans	1½	0.55	0.02	30
R624	-15min	soybeans	1	0.73	0.01	70
Point 4 (head-upside) 1/25/79 12:00, 3:00 - 3:10pm						
R641	on*	soybeans	5sec.	4.38g	0.08m^3	50g/m^3
R642	off-5min	soybeans	7	6.57	0.12	50
R643	-10min	soybeans	14	7.10	0.25	30
R644	-15min	soybeans	8	7.91	0.13	60
Point 5 (head-top) 1/25/79 3:20 - 3:35pm						
R651	on*	soybeans	3½sec.	5.39g	0.06m^3	90g/m^3
R652	off-5min	soybeans	3	3.63	0.04	90
R653	-10min	soybeans	3½	4.06	0.06	70
R654	-15min	soybeans	4	3.43	0.07	50
Point 6 (head-discharge spout) 1/25/79 3:40 - 4:00pm						
R661	on*	soybeans	2½sec.	3.51g	0.04m^3	90g/m^3
R662	off-5min	soybeans	2½	3.79	0.04	90
R663	-10min	soybeans	2	3.68	0.03	120
R664	-15min	soybeans	2	2.29	0.03	80
Point 7 (middle-downside) 1/25/79 11:30 - 11:50am						
R671	on*	soybeans	10sec.	15.04g	0.16m^3	90g/m^3
R672	off-5min	soybeans	8	6.98	0.13	50
R673	-10min	soybeans	12	5.15	0.20	26
R674	-15min	soybeans	11	6.52	0.19	34

Scale - shipping (#4) 60-80,000 bu/hr 1,00 bu cap.
fed from conveyor 49 (sampled earlier)
* blast gate of off upper garner

Point 1 (upper garner) 1/20/79 9:20 - 9:30pm						
R711	on*	corn	60sec.	15.76g	1.21m^3	13g/m^3
R712	off-5min	corn	50	14.80	0.82	18
R713	-10min	corn	54	13.24	0.97	14
R714	(no grain in scale)					
Point 1 (upper garner) 1/25/79 7:30 - 7:45pm						
R715	on*	soybeans	10sec.	4.42g	0.15m^3	30g/m^3
R716	off-5min	soybeans	10	5.06	0.15	34
R717	-10min	soybeans	8	4.05	0.12	34
R718	-15min	soybeans	7	3.95	0.10	40



DIVISION GRAIN LAB					
PLANT LOCATION SEATTLE WASH					
GENERAL PLOT PLAN					
REV.	BY	DATE	SCALE		JOB NO.
			DRAWN KLS	DATE 7/3/79	SK. NO.

SEATTLE, WA

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Truck receiving shed - behind truck, doors closed (S71)
S1 2/14/79 8:53am 15min 1.92g 26.5m^3 .070g/m^3
unloading flat-bottomed trailer - wheat
S2 2/14/79 9:20am 3min 7.49g 5.6m^3 1.340g/m^3
(dust system off) 3 1min intervals (3 trucks)

Rail receiving shed - boxcar unloader, doors open (S72)
S3 2/12/79 9:20am 15min 0.66g 25.5m^3 .030g/m^3
unloading 2 boxcars - wheat & corn
S4 2/12/79 9:40am 5min 2.83g 9.1m^3 .310g/m^3
(dust system off) unloading boxcar - wheat

Rail receiving shed - hopper car pit, doors open (S73)
S5 2/12/79 10:20am 15min 0.04g 33.6m^3 .001g/m^3
unloading hopper cars - corn
S6 2/12/79 10:50am 16min 0.98g 26.7m^3 .040g/m^3
(dust system off) unloading hoppercars - corn

Conveyor tunnel - boxcar rec. belt #18 (S51) (S74)
S7 2/12/79 9:20am 15min 0.77g 23.8m^3 .030g/m^3
unloading wheat, intermittent
S8 2/12/79 9:40am 5min 0.48g 8.1m^3 .060g/m^3
(dust system off) unloading wheat, intermittent

Conveyor tunnel - hopper car rec. belt(#19) (S75)
S9 2/12/79 10:20am 15min 0.49g 24.6m^3 .020g/m^3
unloading corn
S10 2/12/79 10:50am 15min 3.23g 23.7m^3 .140g/m^3
(dust system off) unloading corn

Conveyor tunnel - rail rec. belts (#2 & 3) (S52) (S76)
S11 2/12/79 11:25am 15½min 0.23g 25.2m^3 .010g/m^3
receiving wheat
S12 2/12/79 2:55pm 14½min 2.11g 25.8m^3 .080g/m^3
(dust systems off) receiving wheat

Conveyor tunnel - bin 512, conv. #5 (S53 & S54) (S77 & S78)
S13 2/12/79 4:00pm 15min 0.08g 25.7m^3 .003g/m^3
loading ship - corn, conveyors 5, 6, & 7
S14 2/12/79 4:25pm 10min 0.06g 17.1m^3 .003g/m^3
(dust systems off) loading ship - corn

Conveyor tunnel - under bin #503, conv.#6, (S53 & S54) (S77&S78)
S15 2/12/79 4:00pm 15min 0.15g 25.1m^3 .006g/m^3
loading ship - corn, conveyors 5, 6, & 7
S16 2/12/79 4:25pm 12min 0.07g 20.7m^3 .003g/m^3
(dust systems off) loading ship - corn

Headhouse - basement, center; leg boots & conveyors (S55) (S79)
S17 2/12/79 11:25am 15min 0.39g 28.0m^3 .010g/m^3
receiving truck & rail, shipping - corn
S18 2/12/79 3:00am 15min 0.86g 25.7m^3 .030g/m^3
(dust systems off)

Headhouse - ground floor, near cleaner
S19 2/14/79 1:00pm 15min 0.04g 30.2m^3 .001g/m^3
cleaning corn, loading ship - corn, receiving rail & truck
S20 2/14/79 1:30pm 9min 0.03g 18.2m^3 .002g/m^3
(dust system off)

SEATTLE, WA

WORK AREA SAMPLES - HI-VOL SAMPLER (AIRBORNE)

Headhouse - bin floor, level 145, center (S56) (S80)

S21 2/13/79 3:30pm 15min 0.05g 29.8m³ .002g/m³
shipping - corn, receiving rail & truck

S22 2/13/79 3:50pm 15min 0.11g 30.2m³ .004g/m³
(dust system off)

Headhouse - distribution floor, level 176, conv.#9,10 (S57) (S81)

S23 2/14/79 9:40am 15min 0.66g 28.3m³ .023g/m³
receiving rail & truck, shipping corn

S24 2/14/79 10:10am 10min 0.23g 19.1m³ .012g/m³
(dust systems off)

Headhouse - cleaner floor, level 195 (S58) (S82)

S25 2/14/79 11:24am 15min 0.16g 27.3m³ .006g/m³
next to cleaner, corn going to ship - 20,000 bu/hr

S26 2/14/79 1:55pm 5min 1.24g 9.1m³ .140g/m³
(dust system off)

Headhouse - leg head area, level 213 (S59) (S83)

S27 2/13/79 3:27pm 15min 0.24g 28.5m³ .008g/m³
rail receiving - corn, wheat, milo; shipping - corn

S28 2/13/79 3:47pm 15min 0.09g 28.5m³ .003g/m³
(dust systems off)

Bin deck - conv. #9 & #10, near 3rd tripper (S60) (S84)

S29 2/14/79 9:40am 15min 1.05g 26.2m³ .040g/m³
rail receiving

S30 2/14/79 10:10am 10min 0.60g 18.3m³ .033g/m³
(dust system off)

WORK AREA SAMPLES - LAYER (SETTLED)

S51 Conveyor tunnel - boxcar receiving (S7)
44.89g 0.20m² floor near conveyor # 18

S52 Conveyor tunnel - rail receiving (S11)
8.46g 0.20m² floor between conveyors #2 & 5, east end

S53 Conveyor tunnel - beneath bins (S13 & S15)
16.07g 0.20m² floor beneath bin 117

S54 Conveyor tunnel - beneath bins (S13 & S15)
11.32g 0.20m² floor beneath bin 307

S55 Headhouse - basement (S17)
13.11g 0.20m² floor next to truck leg

S56 Headhouse - bin floor, level 145 (S21)
1.80g 0.40m² near truck leg casing

S57 Headhouse - distribution floor, level 176 (S23)
4.71g 0.20m² floor next to conveyors #9 & #10

S58 Headhouse - cleaner floor, level 195 (S25)
23.65g 0.20m² floor next to truck conv.#11 (wheat)

S59 Headhouse - leg head, scale floor, level 213 (S27)
4.74g 0.20m² floor along center railing

S60 Bin deck - along belts #9 & #10 (S29)
12.20g 0.20m² floor next to walkway at 3rd tripper

SEATTLE, WA

WORK AREA SAMPLES - PERSONAL SAMPLER (RESPIRABLE)

S71	Truck receiving shed (S1)	
2/13/79	receiving wheat 5hr	.0008g/m^3
S72	Rail receiving shed - boxcar unloader (S3)	
2/9/79	receiving corn, wheat, & milo 7¼hr	.0004g/m^3
S73	Rail receiving shed - hoppercars (S3)	
2/9/79	near operator, rec. corn & wheat 73/4hr.	.0004g/m^3
S74	Conveyor tunnel - boxcar receiving (S7)	
2/9/79	receiving corn, wheat & milo 7½hr	.0009g/m^3
S75	Conveyor tunnel - hoppercar receiving (S9)	
2/9/79	receiving wheat & corn 73/4hr	.0030g/m^3
S76	Conveyor tunnel - rail receiving conv. #2 & #3 (S11)	
2/13/79	receiving wheat, corn & milo 6½hr	.0006g/m^3
S77	Conveyor tunnel - beneath bin #702, conv. #6&7 (S13 & S15)	
2/10/79	shipping wheat 8 3/4 hr.	.0006g/m^3
S78	Conveyor tunnel - beneath bin #512, conv.#4&5 (S13 & S15)	
2/10/79	shipping wheat 8½hr	.0014g/m^3
S79	Headhouse - basement (S17)	
2/13/79	rec. truck & rail, shipping corn 7 3/4hr	.0004g/m^3
S80	Headhouse - bin floor, level 145 (S21)	
2/12/79	receiving truck & rail 8½hr	.0005g/m^3
S81	Headhouse - distribution floor, level 176 (S23)	
2/12/79	rec. truck & rail: wheat, corn & milo 8½hr.	.0009g/m^3
S82	Headhouse - cleaner floor, level 195 (S25)	
2/12/79	cleaning corn 8 hr	.0003g/m^3
S83	Headhouse - leg head, scale floor, level 213 (S27)	
2/10/79	rec. corn, wheat, milo	.0006g/m^3
S84	Bin deck - conv. #9 & #10 (S29)	
2/12/79	rail rec. - corn, wheat & milo 8¼hr	.0013g/m^3
S85	Inspection Office	
2/13/79	attached to test weight device 6½hr	.0022g/m^3

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Belt conveyor - truck receiving - 25,000 bu/hr						
intermittent loading - wheat						
*blast gates at discharge and leg boot						
Point 1 (loading point) 2/5/79 9:30 - 9:45am						
S111	on*	wheat	60sec.	1.60g	$1.38m^3$	$1.2g/m^3$
S112	off-5min	wheat	60	0.80	1.51	0.5
S113	-10min	wheat	60	0.64	1.54	0.4
S114	-15min	wheat	60	0.45	1.54	0.3
Point 3 (discharge-top) 2/5/79 9:50 - 10:10am						
S131	on*	wheat	60sec.	0.46g	$1.51m^3$	$0.3g/m^3$
S132	off-5min	wheat	60	0.71	1.51	0.5
S133	-10min	wheat	60	0.22	1.51	0.2
S134	-15min	wheat	60	0.29	1.54	0.2
Point 4 (discharge spout) 2/5/79 10:20, 11:05 - 11:20am						
S141	on*	wheat	8sec.	2.74g	$0.15m^3$	$18g/m^3$
S142	off-5min	wheat	9	4.63	0.37	12
S143	-15min	wheat	19	4.72	0.37	13
S144	-20min	wheat	16	4.12	0.31	13

Belt conveyor - boxcar receiving - 50,000 bu/hr						
intermittent loading, various grains						
* blast gates at discharge and leg boot						
Point 1 (loader from conv. 18) 2/6/79 9:00 - 9:40am						
S211	on*	corn	22sec.	7.92g	$0.48m^3$	$16g/m^3$
S212	off-5min	wheat	60	5.00	1.32	4
S213	-10min	corn	60	5.40	1.31	4
S214	-15min	corn	60	6.24	1.31	5
Point 3 (discharge-top) 2/6/79 9:55 - 10:25am						
S231	on*	corn	60sec.	2.45g	$1.43m^3$	$2g/m^3$
S232	off-5min	corn	60	1.12	1.41	0.8
S233	-10min	corn	60	0.62	1.42	0.4
S234	-15min	corn	37	5.09	0.72	7
Point 4 (discharge spout) 2/6/79 10:35 - 12:00am						
S241	on*	milo	24sec.	5.36g	$0.48m^3$	$11g/m^3$
S242	off	corn	60	8.95	1.19	8
S243	off	corn	33	19.94	0.66	30
S244	off	wheat	15	4.37	0.28	16

Belt conveyor - bin reclaim #4 50,000 bu/hr						
continuous, transfer from shipping bin #201						
* blast gates at discharge and shipping leg boot						
Point 1 (loader from bin 201) 2/7/79 8:15 - 9:00am						
S311	on*	wheat	30sec.	5.38g	$0.58m^3$	$9g/m^3$
S312	off-5min	wheat	32	5.76	0.61	9
S313	-10min	wheat	31	6.73	0.59	11
S314	-15min	wheat	26	9.05	0.51	18
Point 3 (discharge-top) 2/7/79 9:35 - 9:50am						
S331	on*	wheat	60sec.	1.56g	$1.46m^3$	$1g/m^3$
S332	off-5min	wheat	60	1.52	1.48	1
S333	-10min	wheat	60	1.29	1.49	1
S334	-15min	wheat	60	1.33	1.51	1
Point 4 (discharge spout) 2/7/79 10:00 - 10:20am						
S341	on*	wheat	27sec.	11.93g	$0.56m^3$	$21g/m^3$
S342	off-5min	wheat	56	15.73	1.20	13
S343	-10min	wheat	60	13.54	1.34	10
S344	-15min	wheat	60	15.87	1.39	11

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - truck receiving leg 25,000 bu/hr
intermittent loading - wheat; leg has one solid casing
* blast gates on conveyor discharge and leg boot

Point 1 (boot-downside) 2/5/79 1:55 - 2:15pm

S411	on*	wheat	16sec.	8.90g	0.32m^3	28g/m^3
S412	off-5min	wheat	14	4.58	0.28	16
S413	-10min	wheat	60	2.94	1.45	2
S414	-15min	wheat	18	5.52	0.35	16

Point (boot-upside) 2/5/79 2:20pm 2/8/79 8:30 - 8:40am

S412	on*	wheat	6½sec.	1.41g	0.11m^3	13g/m^3
S422	off	wheat	19	6.86	0.34	20
S423	off	wheat	9	15.03	0.14	100
S424	off	wheat	20	11.42	0.43	27

Point 4 (head-upside) 2/9/79 8:40 - 9:10am

S441	on*	wheat	19sec.	8.54g	0.39m^3	22g/m^3
S442	off-5min	wheat	60	3.21	1.18	3
S443	-10min	wheat	11	3.73	0.23	16
S444	-15min	wheat	14	2.73	0.29	9

Point 5 (head-top) 2/13/79 9:15 - 9:50am

S451	on*	wheat	12sec.	15.02g	0.18m^3	80g/m^3
S452	off-5min	wheat	12	6.86	0.22	30
S453	-10min	wheat	18	8.94	0.36	25
S454	-15min	wheat	40	6.23	0.77	8

Point 6 (head-discharge) 2/13/79 10:00 - 10:50am

S461	on*	wheat	14sec.	6.88g	0.28m^3	25g/m^3
S462	off-5min	wheat	51	51.55	1.00	50
S463	-10min	wheat	15	2.50	0.28	9
S464	-40min	wheat	41	6.04	0.90	7

Point 7 (middle-discharge) 2/8/79 9:10 - 10:55am

S471	on*	wheat	25sec.	6.60g	0.90m^3	7g/m^3
S472	off-5min	wheat	50	4.00	1.18	3
S473	-15min	wheat	23	5.12	0.52	10
S474	-90min	wheat	30	9.08	0.52	18

Bucket elevator - boxcar receiving leg 50,000 bu/hr.
intermittent loading; combined up & down casing
* blast gates on conveyor discharge and leg boot

Point 1 (boot-downside) 2/6/79 10:45 - 2:02pm

S511	on*	wheat	60sec.	3.81g	1.30m^3	3g/m^3
S512	off	wheat	60	2.85	1.19	2
S513	off	wheat	60	6.97	1.19	6
S514	off	milo	14	3.44	0.26	13

Point 2 (boot-upside) 2/6/79 2:10 - 2:45pm

S521	on*	milo	3½sec.	2.89g	0.07m^3	40g/m^3
S522	off-5min	milo	3½	6.60	0.07	90
S523	-10min	milo	5½	7.39	0.09	80
S524	-35min	milo	3½	3.15	0.06	50

Point 4 (head-upside) 2/6/79 3:00 - 3:30pm

S541	on*	milo	6½sec.	10.36g	0.11m^3	90g/m^3
S542	off-5min	milo	11	19.67	0.19	100
S543	-25min	milo	22	18.17	0.39	50
S544	no sample taken					

SEATTLE, WA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Bucket elevator - boxcar receiving leg (continued)						
Point 5 (head-top) 2/6/79 3:40 - 4:00pm						
S551	on*	corn	17sec.	16.49g	$0.29m^3$	$60g/m^3$
S552	off-5min	wheat	11	11.91	0.19	60
S553	-10min	corn	18	18.89	0.32	60
S554	-15min	corn	8½	14.70	0.16	90
Point 6 (head-discharge) 2/6/79 4:10 - 4:45pm						
S561	on*	corn	13sec.	21.86g	$0.22m^3$	$100g/m^3$
S562	off-5min	corn	9	25.23	0.16	160
S563	-15min	corn	8	18.91	0.13	150
S564	-35min	wheat	60	13.63	1.19	12
Point 7 (middle-downside) 2/6/79 4:40pm 2/7/79 8:40 - 8:50am						
S571	on*	corn	48sec.	18.23g	$0.46m^3$	$40g/m^3$
S572	off	wheat	8½	3.54	0.16	22
S573	off	corn	60	21.53	1.23	18
S574	no sample taken					

Bucket elevator - shipping leg 50,000 bu/hr						
continuous loading - transfer wheat out of bin 201						
* blast gates on conveyor 4 discharge & leg boot						
Point 1 (boot-downside) 2/7/79 9:45 - 10:40am						
S611	on*	wheat	14sec.	14.33g	$0.29m^3$	$50g/m^3$
S612	off-5min	wheat	28	8.47	0.56	15
S613	-10min	wheat	19	14.09	0.36	40
S614	-15min	wheat	18	13.78	0.33	40
Point 2 (boot-upside) 2/7/79 10:55 - 11:10am						
S621	on*	wheat	8sec.	8.01g	$0.13m^3$	$60g/m^3$
S622	off-5min	wheat	6	10.44	0.09	120
S623	-10min	wheat	9	18.41	0.16	120
S624	-15min	wheat	8	9.65	0.14	70
Point 4 (head-upside) 2/7/79 1:30 - 1:50pm						
S641	on*	wheat	18sec.	21.38g	$0.34m^3$	$60g/m^3$
S642	off-5min	wheat	14	24.70	0.28	90
S643	-10min	wheat	14	24.03	0.26	90
S644	-15min	wheat	14	24.16	0.28	90
Point 5 (head-top) 2/7/79 2:00 - 2:20pm						
S651	on*	wheat	17sec.	14.67g	$0.31m^3$	$50g/m^3$
S652	off-5min	wheat	16	18.18	0.30	60
S653	-10min	wheat	14	18.55	0.27	70
S654	-15min	wheat	15	18.65	0.30	60
Point 6 (head-discharge spout) 2/7/79 2:35 - 3:00pm						
S661	on*	wheat	7sec.	11.87g	$0.13m^3$	$90g/m^3$
S662	off-5min	wheat	8	28.98	0.14	210
S663	-10min	wheat	7	28.28	0.13	220
S664	-20min	wheat	8	28.88	0.15	190
Point 7 (middle-downside) 2/7/79 11:25 - 11:40am						
S671	on*	wheat	30sec.	12.35g	$0.61m^3$	$20g/m^3$
S672	off-5min	wheat	28	10.58	0.61	17
S673	-10min	wheat	25	11.43	0.55	21
S674	-15min	wheat	23	11.47	0.51	22

SEATTLE, WA

EQUIPMENT SAMPLES - CARGILL EXPERIMENTAL SAMPLER

Scale - hoppercar receiving 50,000 bu/hr, 500 bu cap
each sample consists of 5 "gate-open" cycles,
except upper garner
* dust system for hoppercar scale

Point 1 (upper garner-continuous) 2/13/79 2:55, 3:20pm						
S711	on*	corn	54sec.	7.82g	$1.02m^3$	$8g/m^3$
S712	off	corn	60	11.65	1.25	9
Point 2 (scale compartment) 2/13/79 2:00, 2:35pm						
S721	on*	corn	60sec.	6.82g	$1.58m^3$	$4g/m^3$
S722	off	corn	49	5.00	1.96	5
Point 3 (lower garner) 2/13/79 2:15, 2:30pm						
S731	on*	corn	60sec.	2.95g	$1.64m^3$	$1.8g/m^3$
S732	off	corn	60	1.64	1.36	1.2

APPENDIX B. PARTICLE SIZE DISTRIBUTIONS

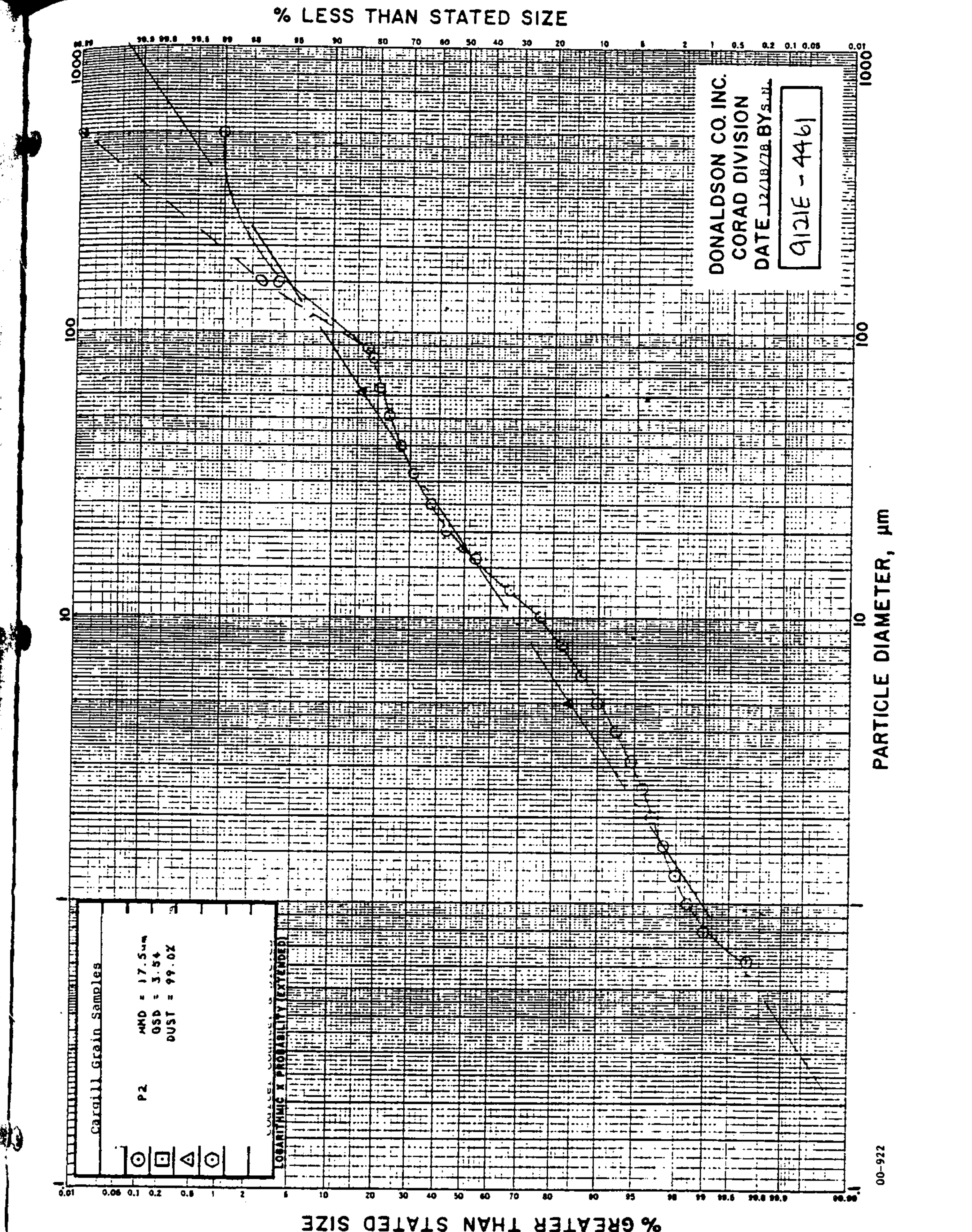
Procedures and discussion of results are in the main body of the report. This section consists of log-probability charts indicating percent weight or volume (read along right side) less than a given particle diameter in micrometers, μm (read along the bottom). Additional data included with each chart are shown in the title block -

Mean mass diameter (MMD), μm

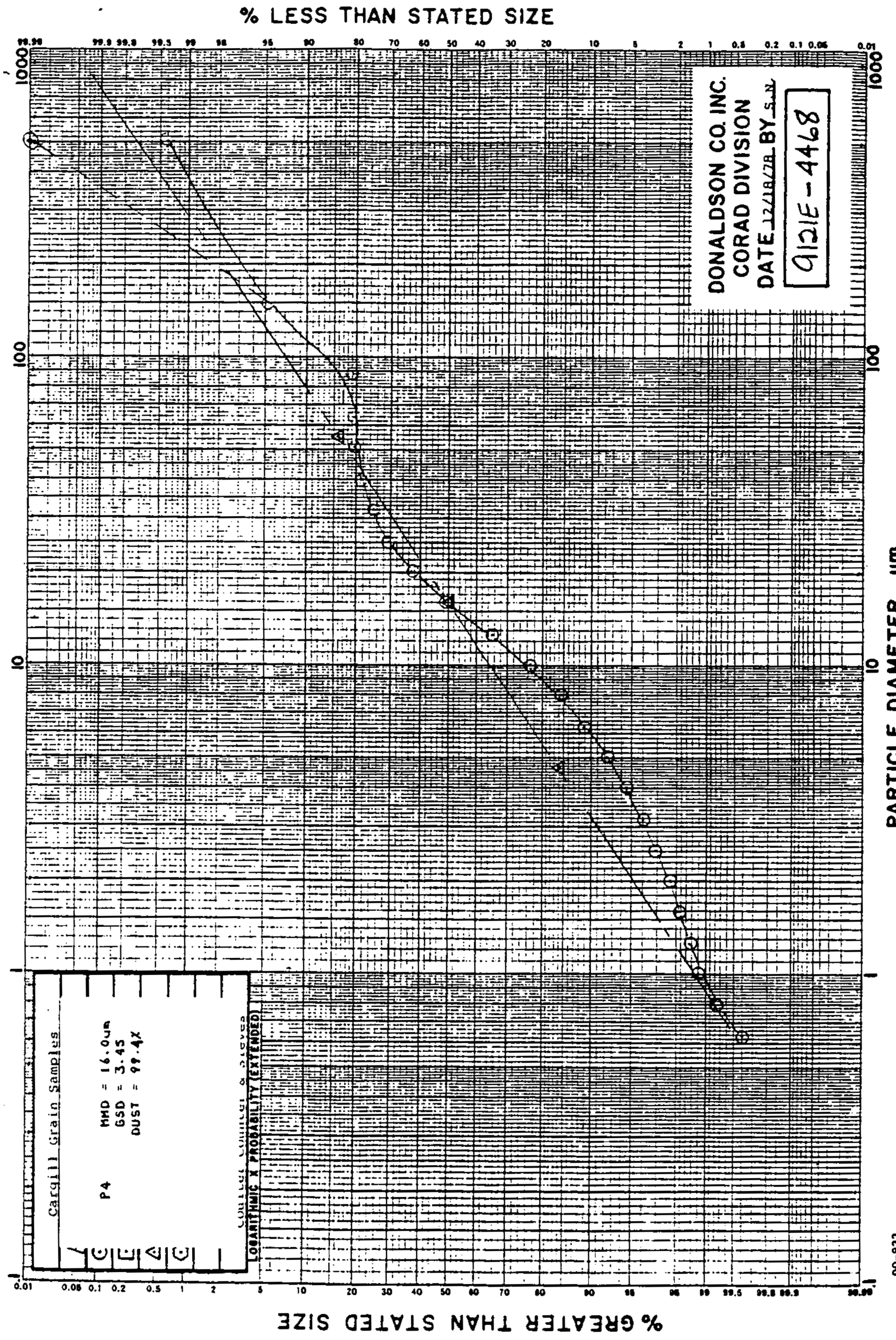
Multiplier for geometric standard deviation

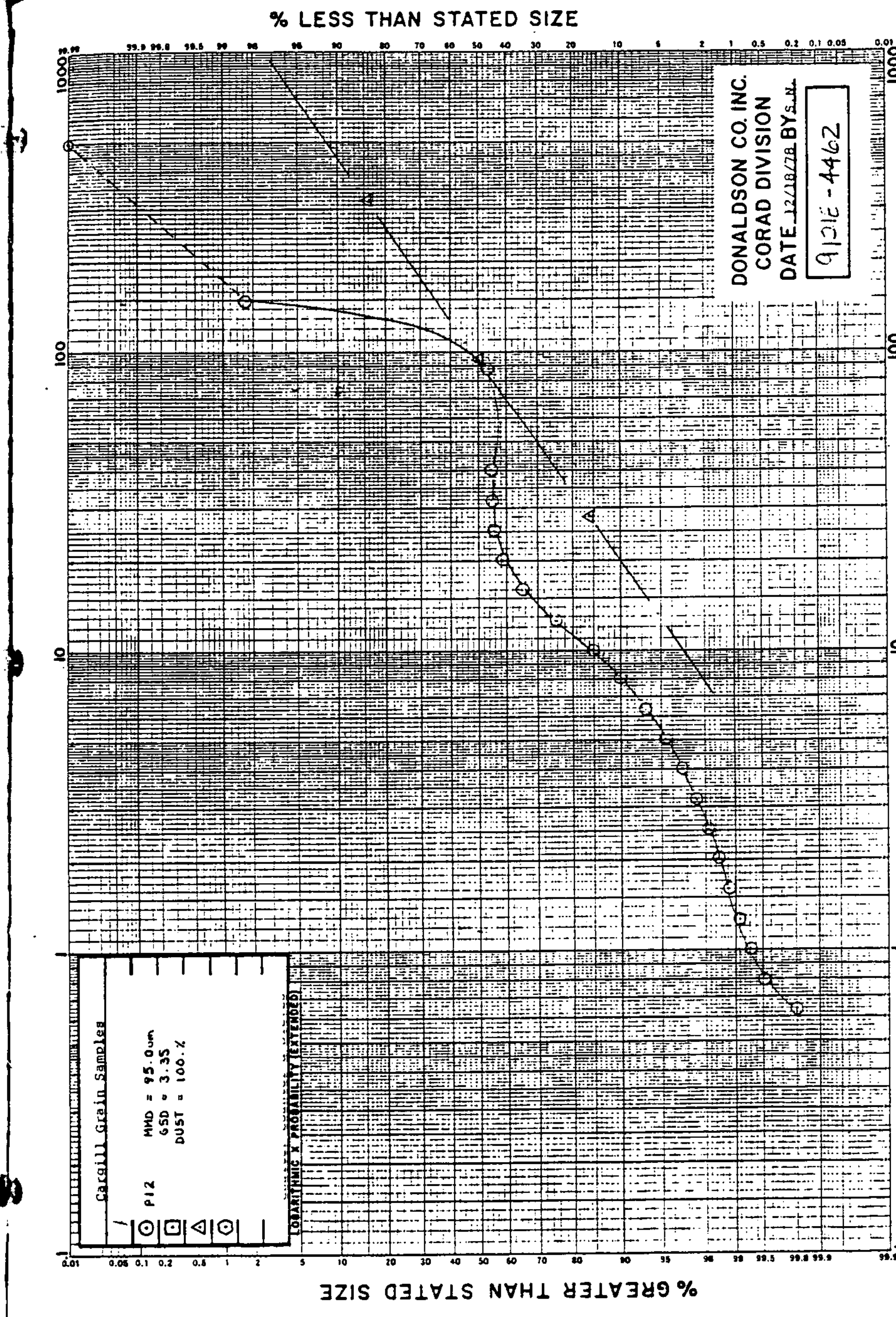
$$M = \left(\frac{\text{dia. @ 84.1\%}}{\text{dia. @ 15.9\%}}\right)^{\frac{1}{2}}$$

Dust, weight of material passing 500 μm sieve, percent.

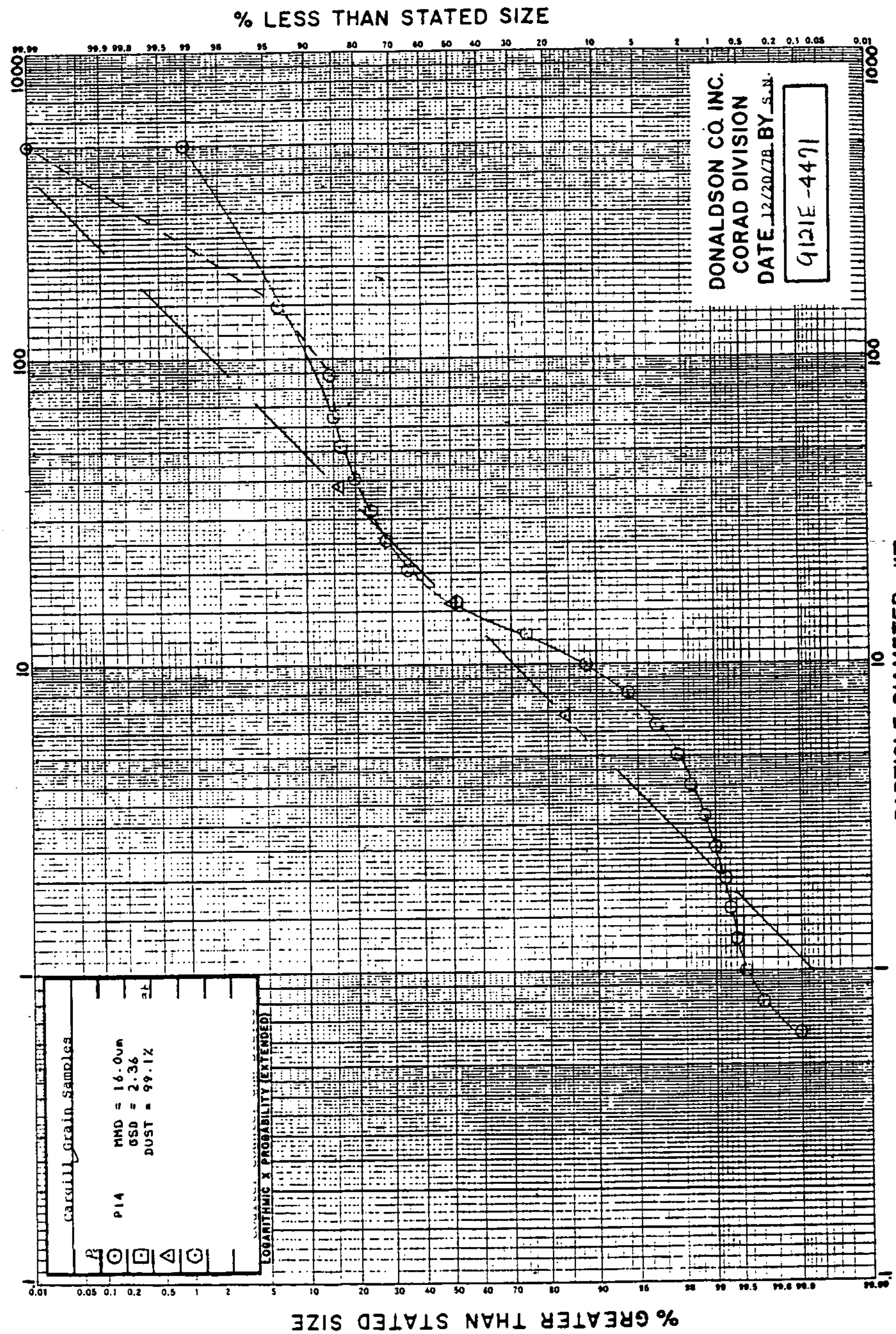


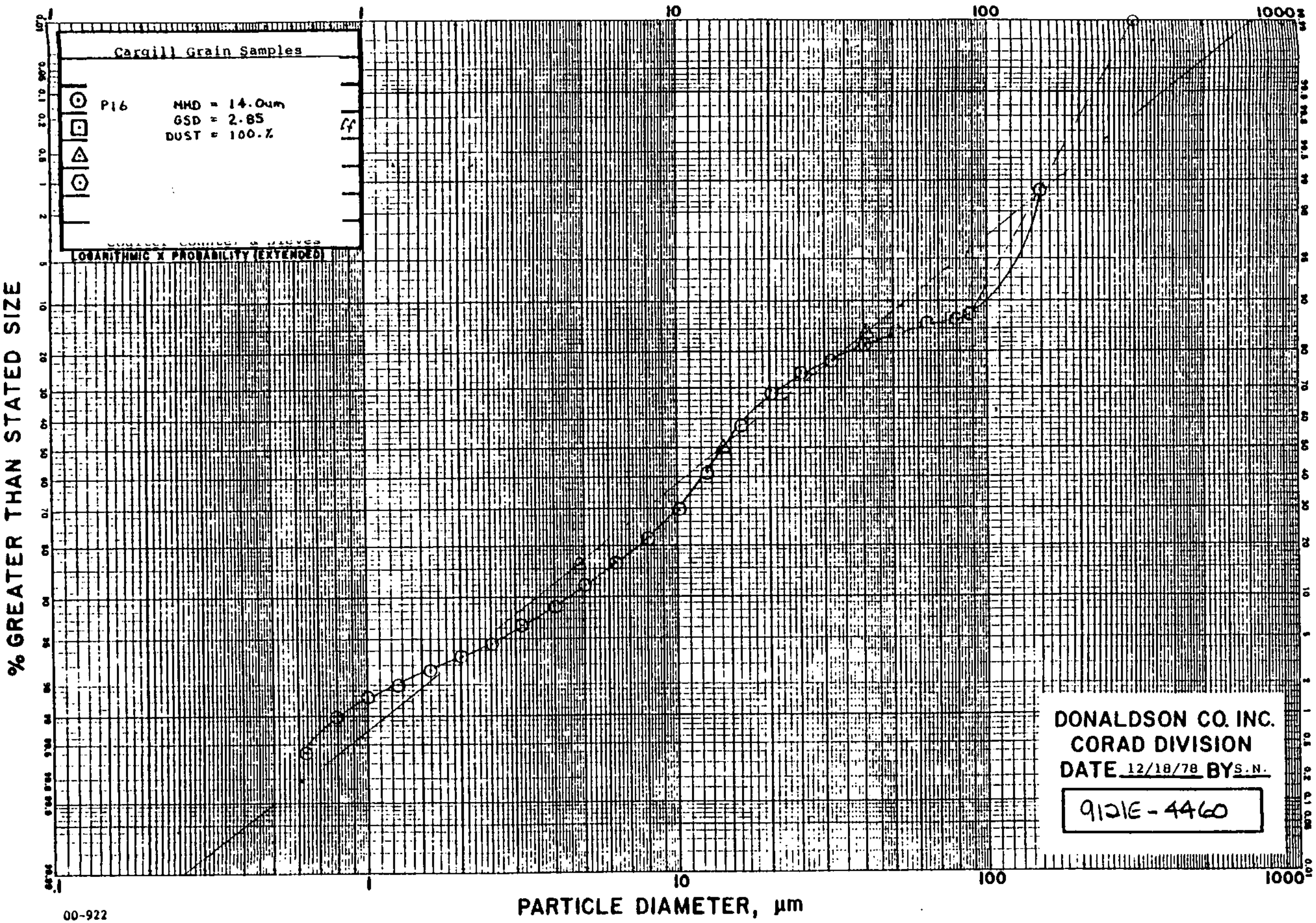
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E - 4461
Cargill Grain Samples
P2
MMD = 17.5 µm
GSD = 3.54
DUST = 99.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N
9121E-4468
Cargill Grain Samples
P4
MMD = 16.0um
GSD = 3.45
DUST = 99.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922



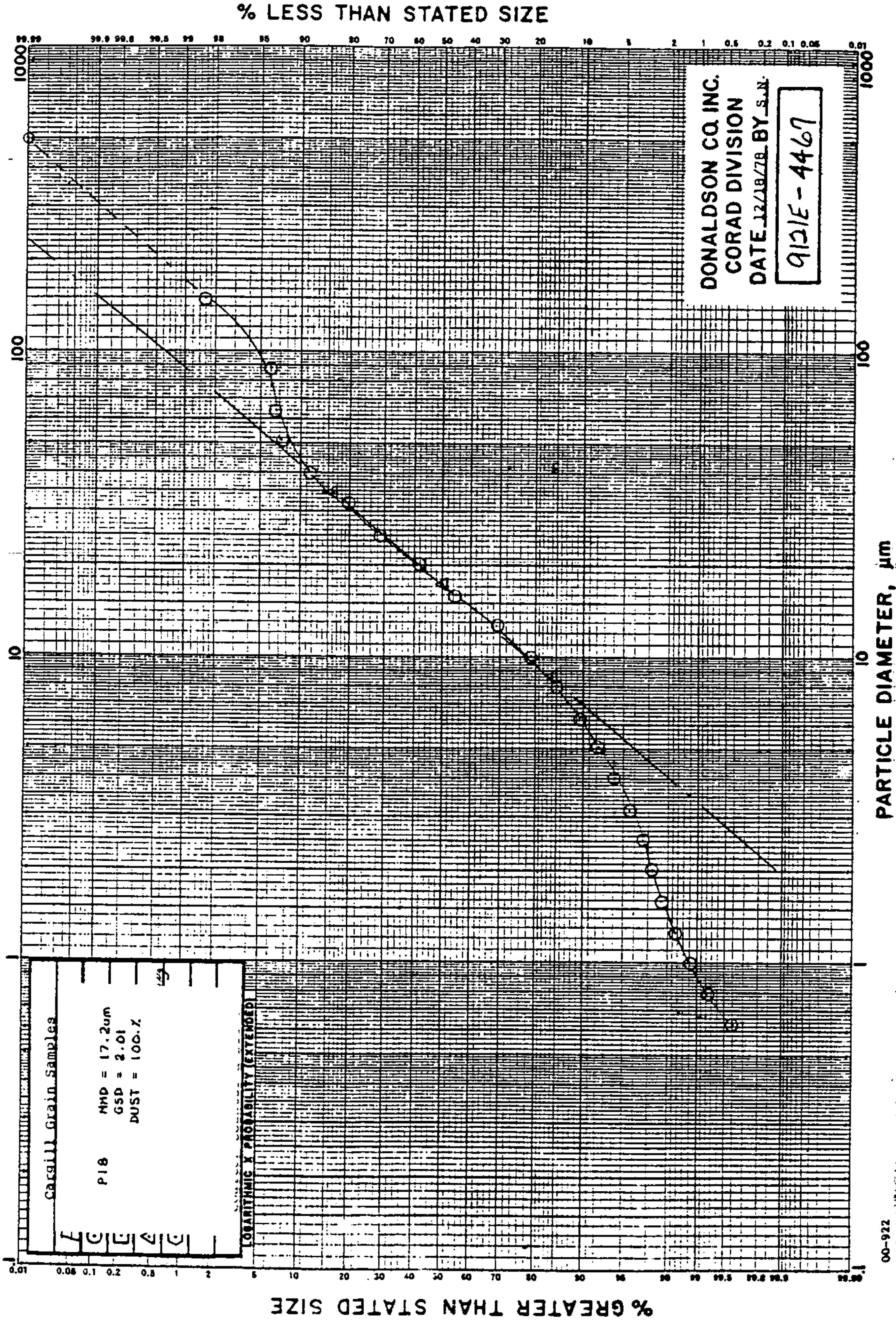
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4462
Cargill Grain Samples
P12
MMD = 95.0um
GSD = 3.35
DUST = 100.%
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/20/78 BY S.N.
9121E-4471
PARTICLE DIAMETER, μm
Cargill Grain Samples
P14
MMD = 16.0um
GSD = 2.36
DUST = 99.1%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-923

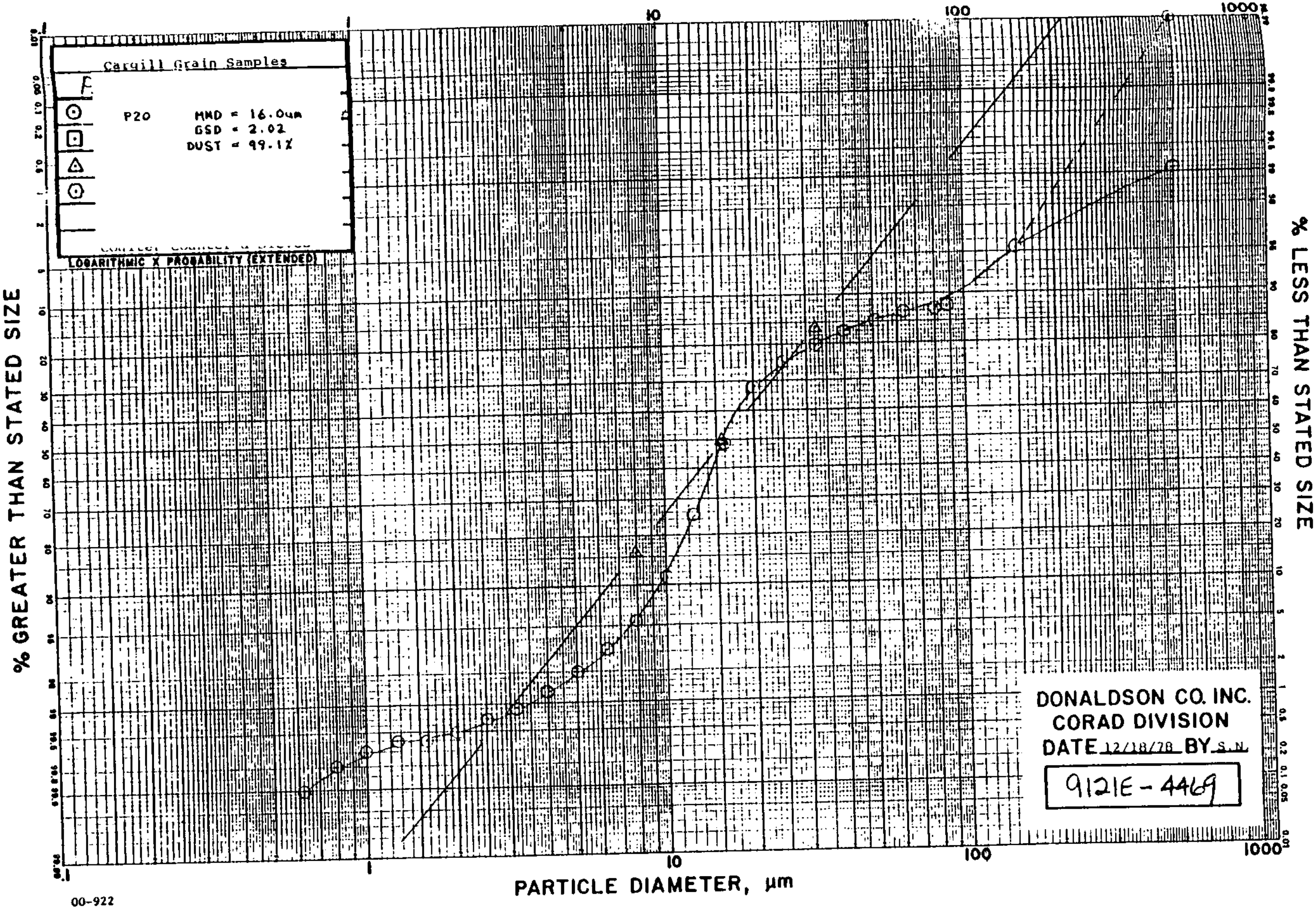


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
Cargill Grain Samples
P16
MMD = 14.0um
GSD = 2.85
DUST = 100.%
LOGARITHMIC X PROBABILITY (EXTENDED)
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4460

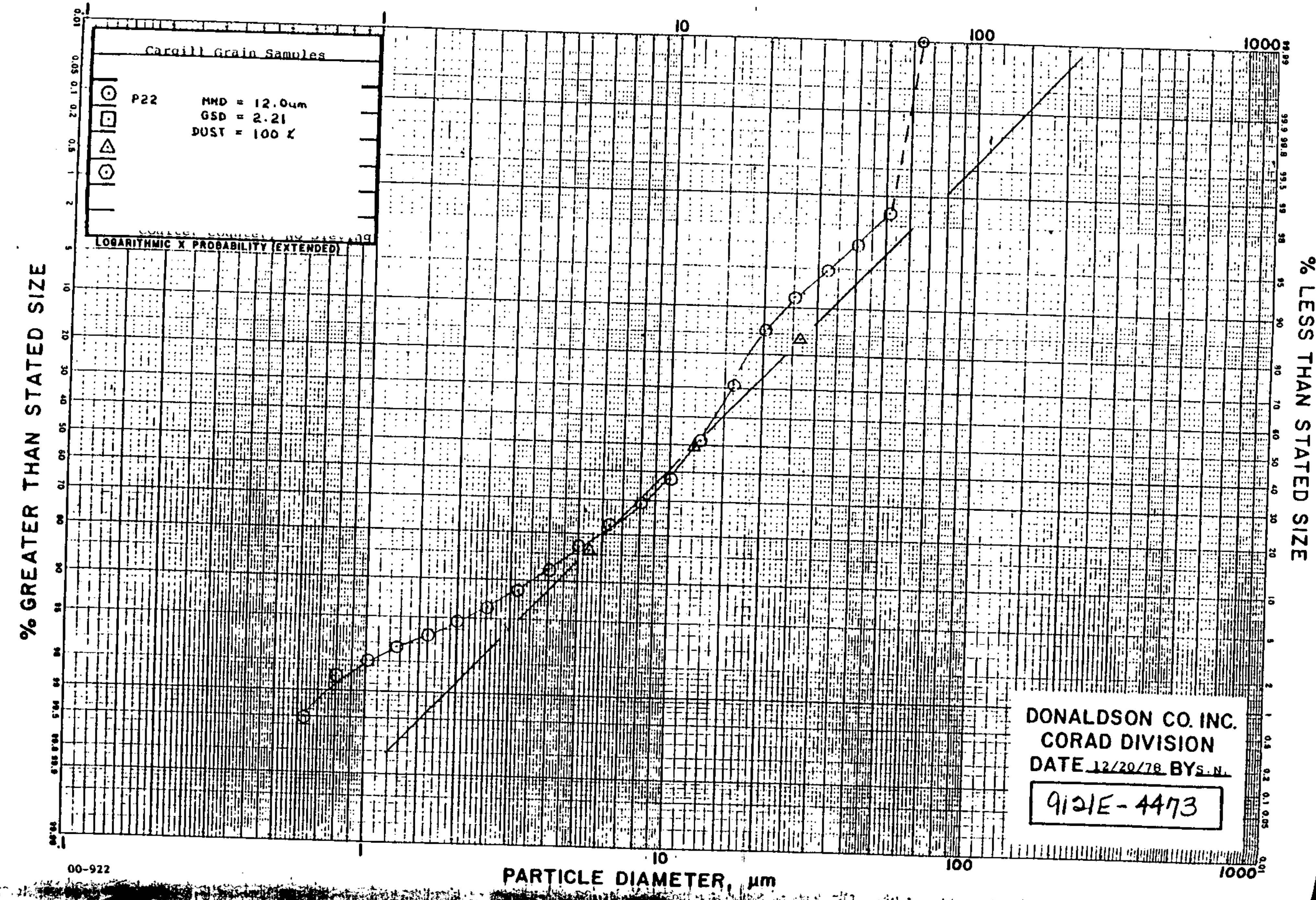
00-922

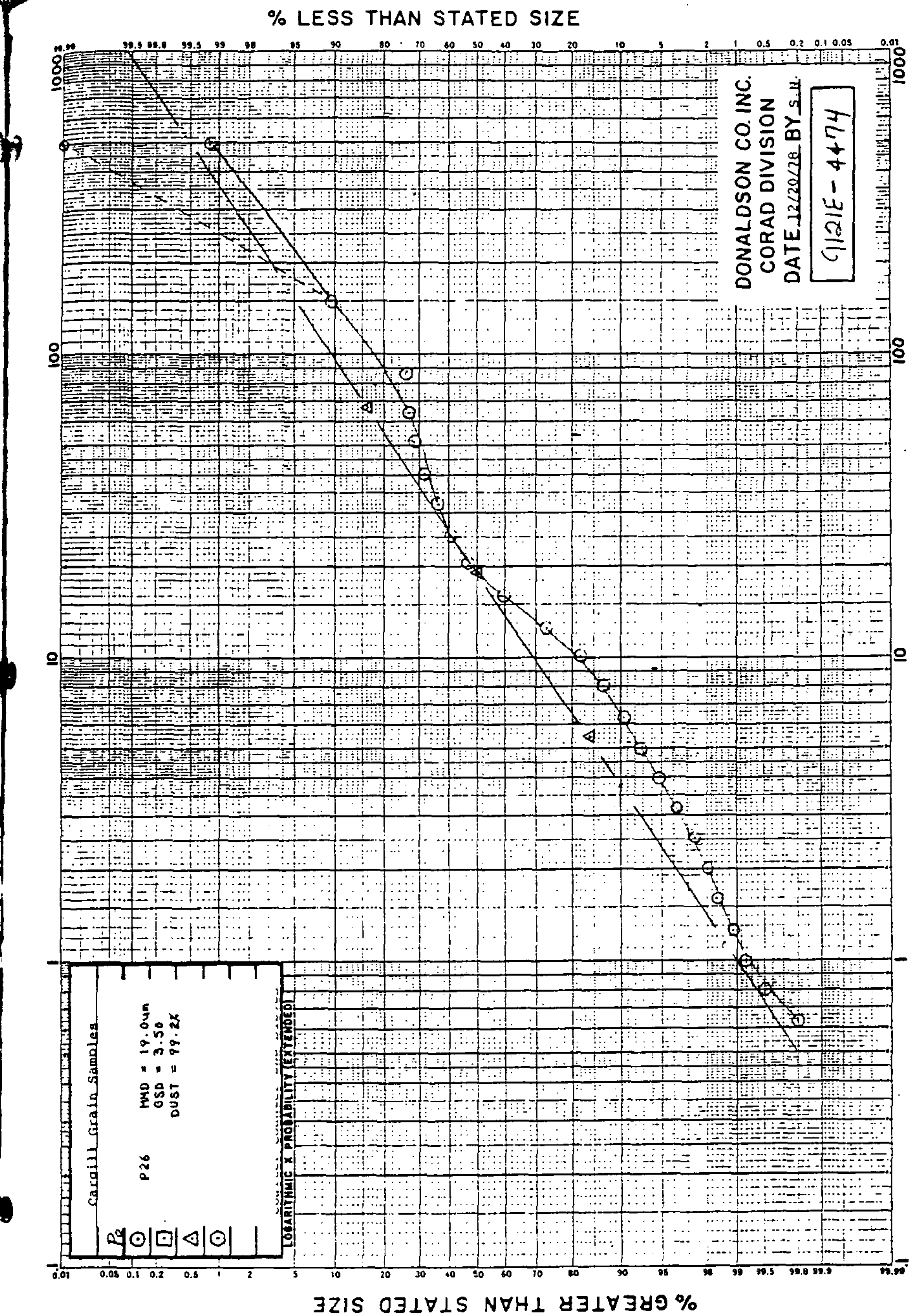


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4467
PARTICLE DIAMETER, µm
Cargill Grain Samples
P18
MMD = 17.2um
GSD = 2.01
DUST = 100.%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

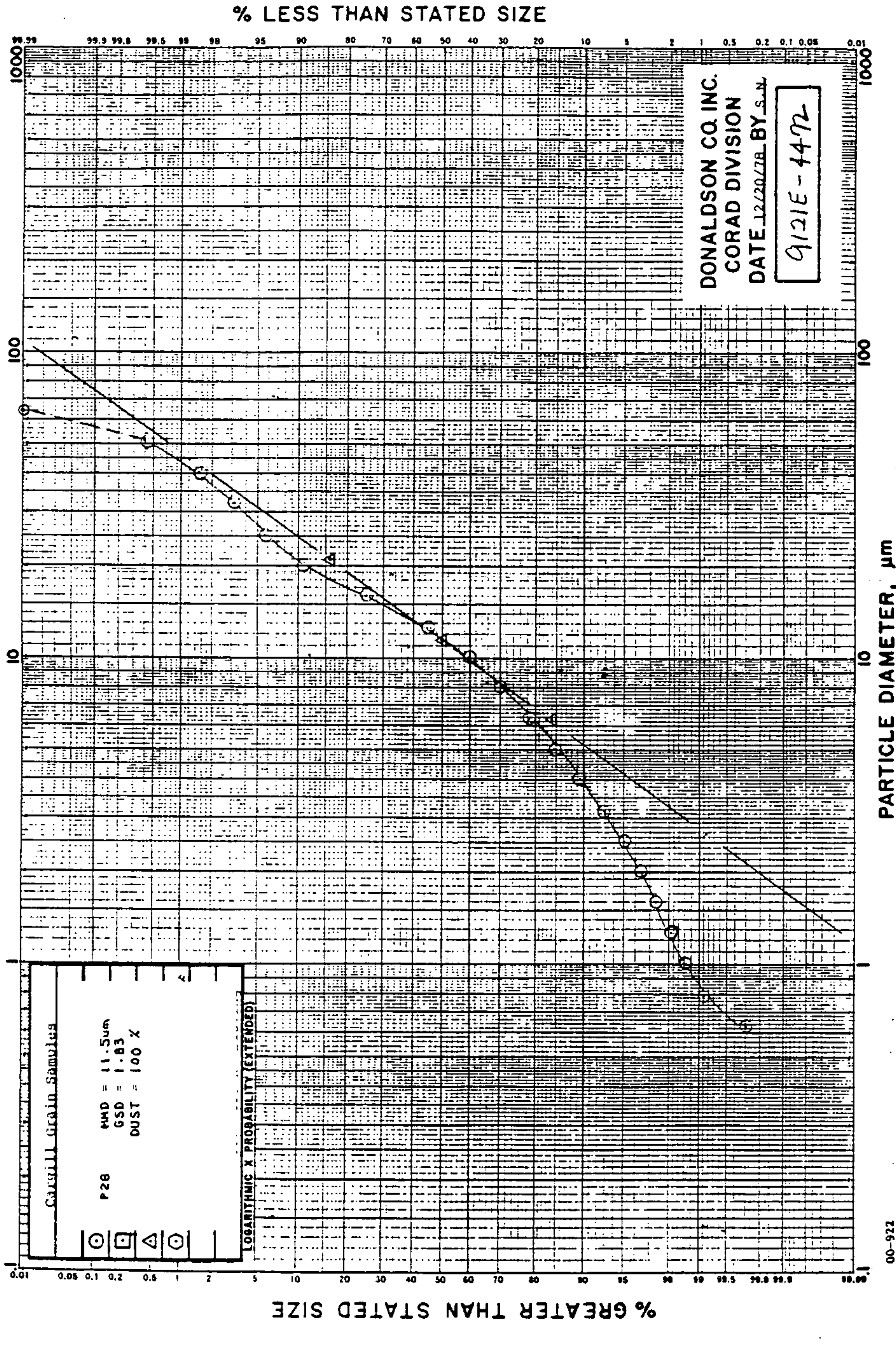


Cargill Grain Samples
P20 MMD = 16.0um
GSD = 2.02
DUST = 99.1%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4469
00-922

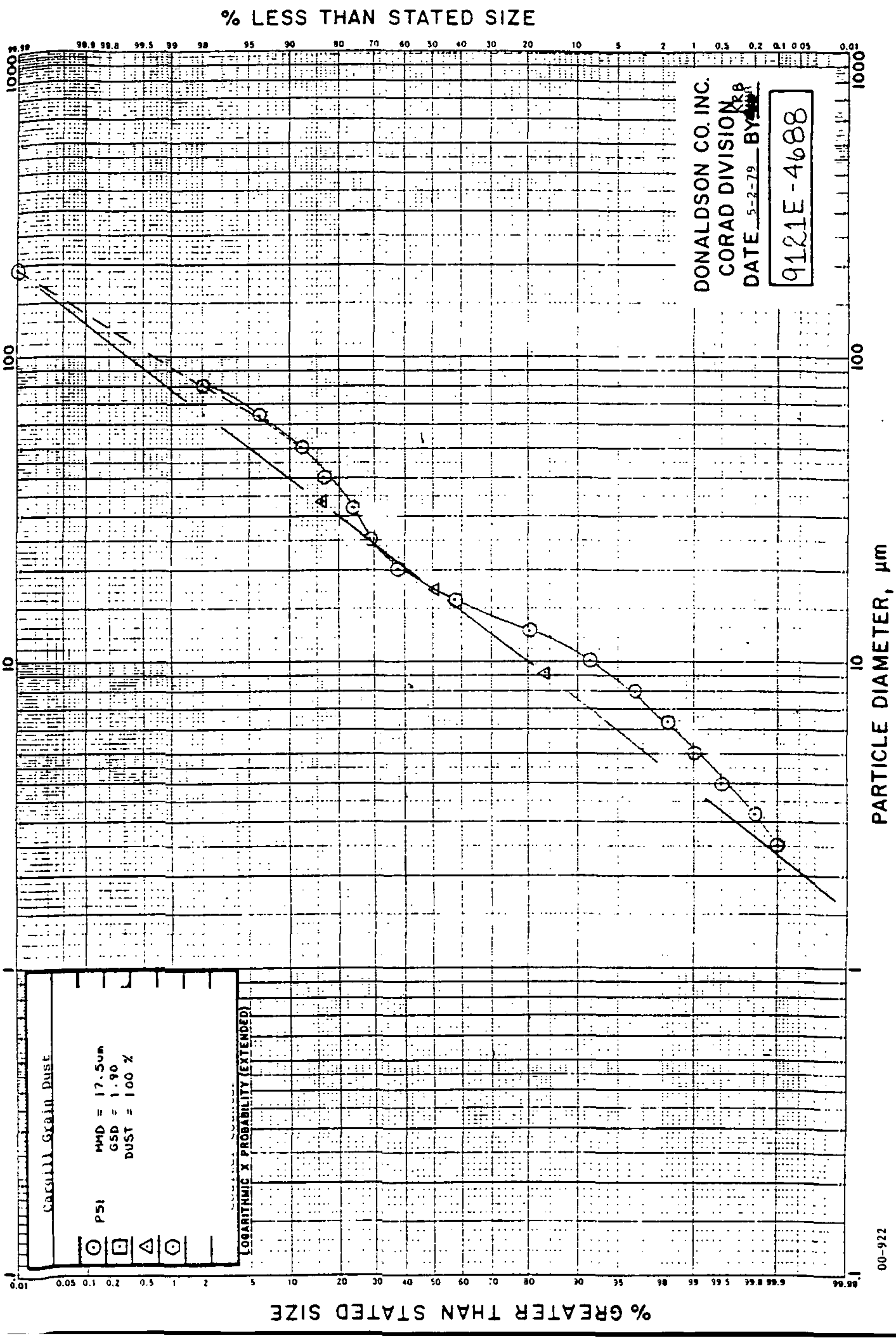

Cargill Grain Samples
P22
MMD = 12.0um
GSD = 2.21
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/20/78 BY S.N.
9121E - 4473
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/20/78 BY S.N.
9121E-4474
PARTICLE DIAMETER, µm
Cargill Grain Samples
P26
MMD = 19.0um
GSD = 3.50
DUST = 99.2%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE

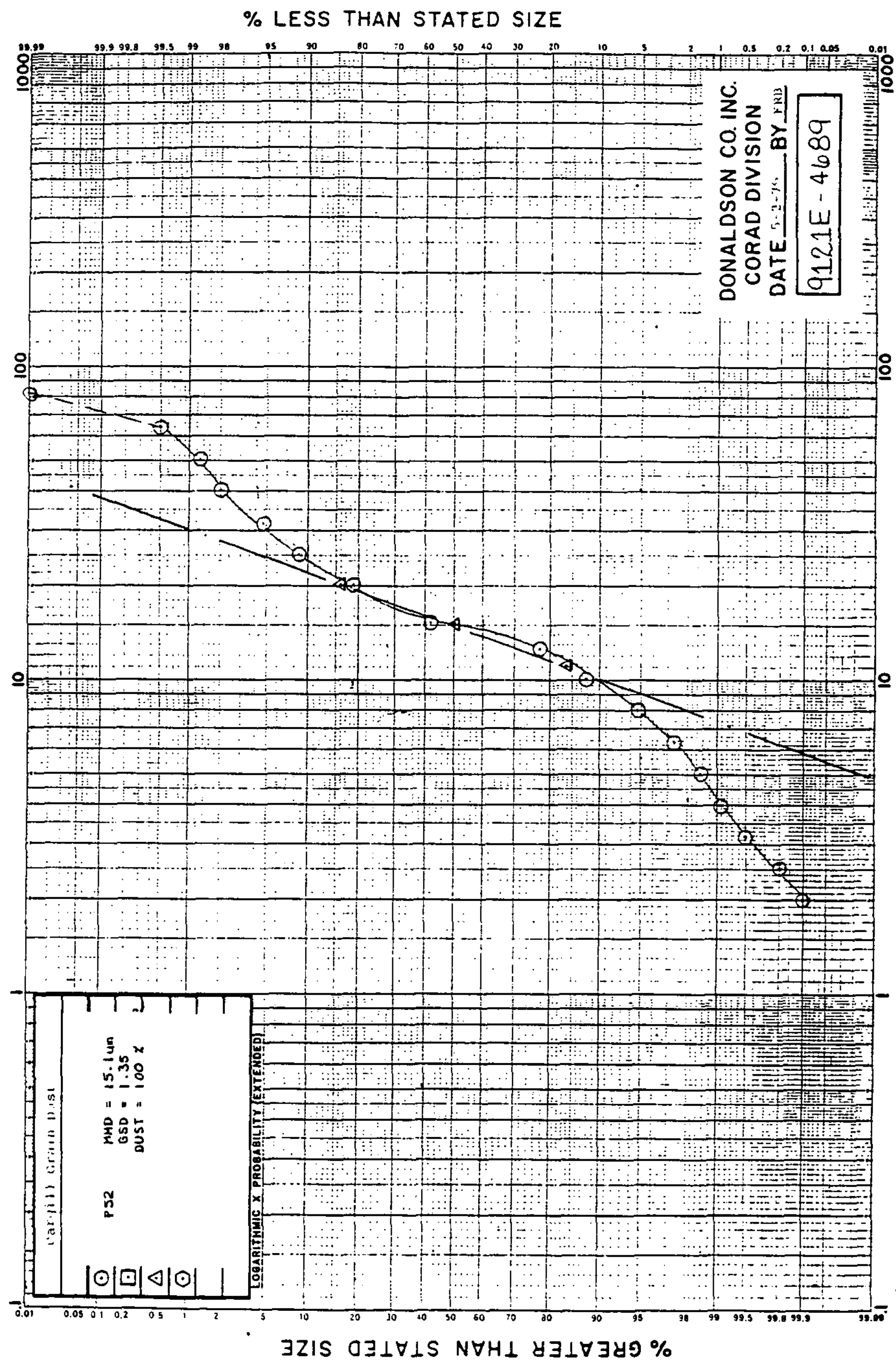
00-922

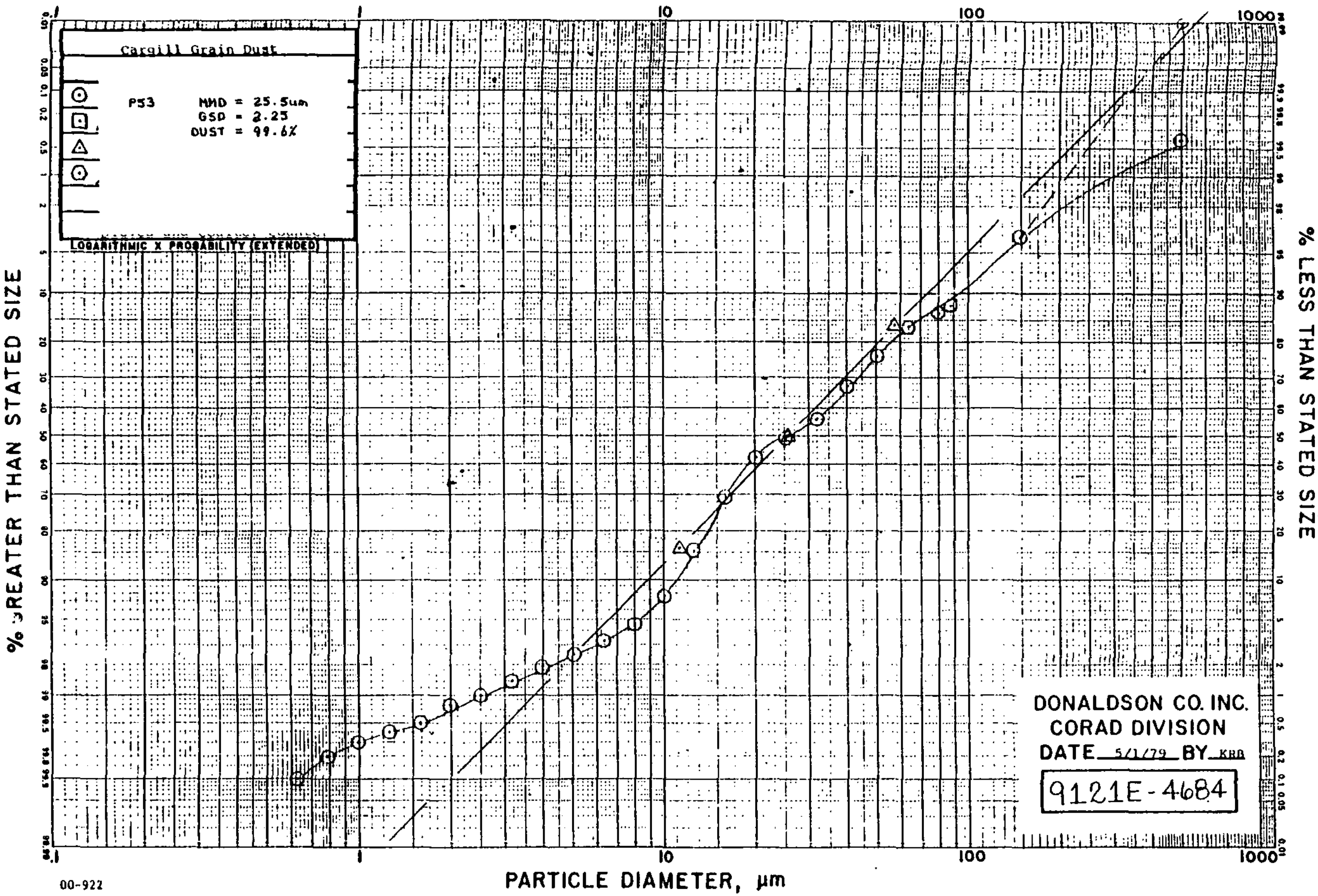


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/20/78 BY S.N
9121E-4472
Cargill Grain Samples
P28
MMD = 11.5um
GSD = 1.83
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

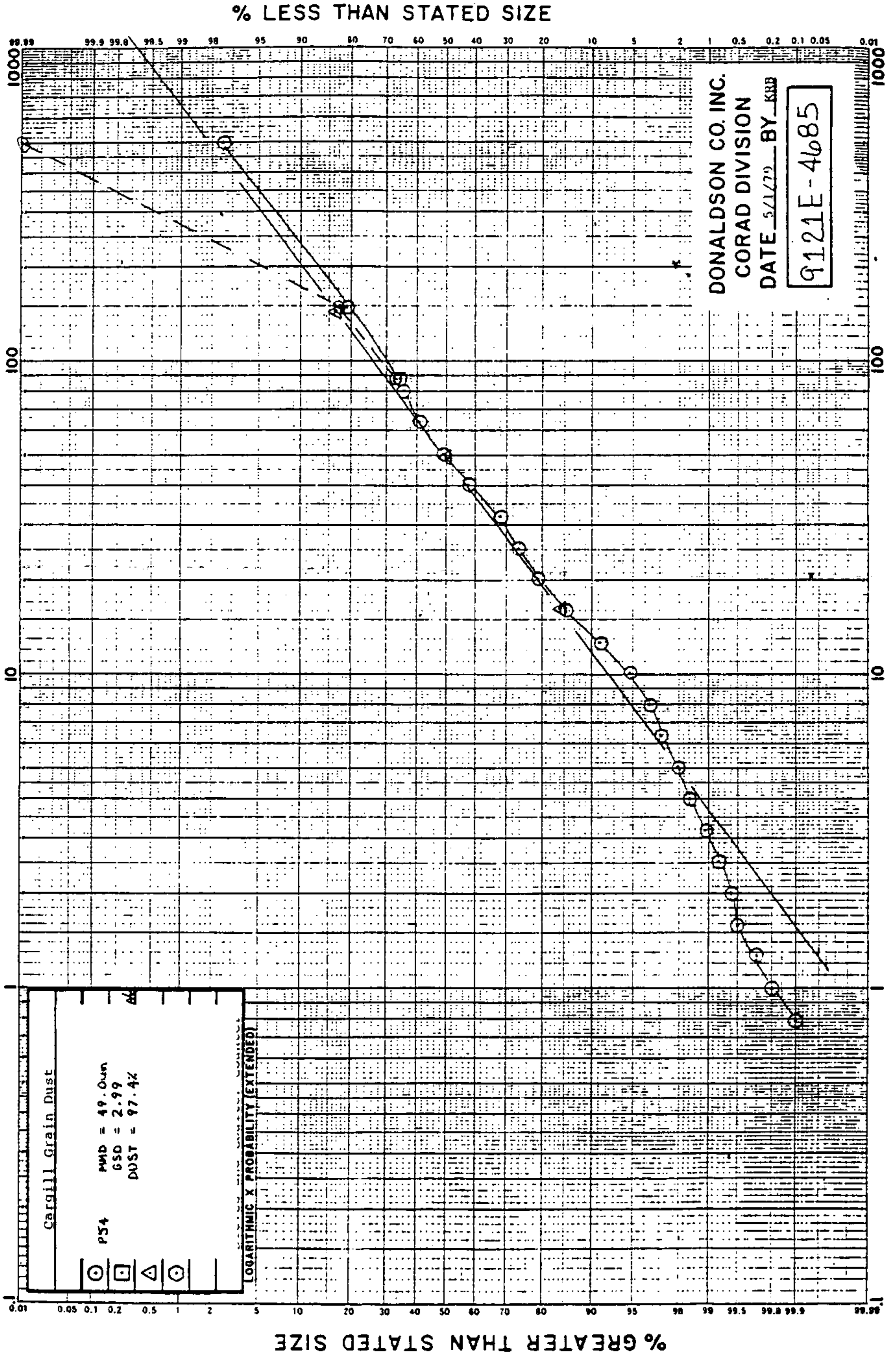


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E-4688
PARTICLE DIAMETER, µm
Cargill Grain Dust
MMD = 17.5um
GSD = 1.90
DUST = 100 %
PSI
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

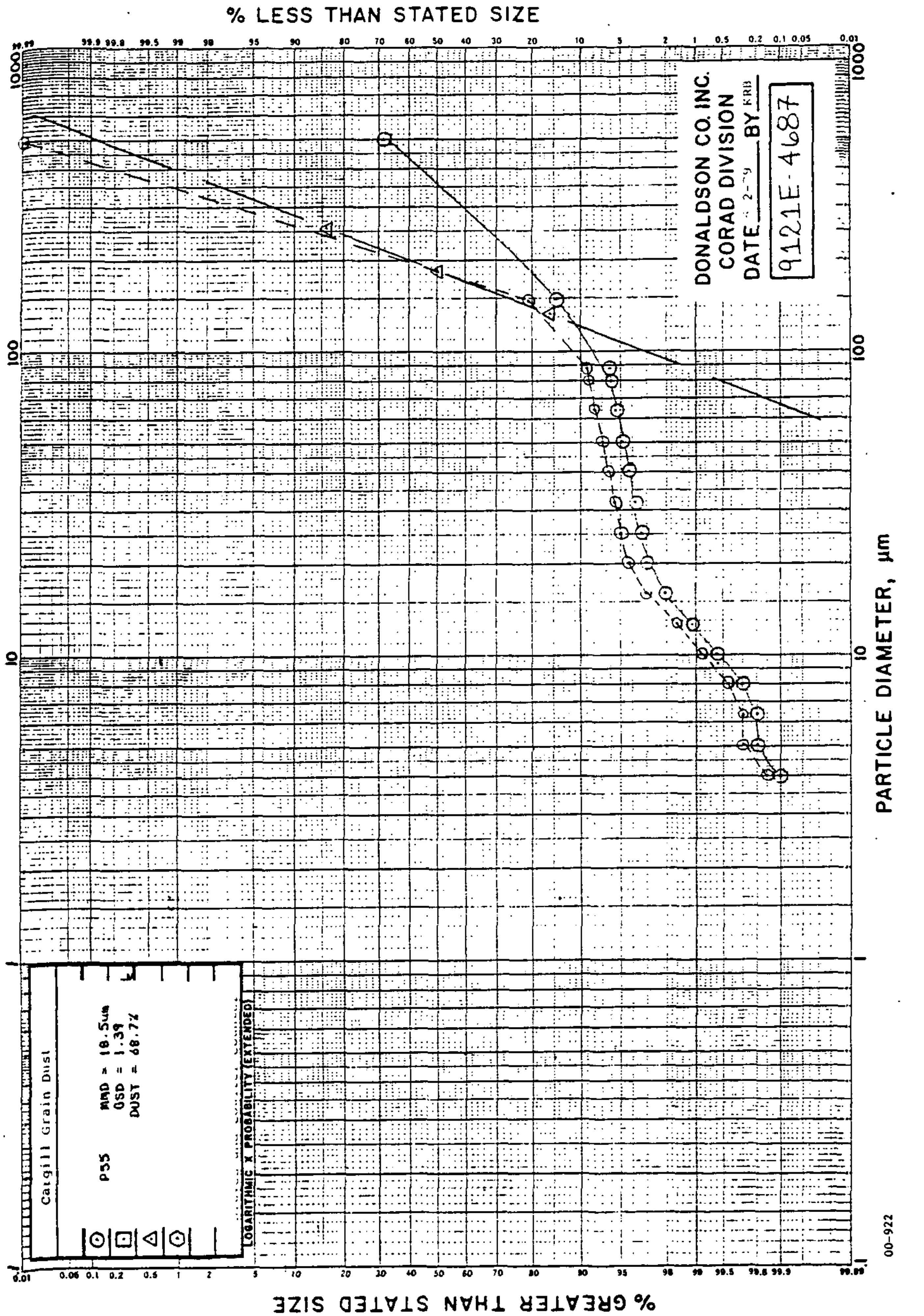

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-78 BY FRB
9121E - 4689
PARTICLE DIAMETER, μm
Cargill Grain Dust
P52
MMD = 15.1um
GSD = 1.35
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



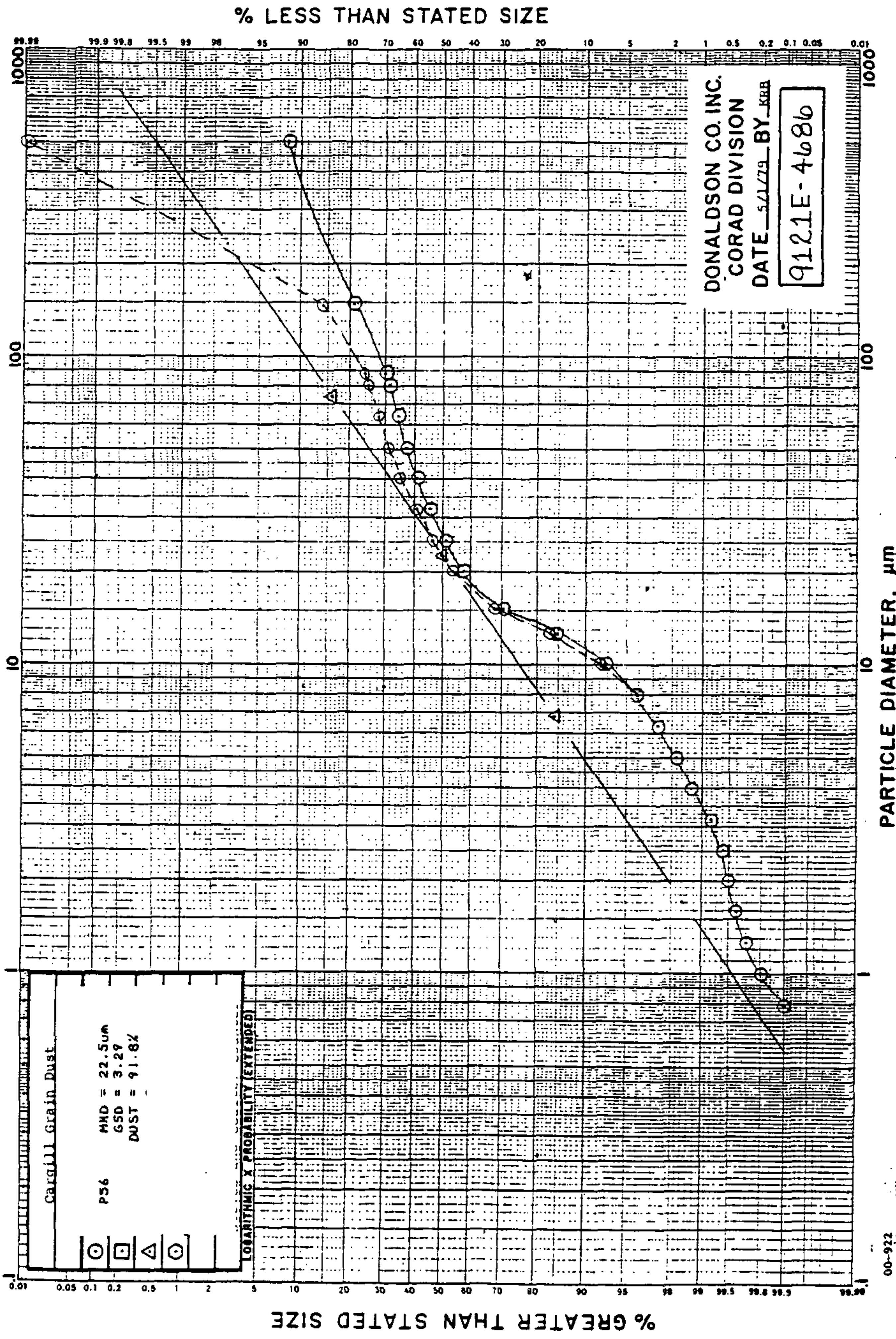
Cargill Grain Dust
P53
MMD = 25.5um
GSD = 2.25
DUST = 99.6%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4684
00-922

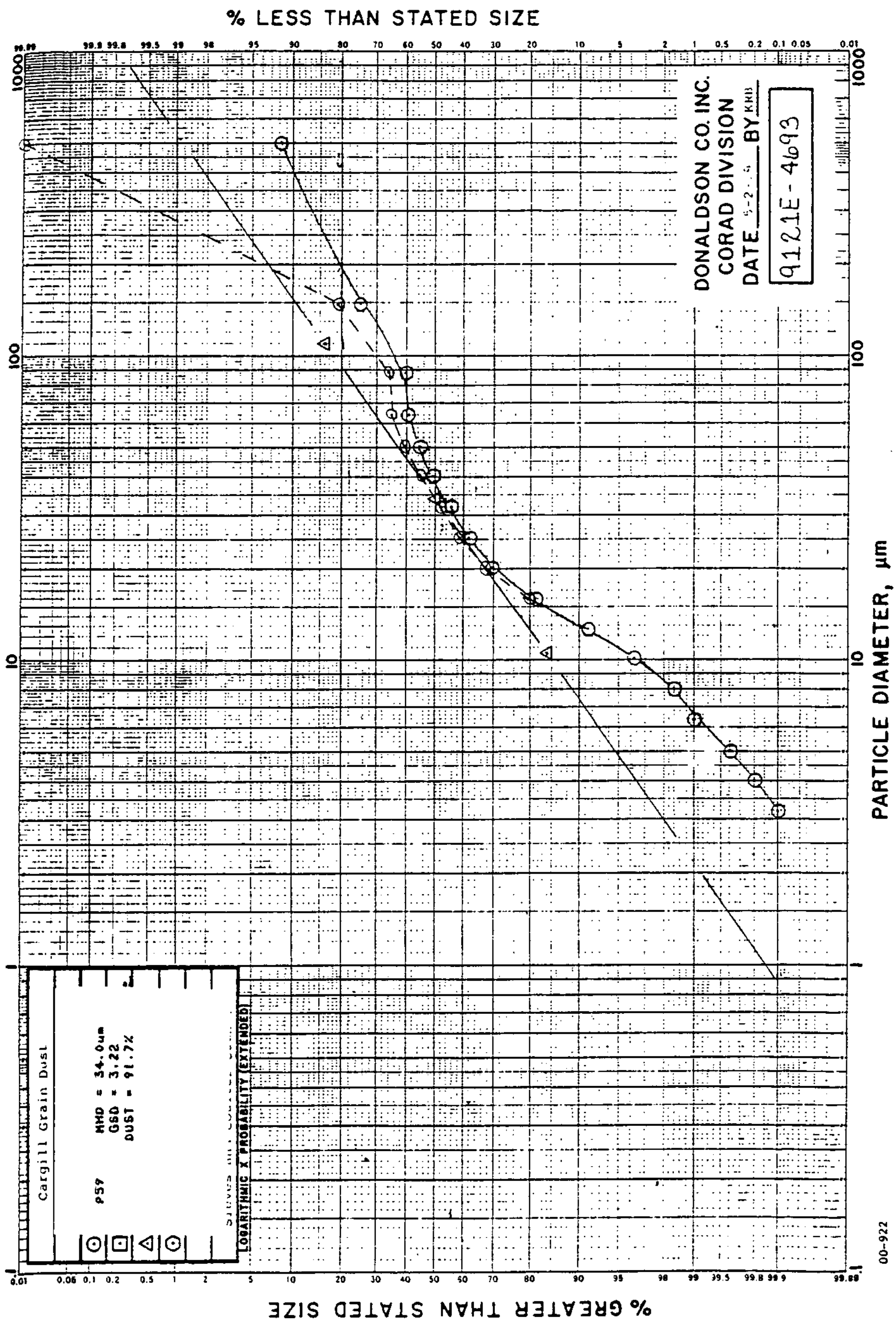


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4685
Cargill Grain Dust
P54
MMD = 49.0um
GSD = 2.99
DUST = 97.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

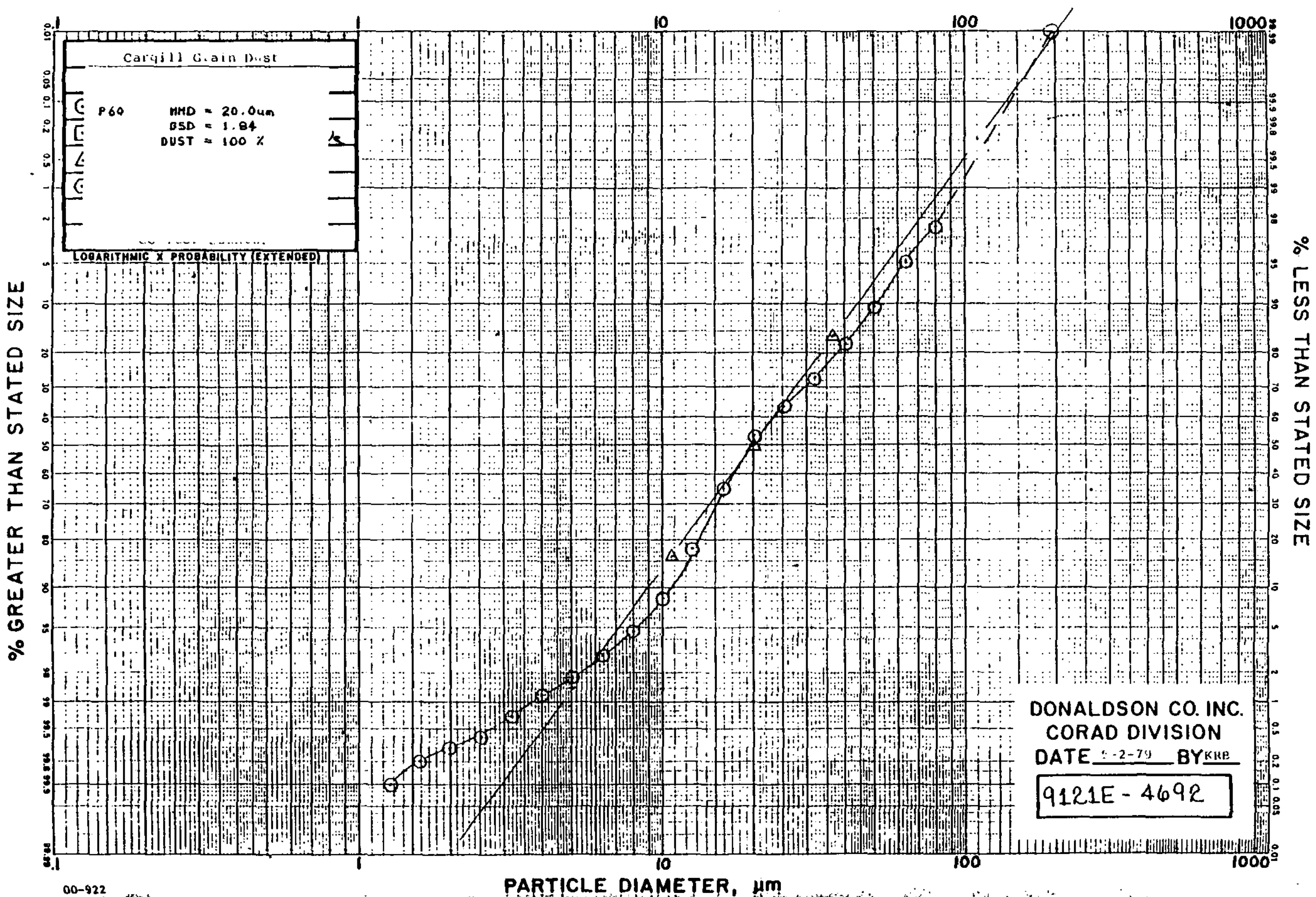


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY
9121E-4687
PARTICLE DIAMETER, µm
Cargill Grain Dust
P55
MMD = 18.5um
OSD = 1.39
DUST = 68.7%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

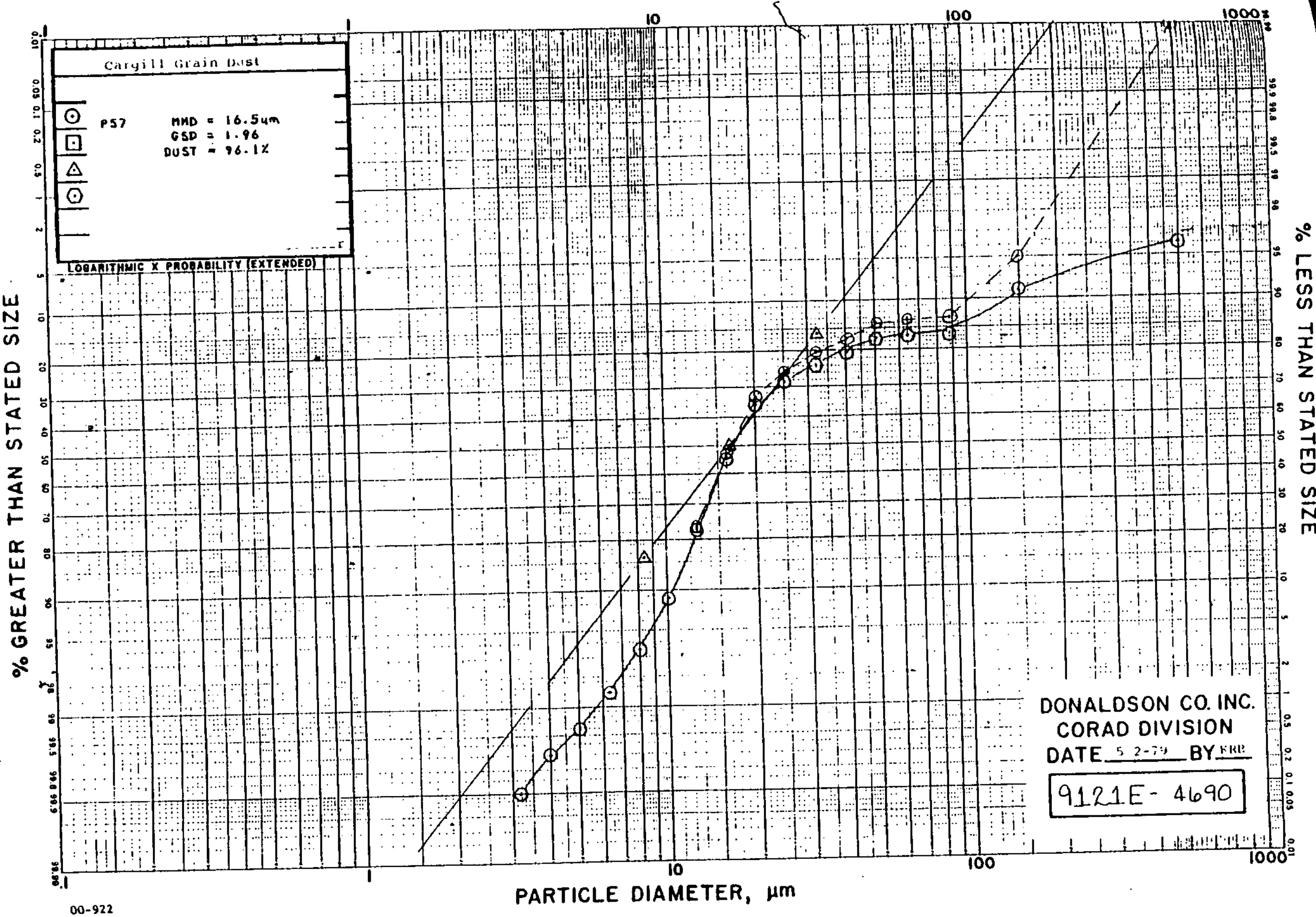

% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4686
Cargill Grain Dust
P56
MMD = 22.5um
GSD = 3.29
DUST = 91.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

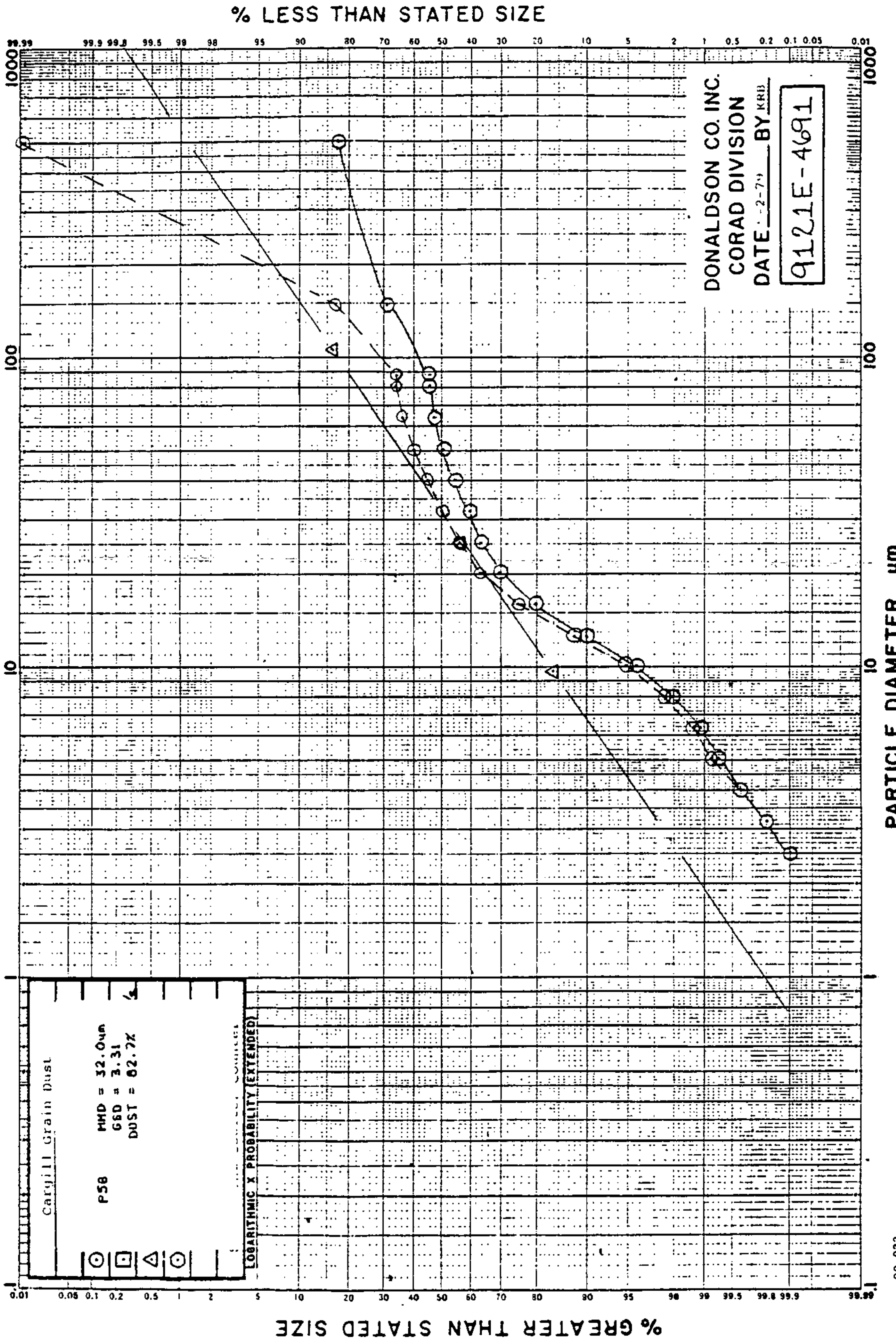


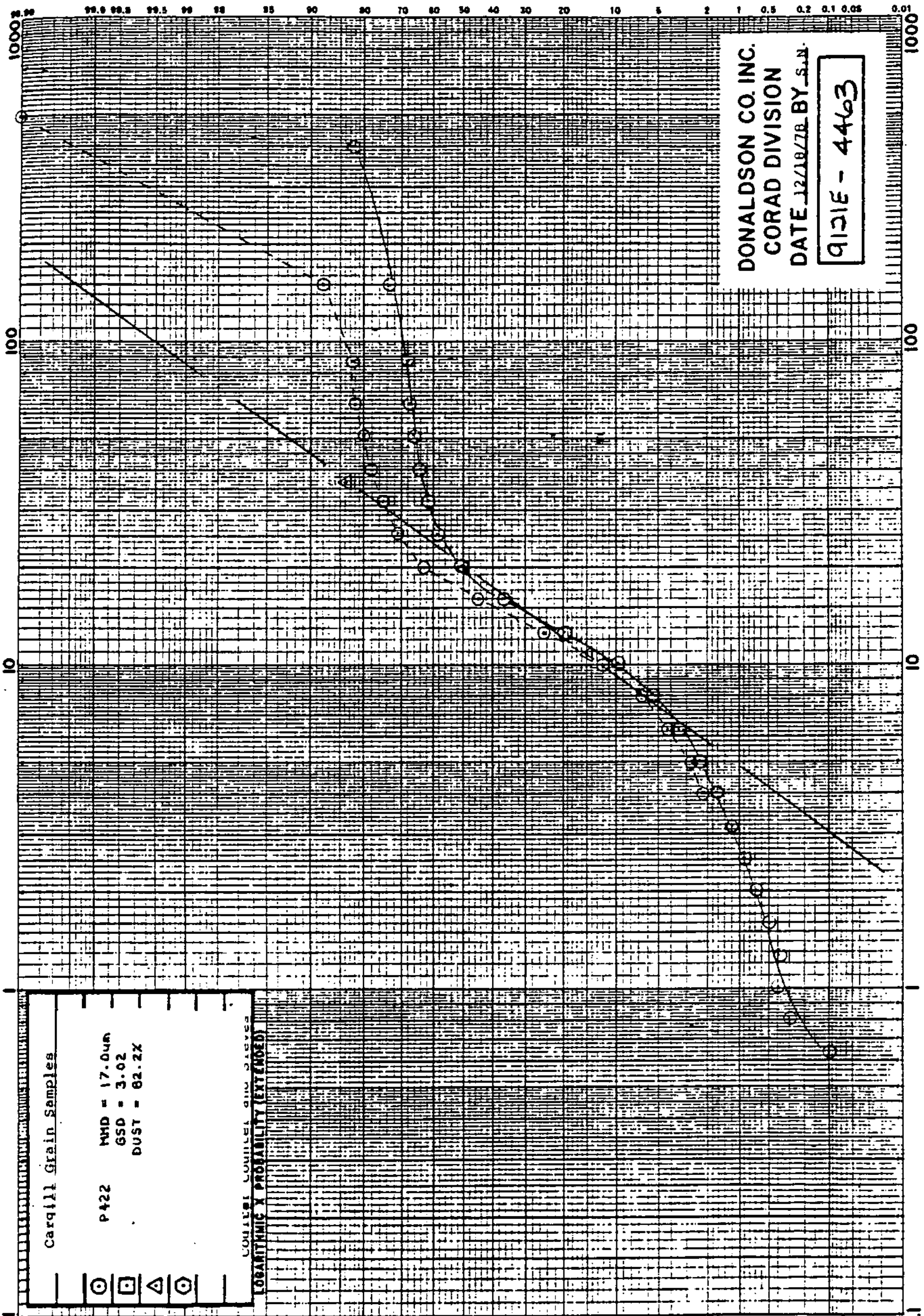
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY KNB
9121E-4693
Cargill Grain Dust
P59
MMD = 34.0um
GSD = 3.22
DUST = 91.7%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



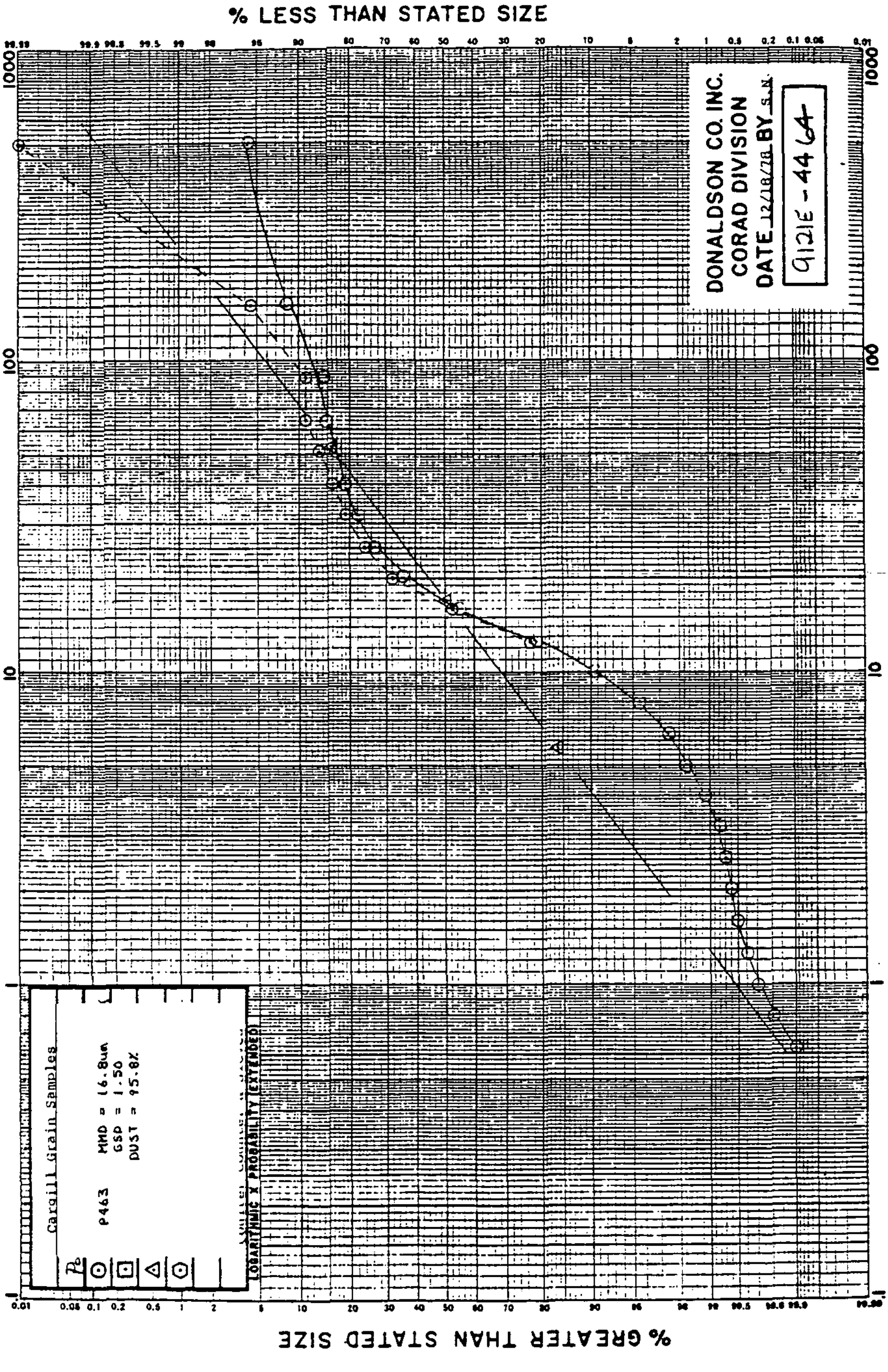
Cargill Grain Dust
P60
MMD = 20.0um
ßSD = 1.84
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
.1
1
10
100
1000
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E - 4692
00-922


Cargill Grain Dust
P57
MMD = 16.5um
GSD = 1.96
DUST = 96.1%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E - 4690
00-922

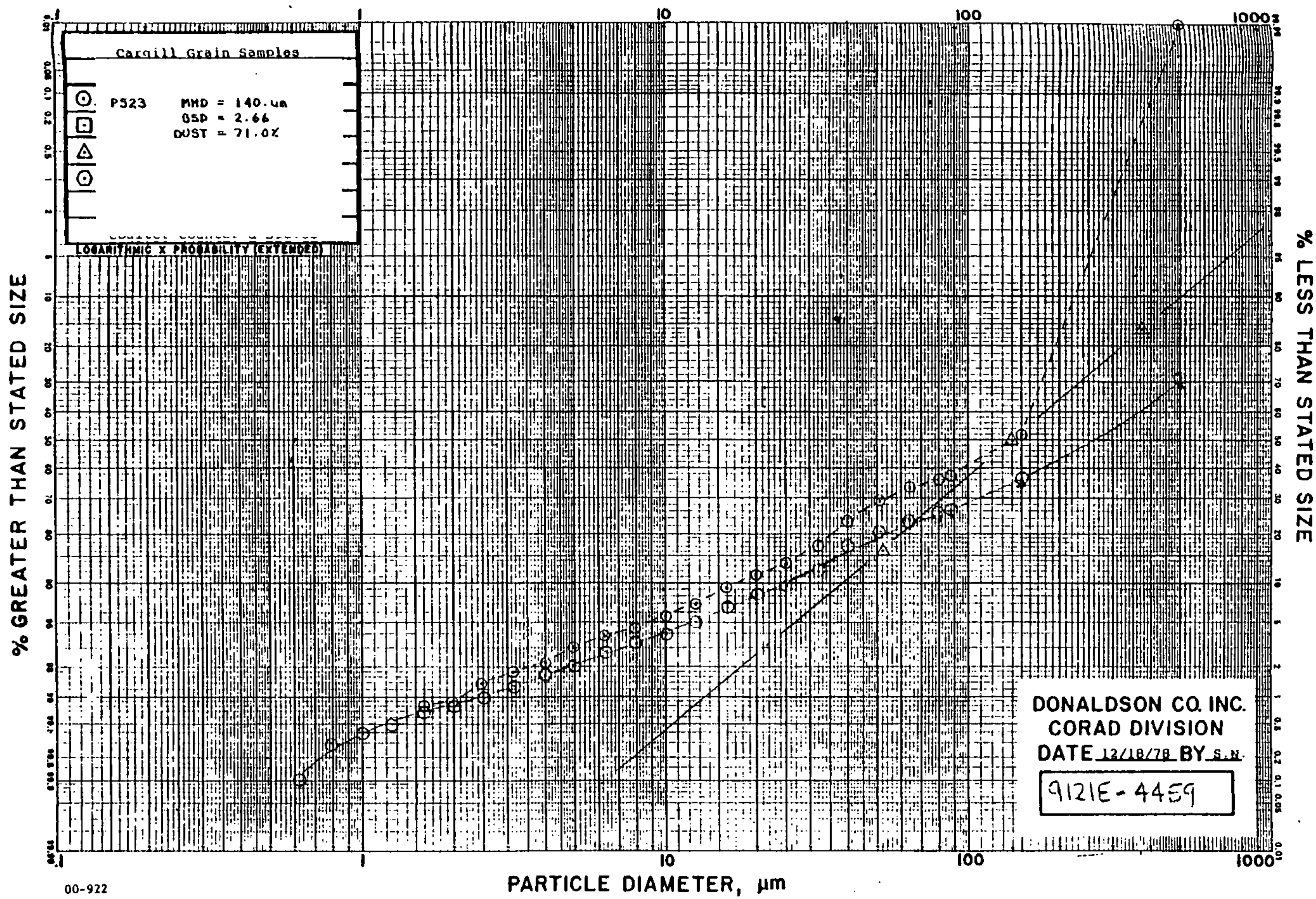

% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE -2-79 BY KRB
9121E-4691
Cargill Grain Dust
P58
MMD = 32.0um
GSD = 3.31
DUST = 82.7%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

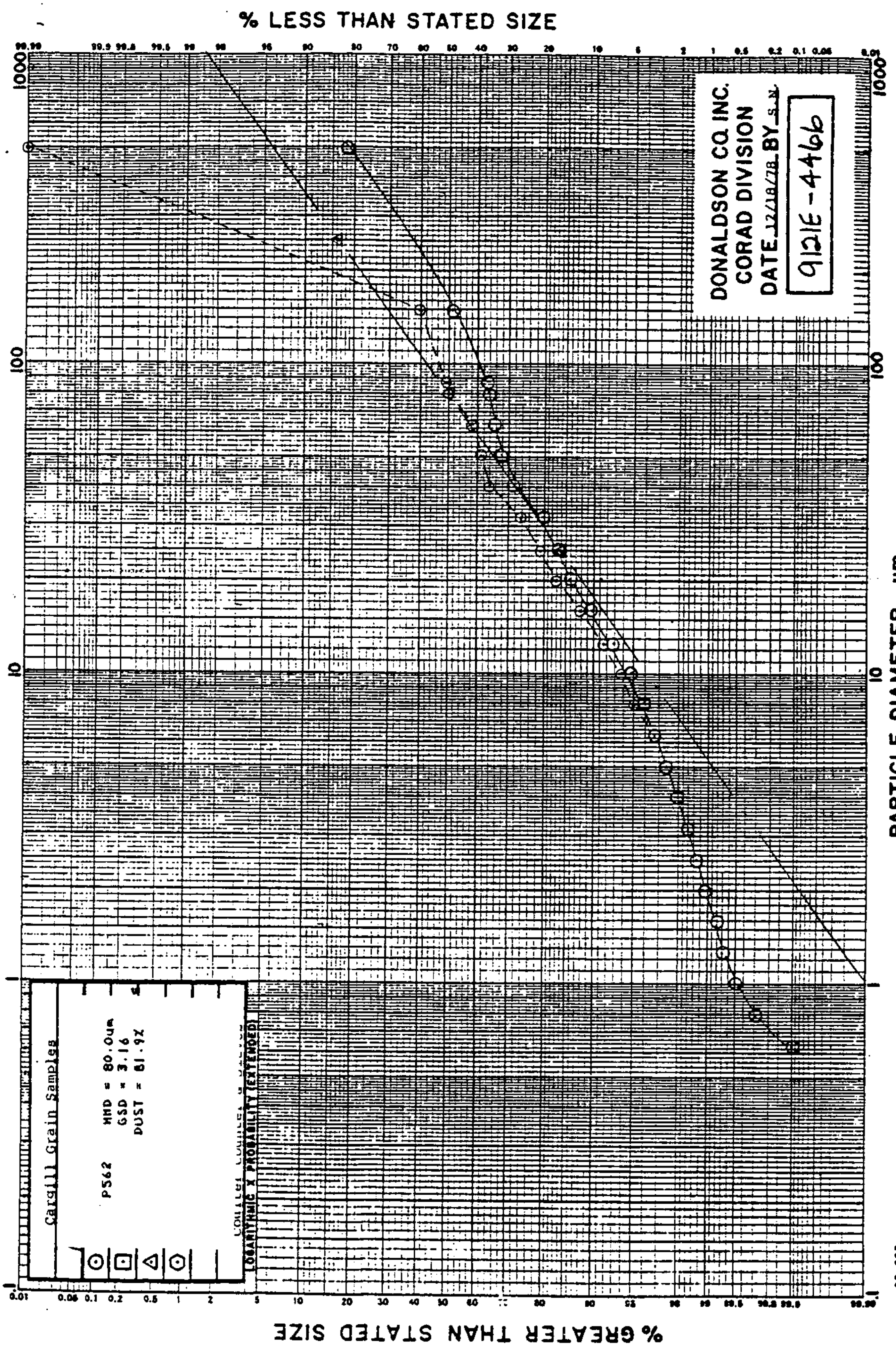


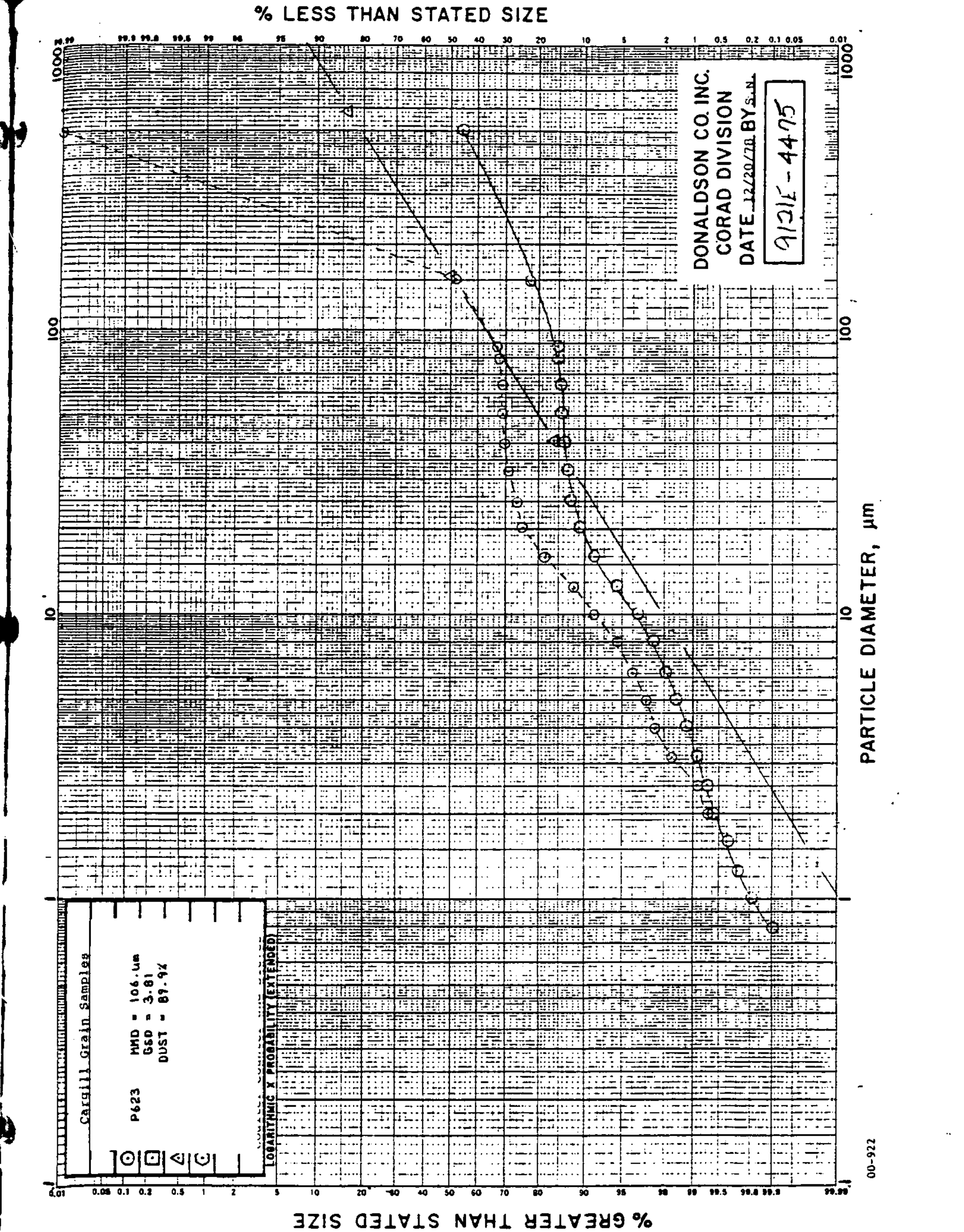
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E - 4463
Cargill Grain Samples
P422 MMD = 17.0um
GSD = 3.02
DUST = 82.2%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

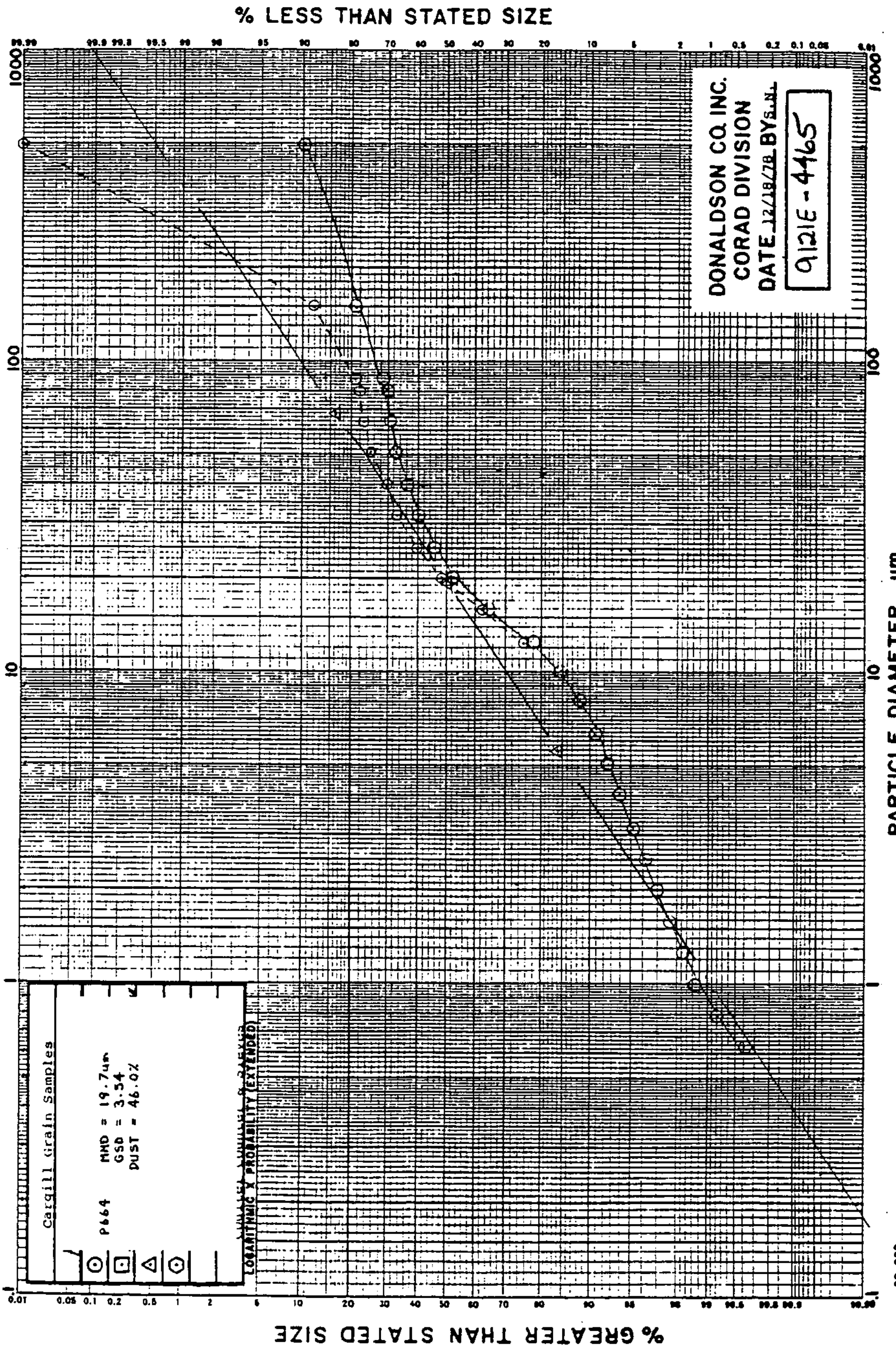


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-44 64
Cargill Grain Samples
P463
MMD = 16.8um
GSD = 1.50
DUST = 95.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

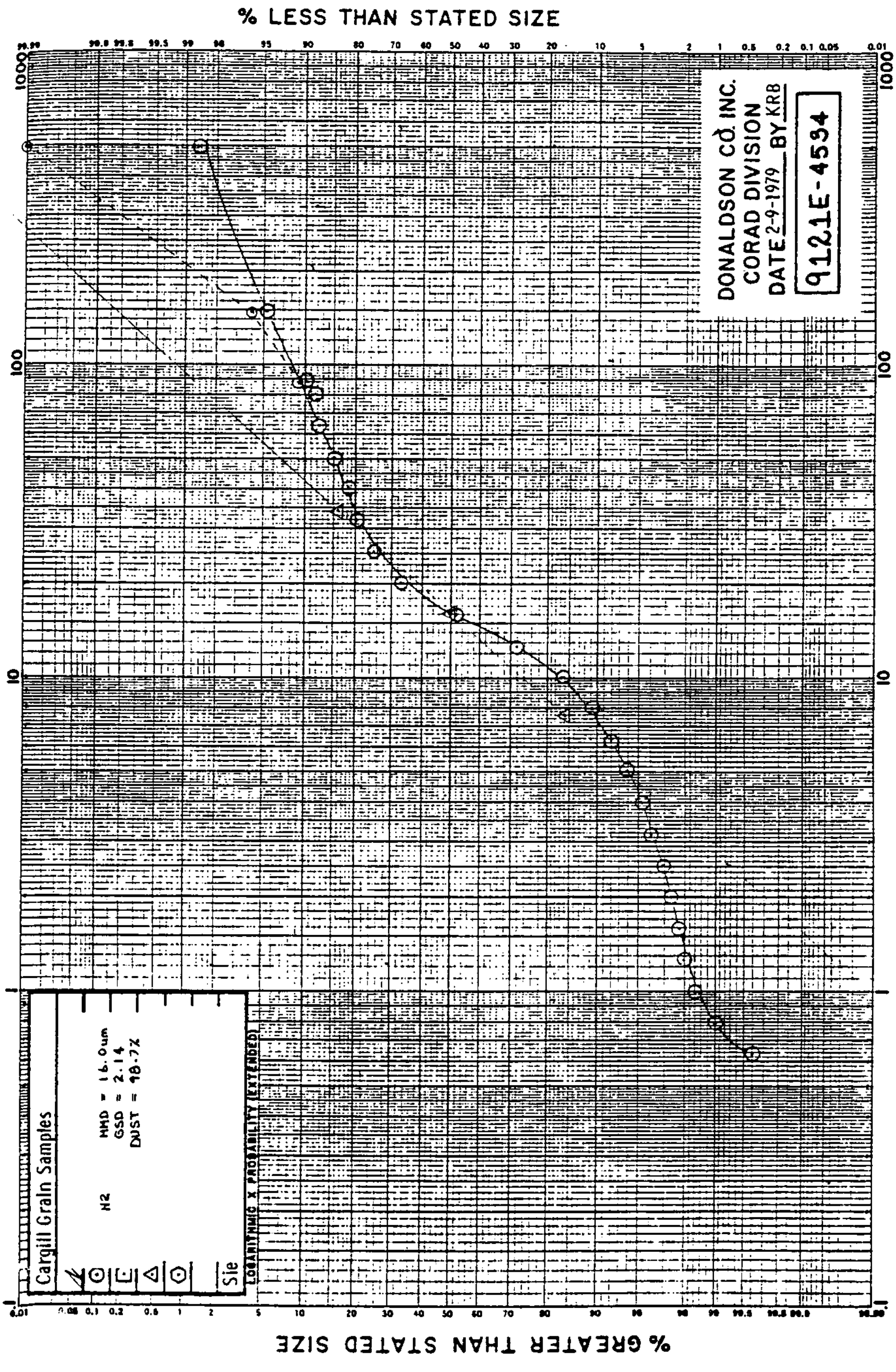

Cargill Grain Samples
P523 MMD = 140. um
GSD = 2.66
DUST = 71.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4459
00-922

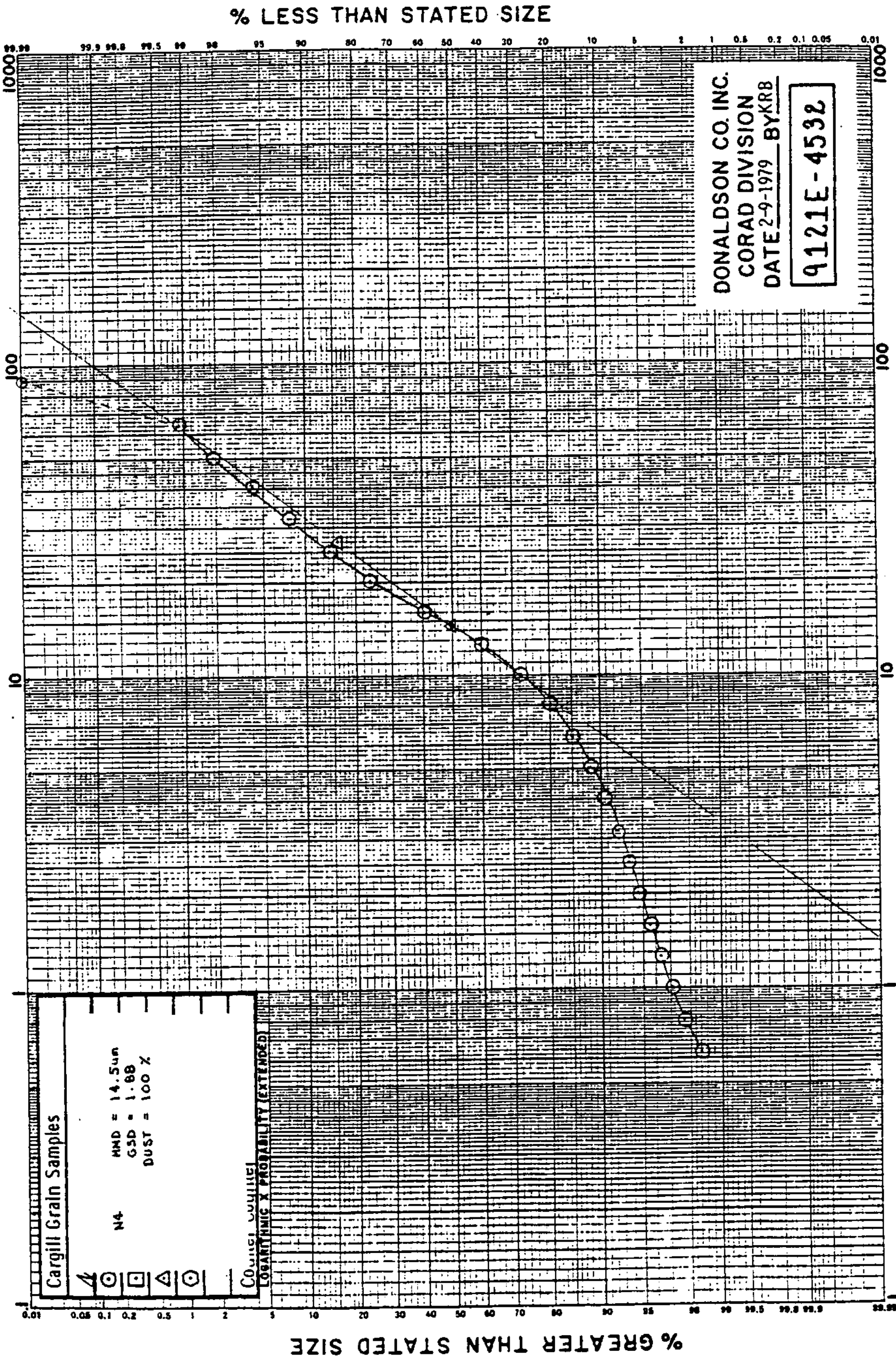

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4466
PARTICLE DIAMETER, µm
Cargill Grain Samples
P562
MMD = 80.0um
GSD = 3.16
DUST = 81.9%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

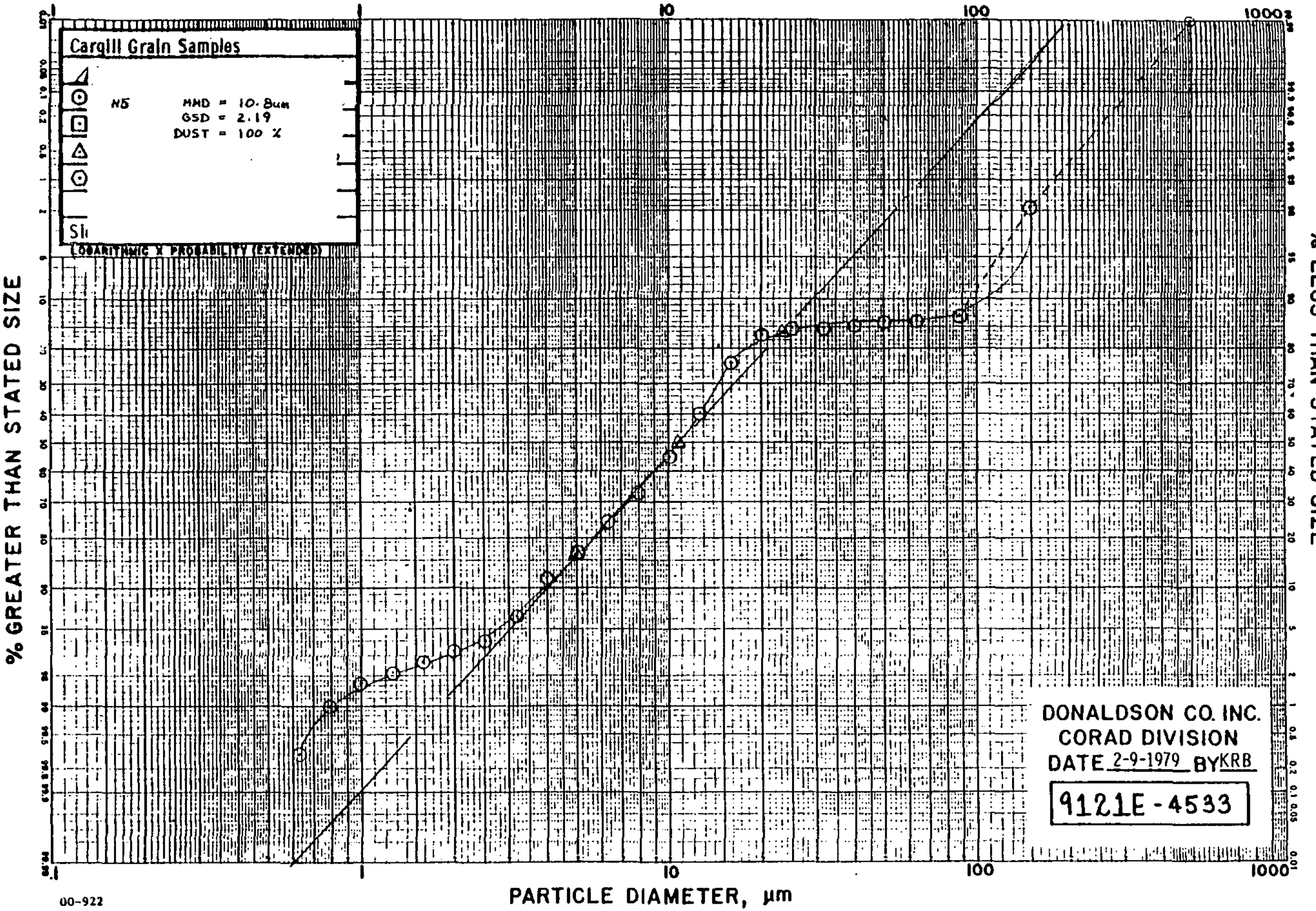

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/20/78 BY S.N.
9121E-4475
PARTICLE DIAMETER, µm
Cargill Grain Samples
P623 MMD = 106.um
GSD = 3.81
DUST = 89.9%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



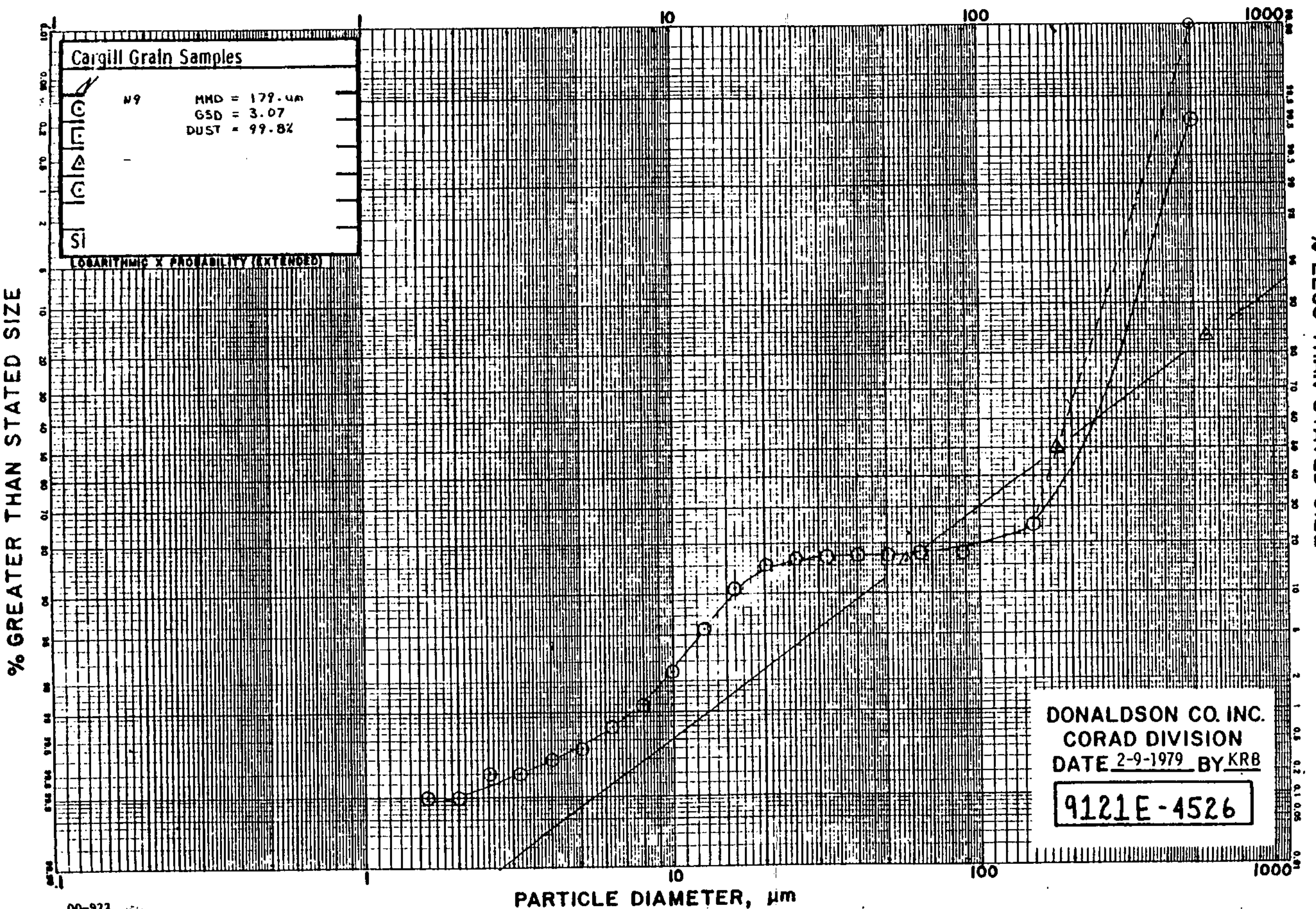
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 12/18/78 BY S.N.
9121E-4465
Cargill Grain Samples
P664
MMD = 19.7um
GSD = 3.54
DUST = 46.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4534
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
Cargill Grain Samples
N2
MMD = 16.0um
GSD = 2.14
DUST = 98.7%
Sie
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

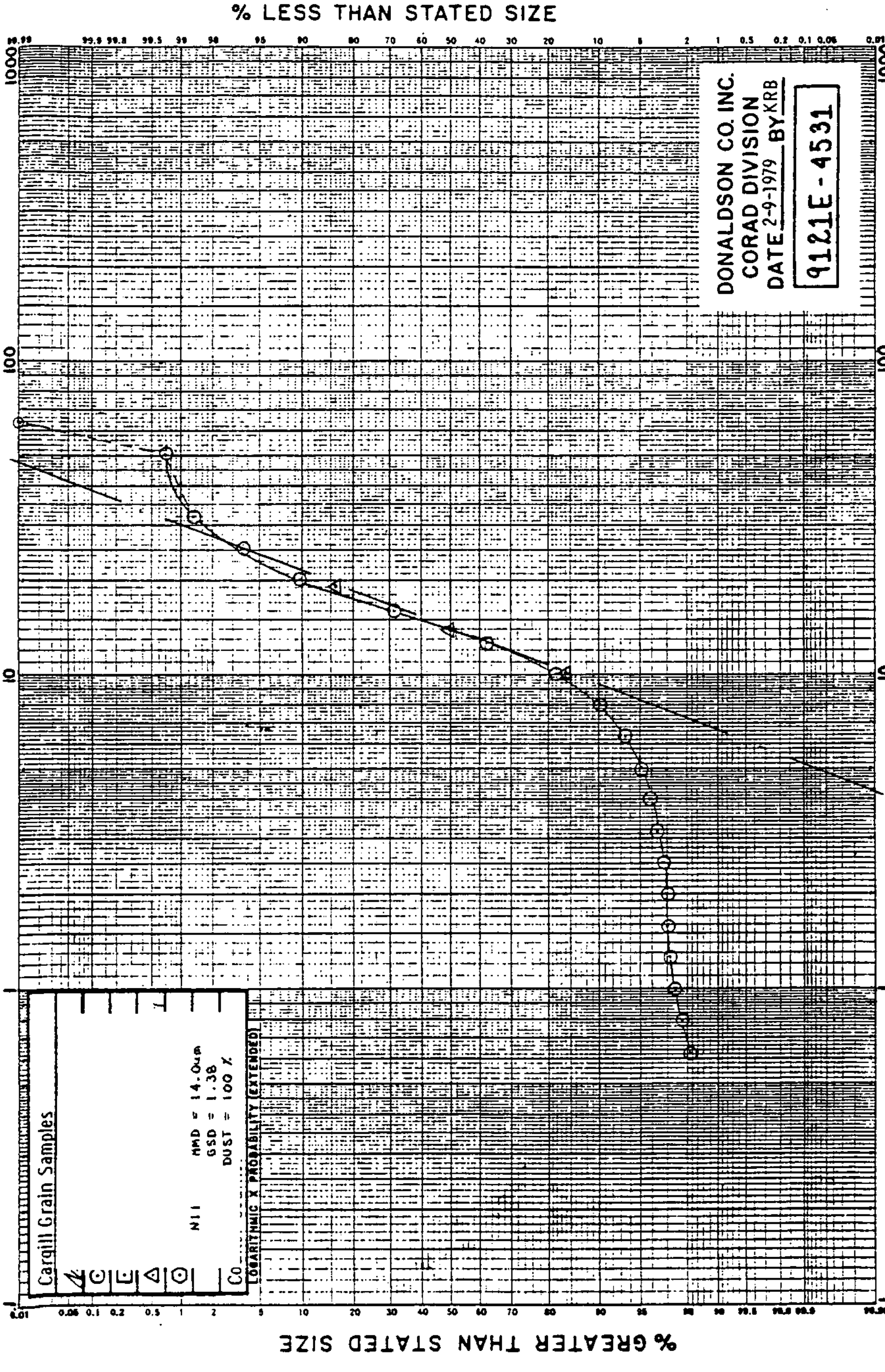

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4532
PARTICLE DIAMETER, µm
Cargill Grain Samples
N4
MMD = 14.5um
GSD = 1.88
DUST = 100 %
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

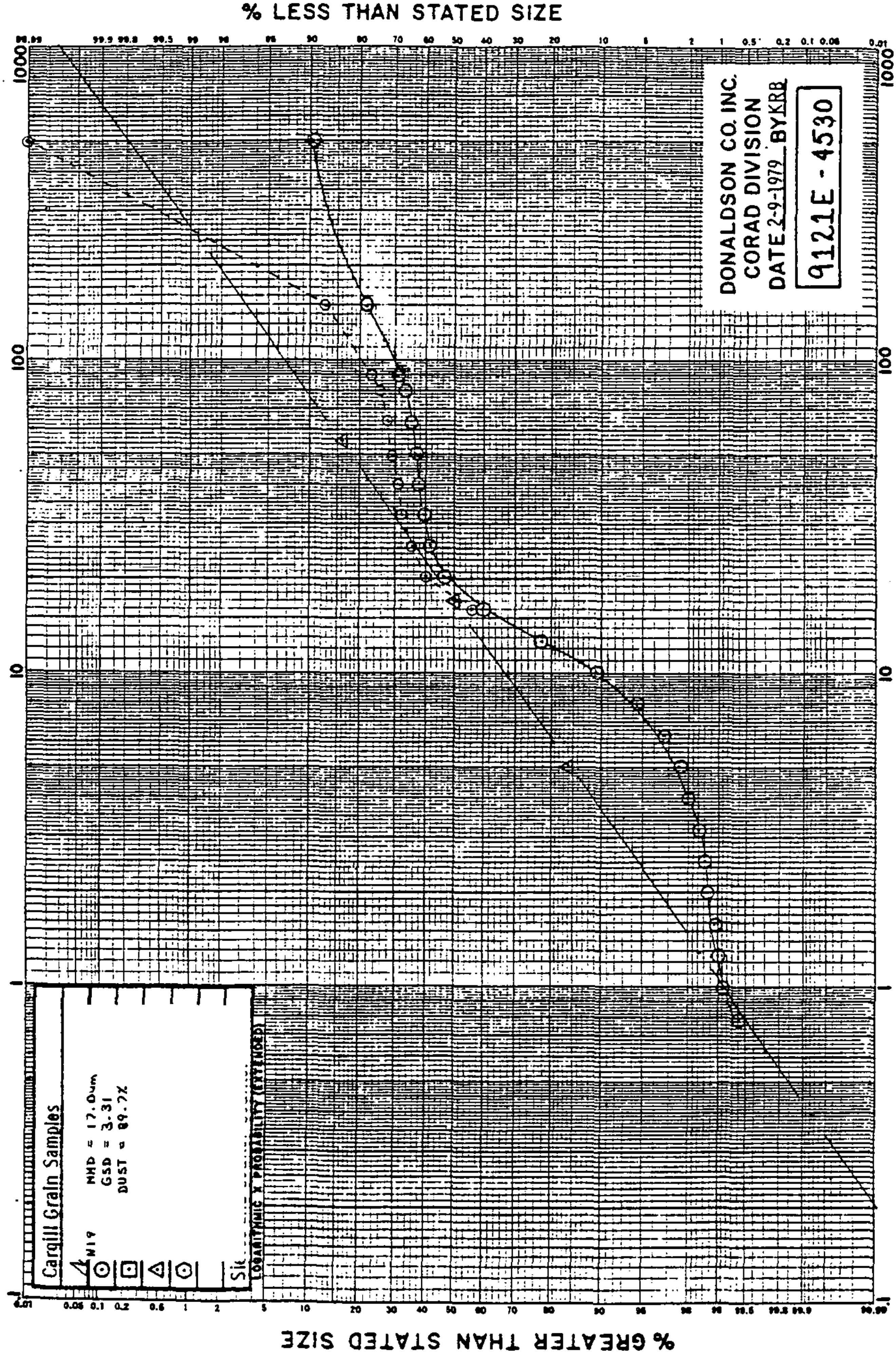


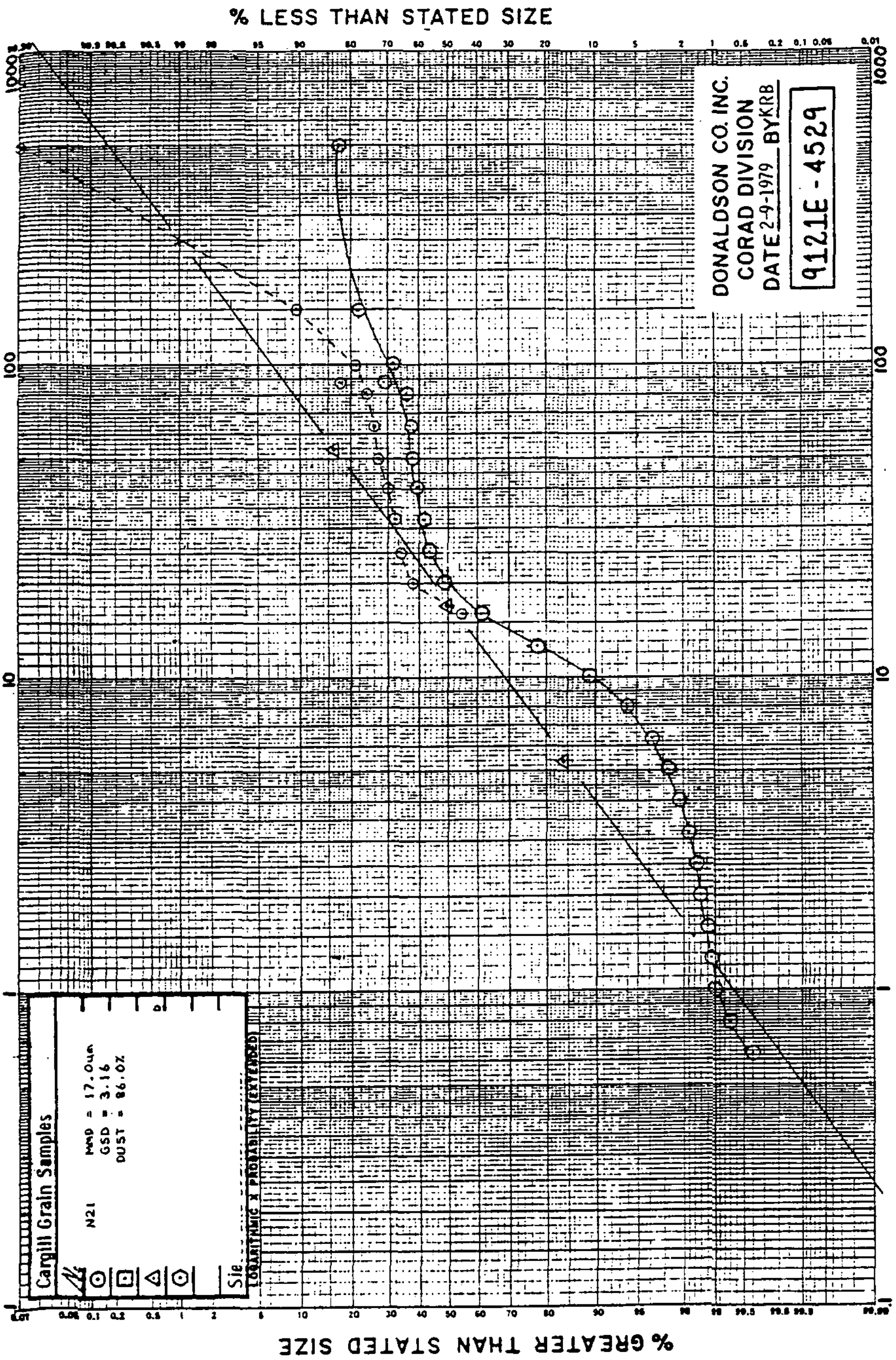
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, μm
Cargill Grain Samples
N5
MMD = 10.8um
GSD = 2.19
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4533
00-922



% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, μm
Cargill Grain Samples
N9
MMD = 179. um
GSD = 3.07
DUST = 99.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4526
00-922

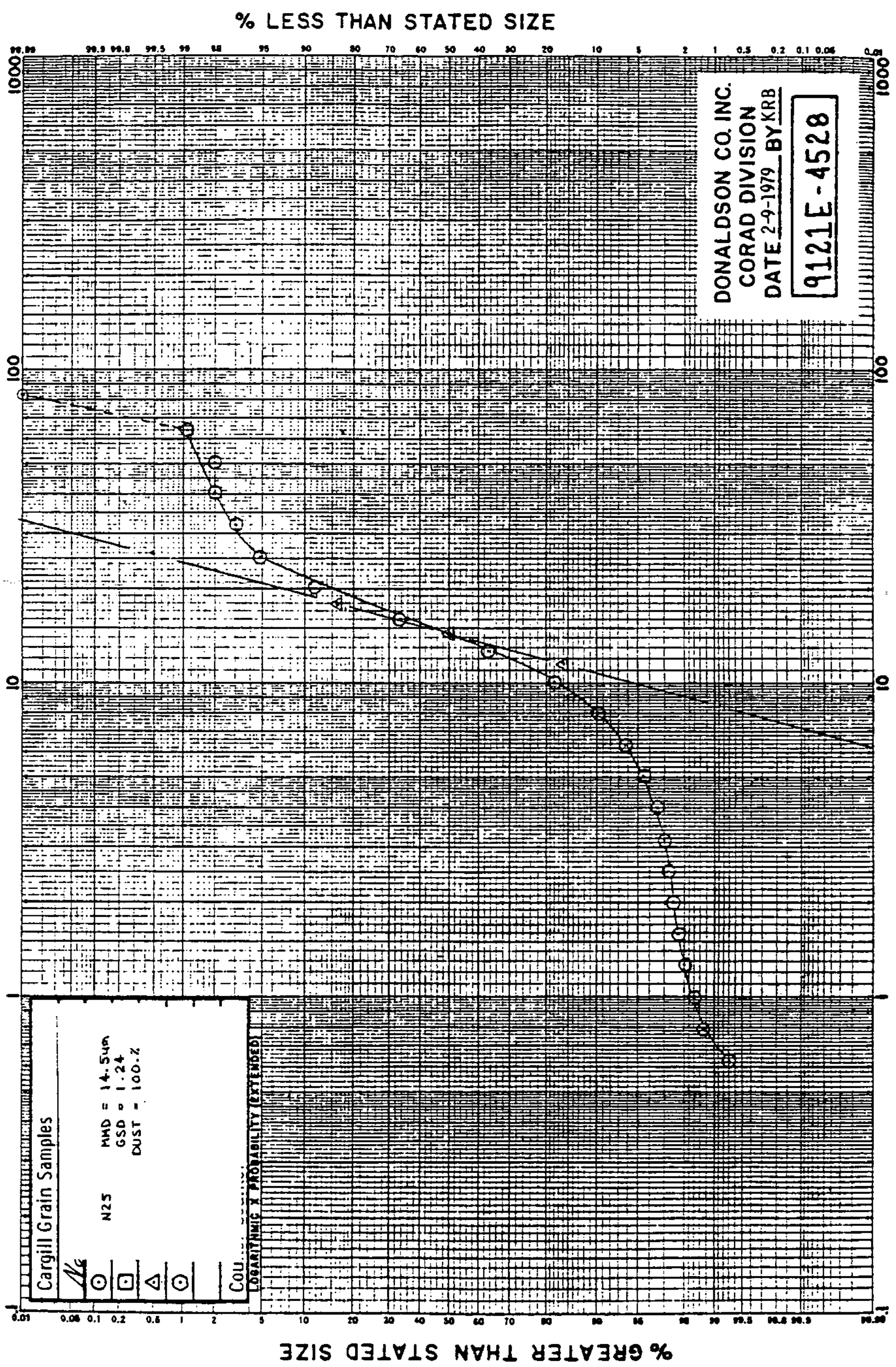

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4531
PARTICLE DIAMETER, µm
Cargill Grain Samples
N11
MMD = 14.0µm
GSD = 1.38
DUST = 100%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E - 4530
PARTICLE DIAMETER, μm
Cargill Grain Samples
N19
MMD = 17.0μm
GSD = 3.31
DUST = 89.7%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

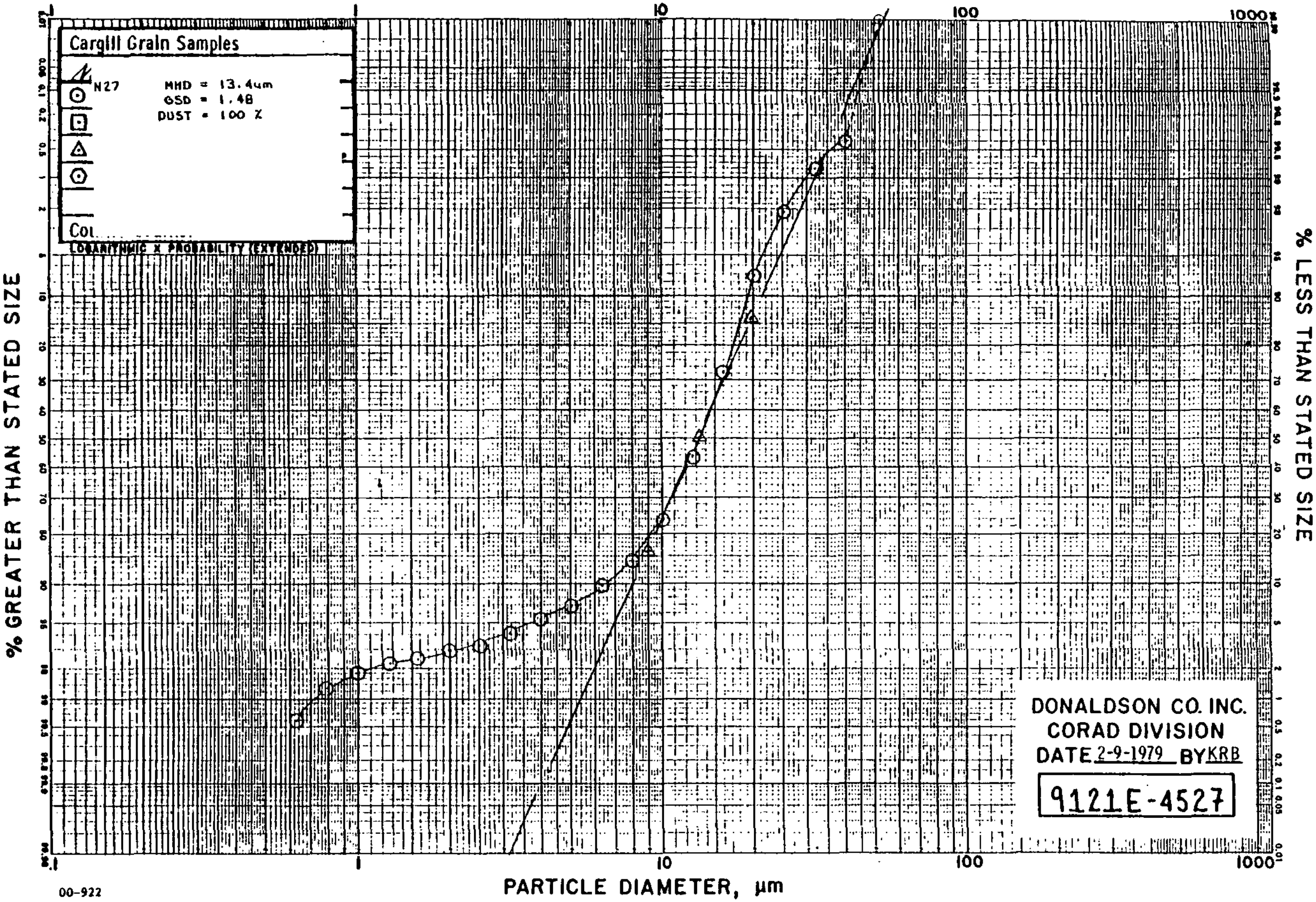


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4529
Cargill Grain Samples
N21
MMD = 17.0um
GSD = 3.16
DUST = 86.0%
LOGARITHMIC X PROBABILITY (EXTENDED)

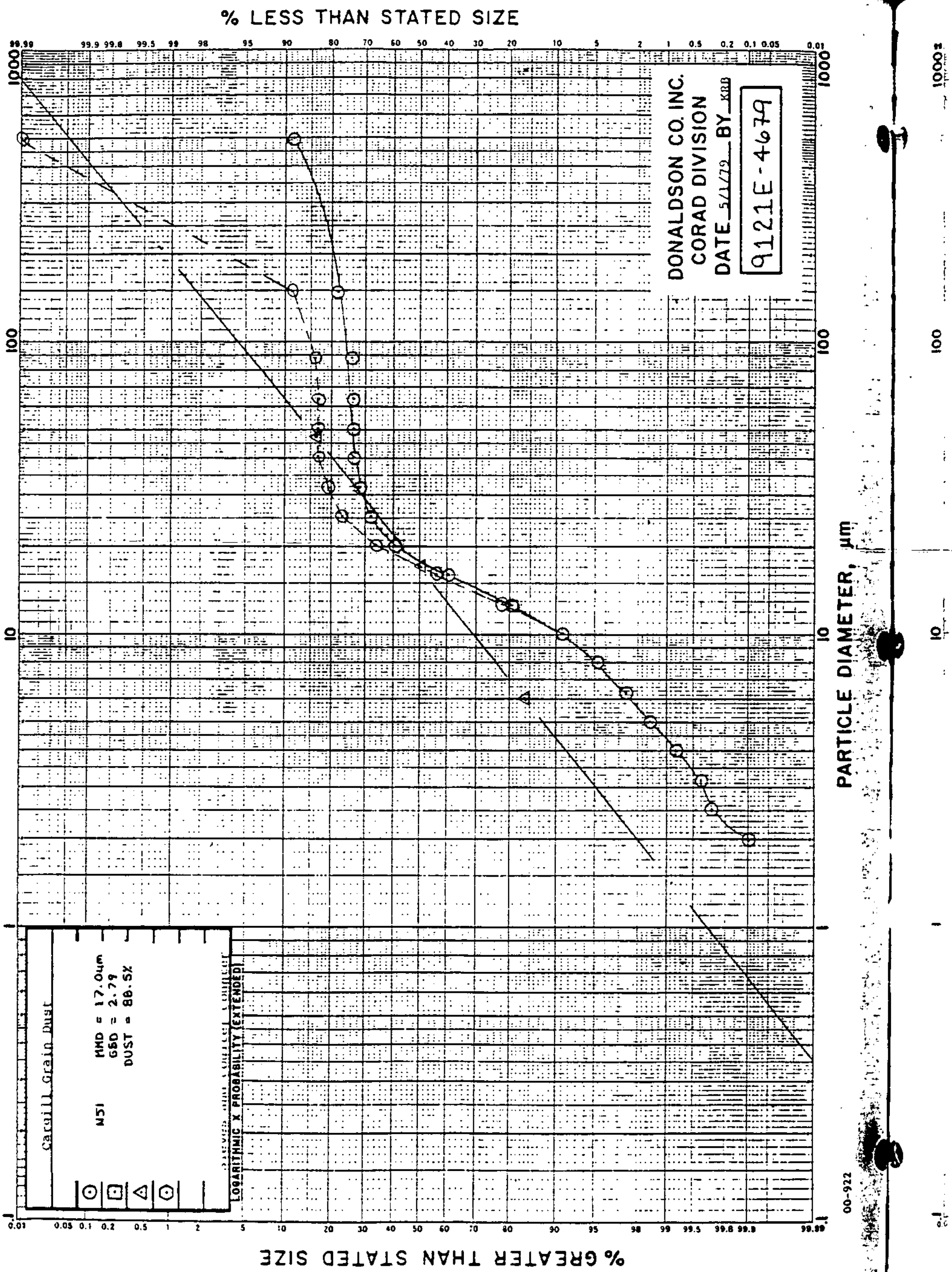
00-922



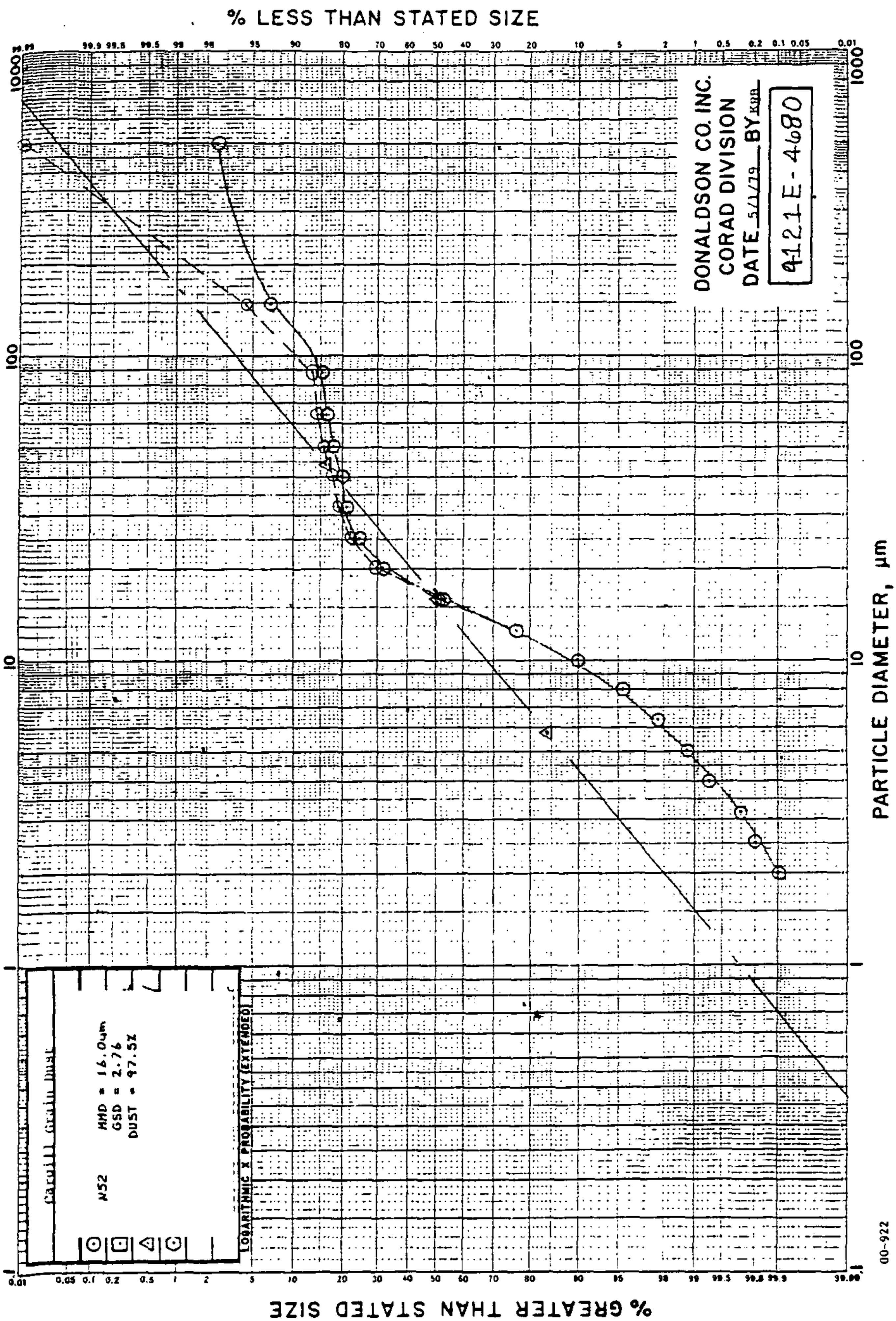
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4528
PARTICLE DIAMETER, µm
Cargill Grain Samples
N25
MMD = 14.5µm
GSD = 1.24
DUST = 100.%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

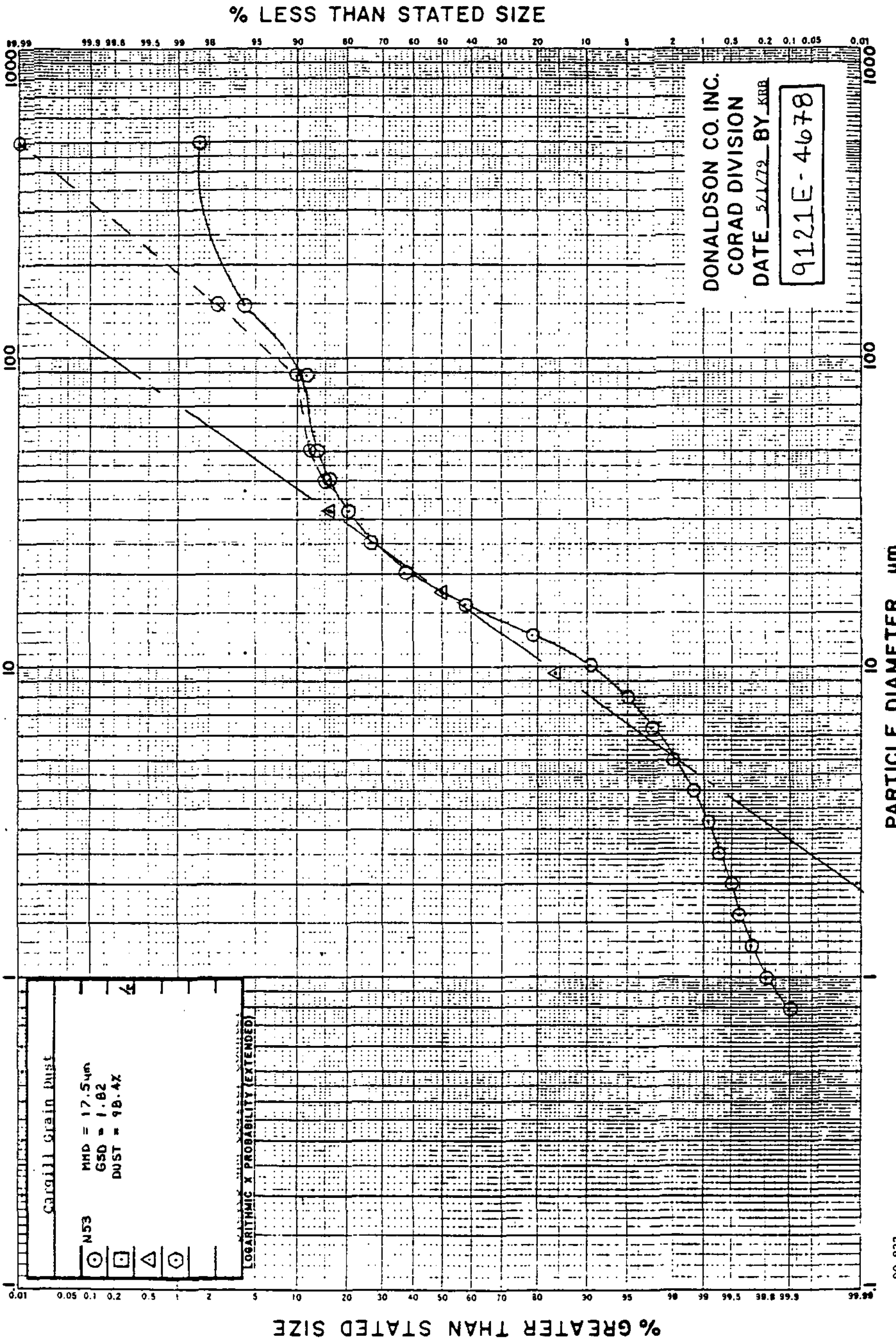


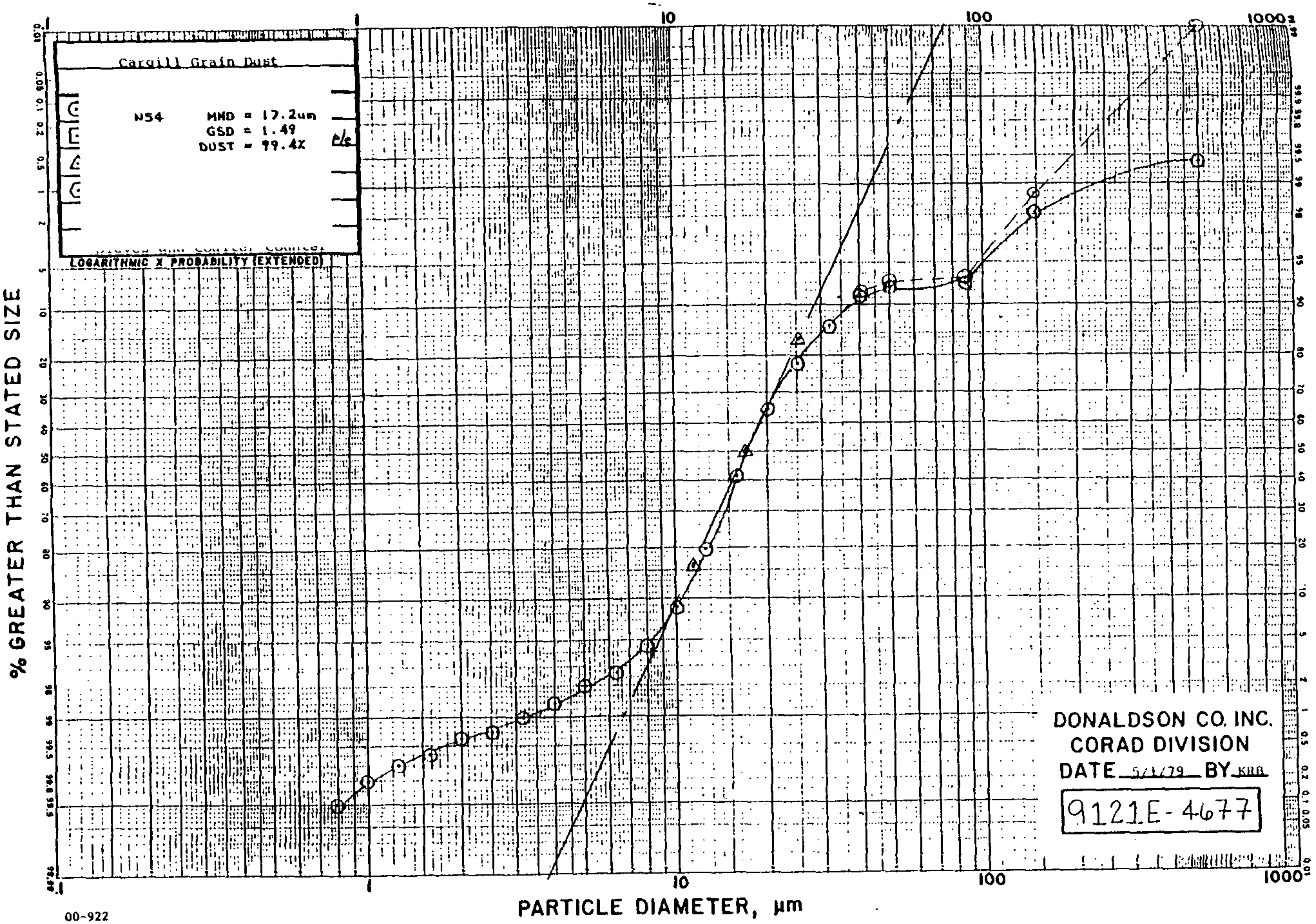
Cargill Grain Samples
N27
MMD = 13.4um
GSD = 1.48
DUST = 100 %
Col
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4527
00-922

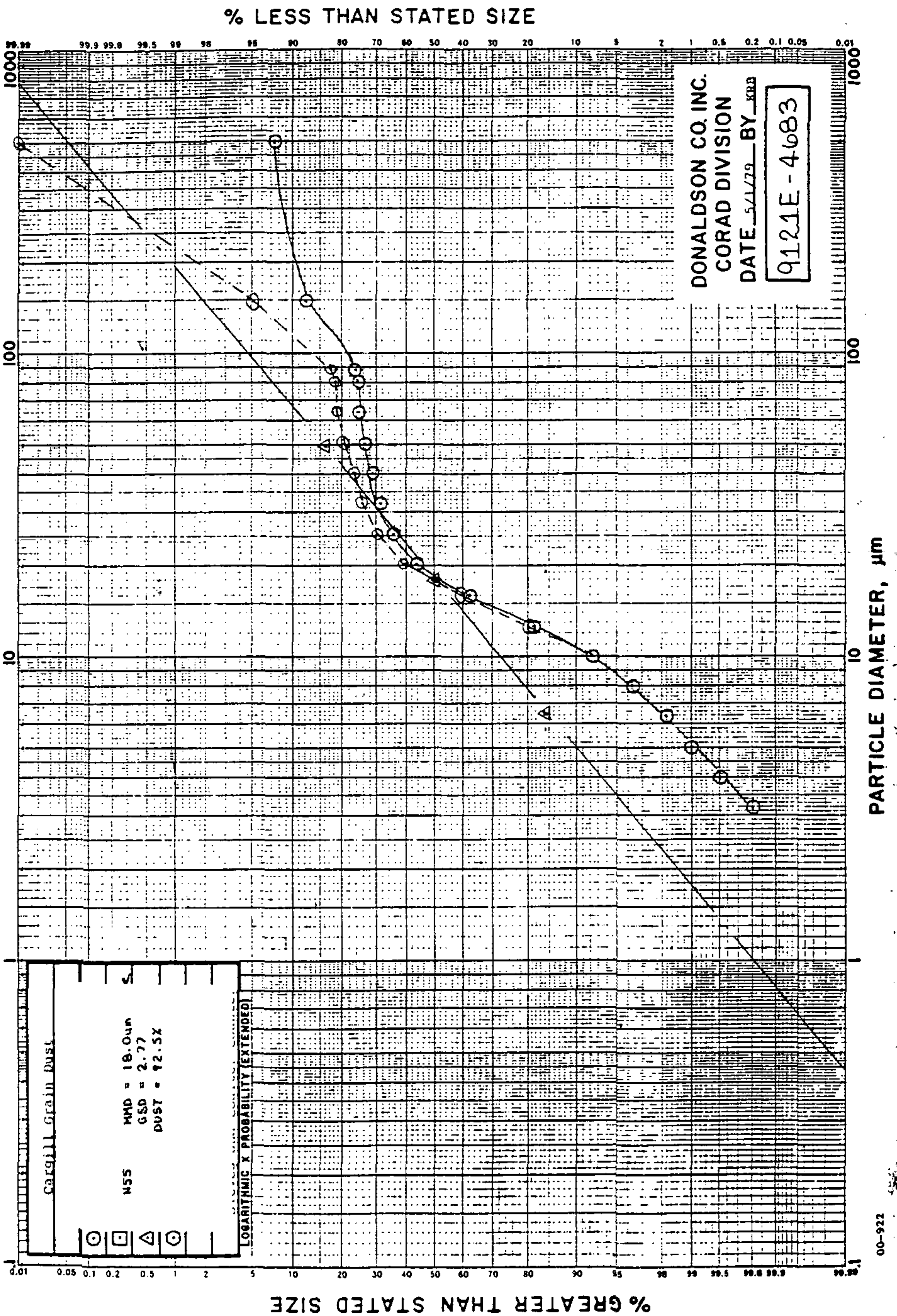


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/11/79 BY KRB
9121E-4679
PARTICLE DIAMETER, µm
Cargill Grain Dust
N51
MMD = 17.0µm
GSD = 2.79
DUST = 88.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

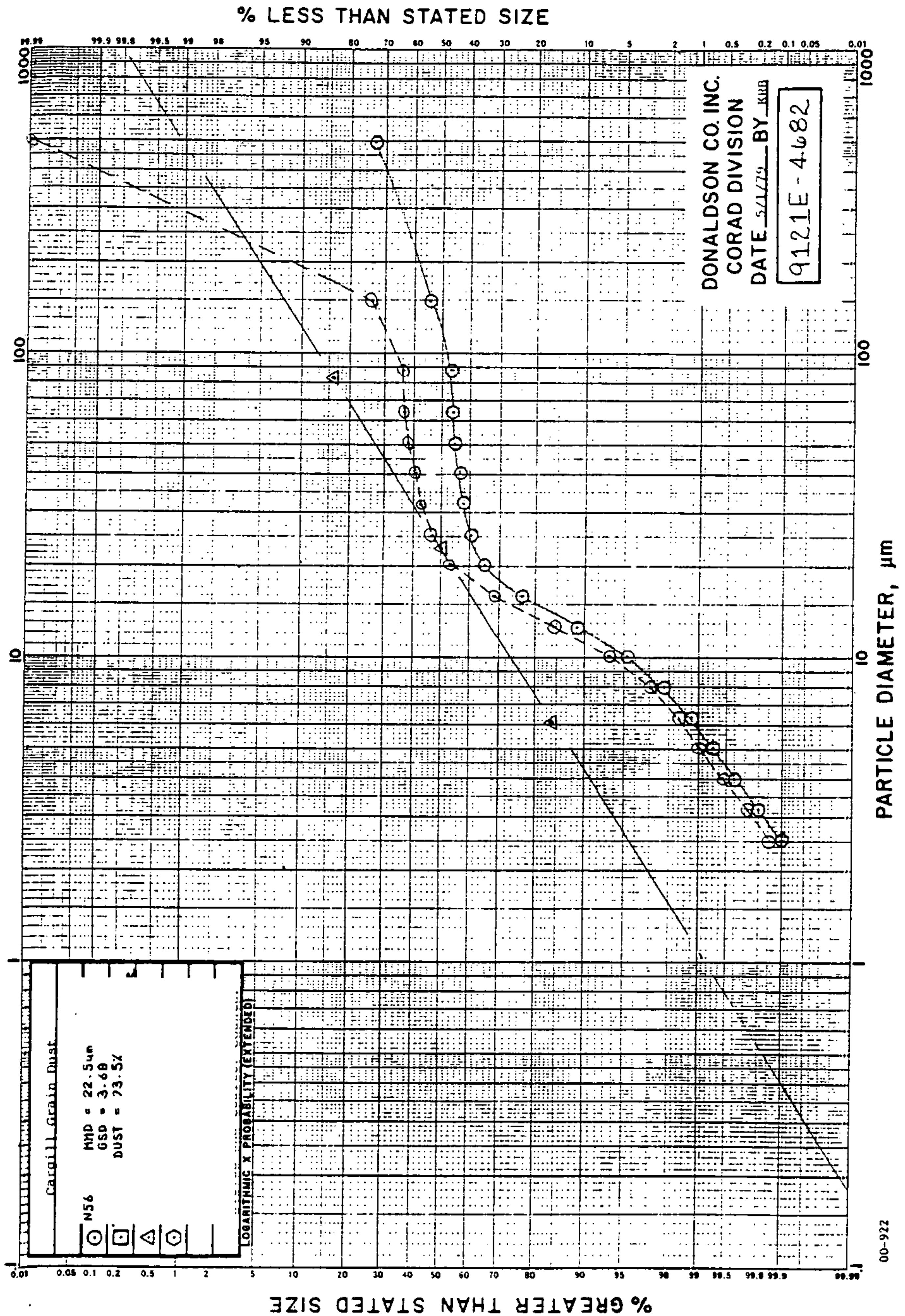

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
4121E-4680
PARTICLE DIAMETER, µm
Cargill Grain Dust
N52
MMD = 16.0µm
GSD = 2.76
DUST = 97.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

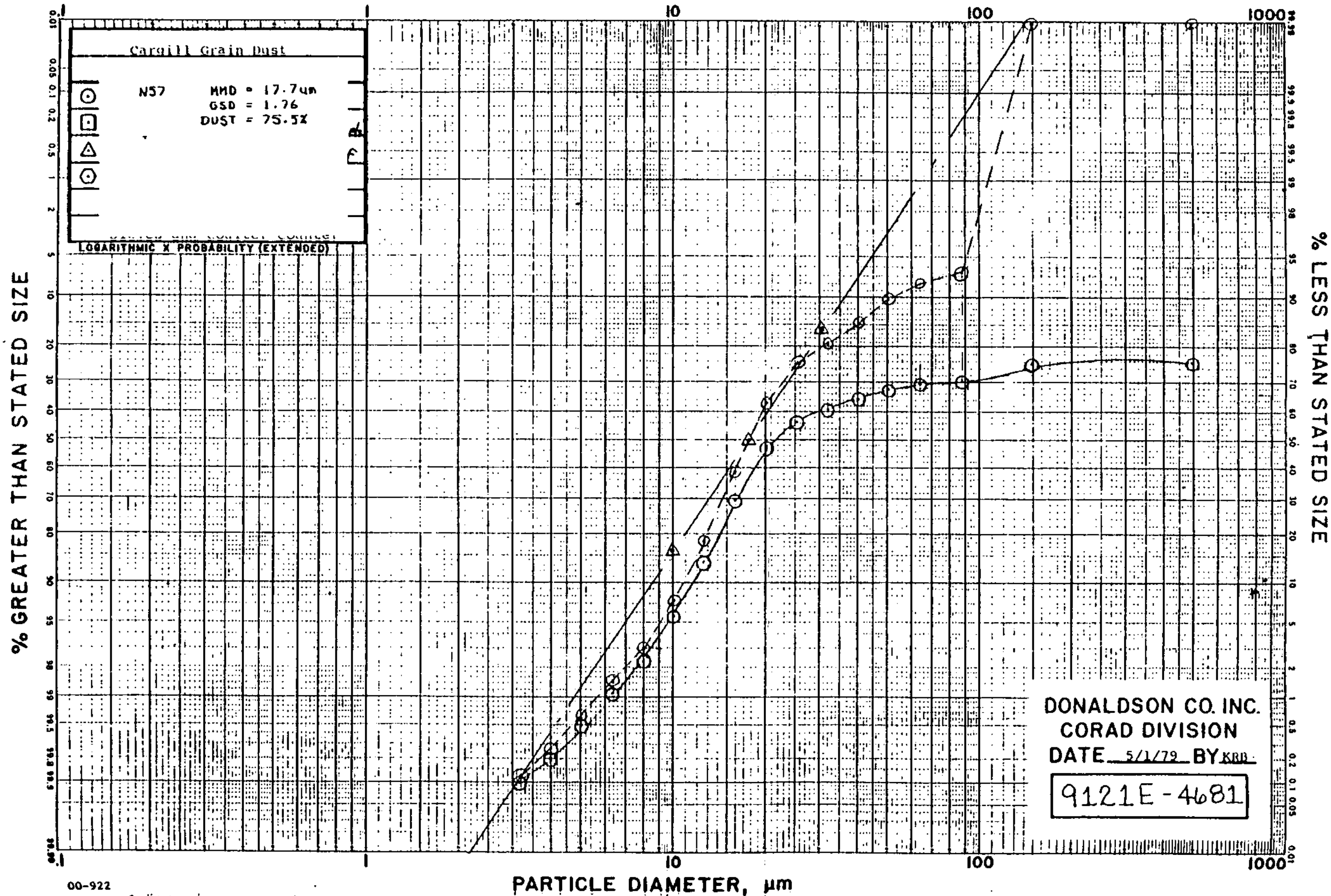

% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4678
Cargill Grain Dust
N53
MMD = 17.5µm
GSD = 1.82
DUST = 98.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

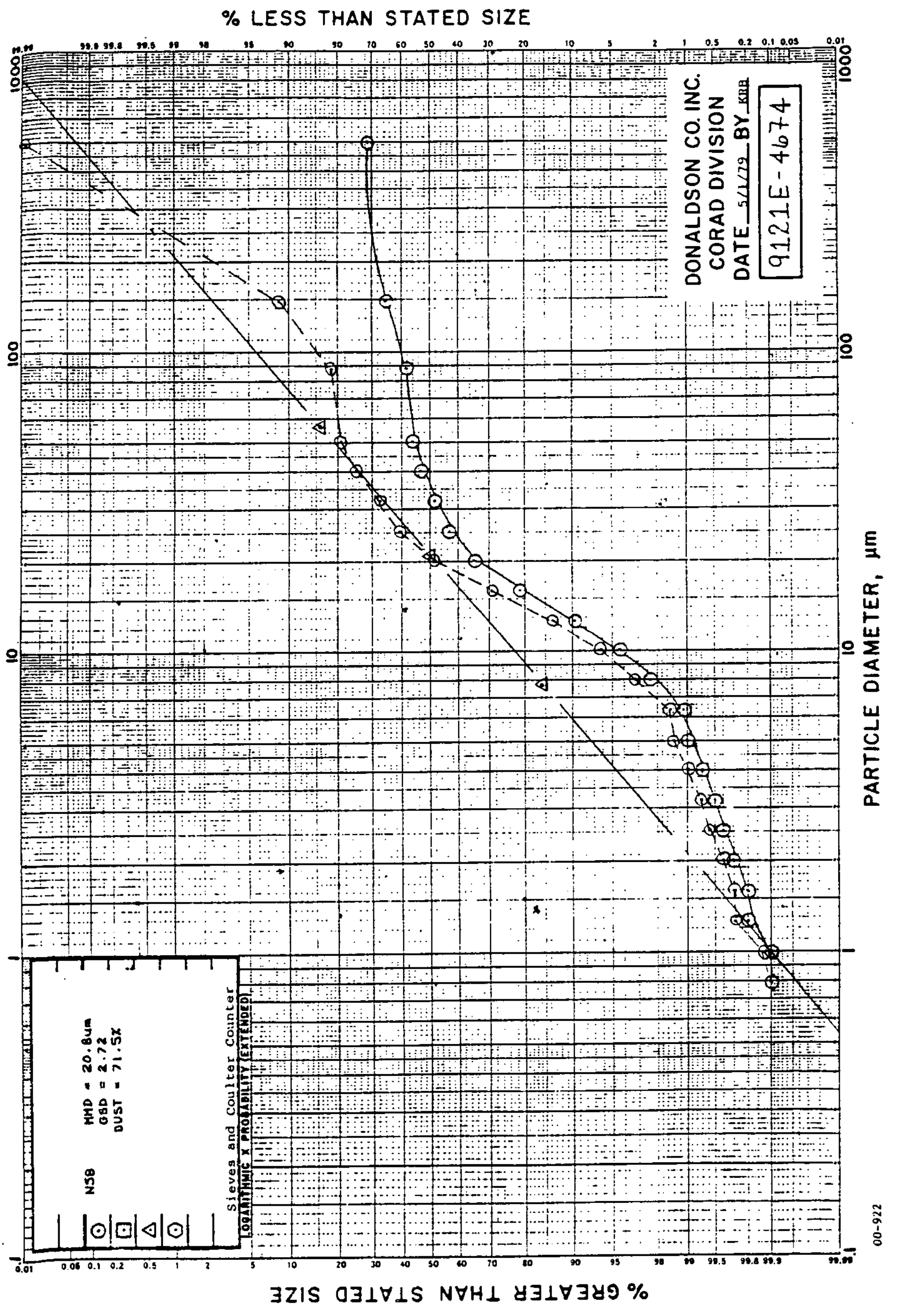

Cargill Grain Dust
N54
MMD = 17.2um
GSD = 1.49
DUST = 99.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4677
00-922



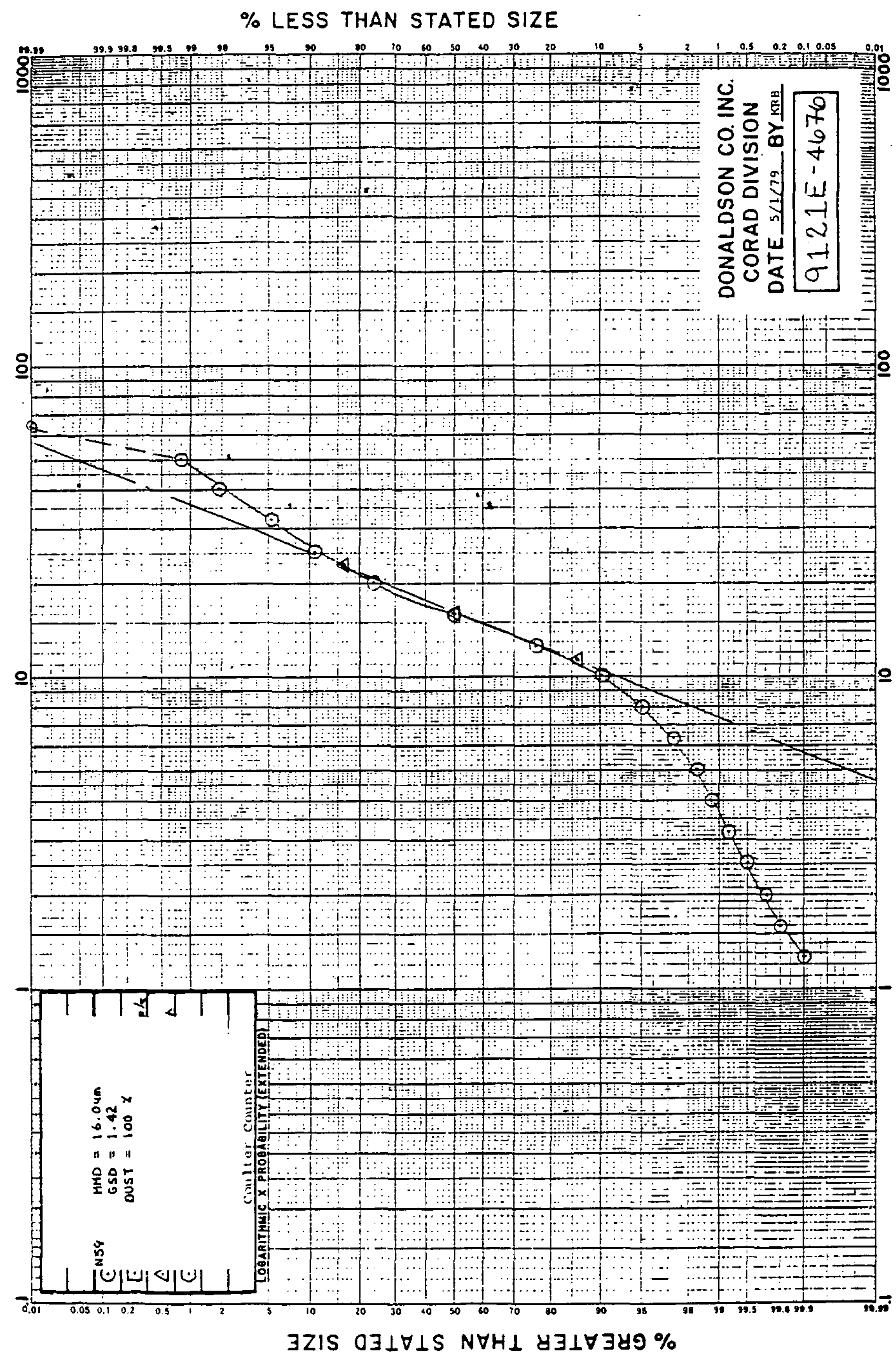
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY
9121E-4683
PARTICLE DIAMETER, µm
Cargill Grain Dust
N55
MMD = 18.0um
GSD = 2.77
DUST = 92.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
9121E-4682
Cargill Grain Dust
N56
MMD = 22.5um
GSD = 3.68
DUST = 73.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

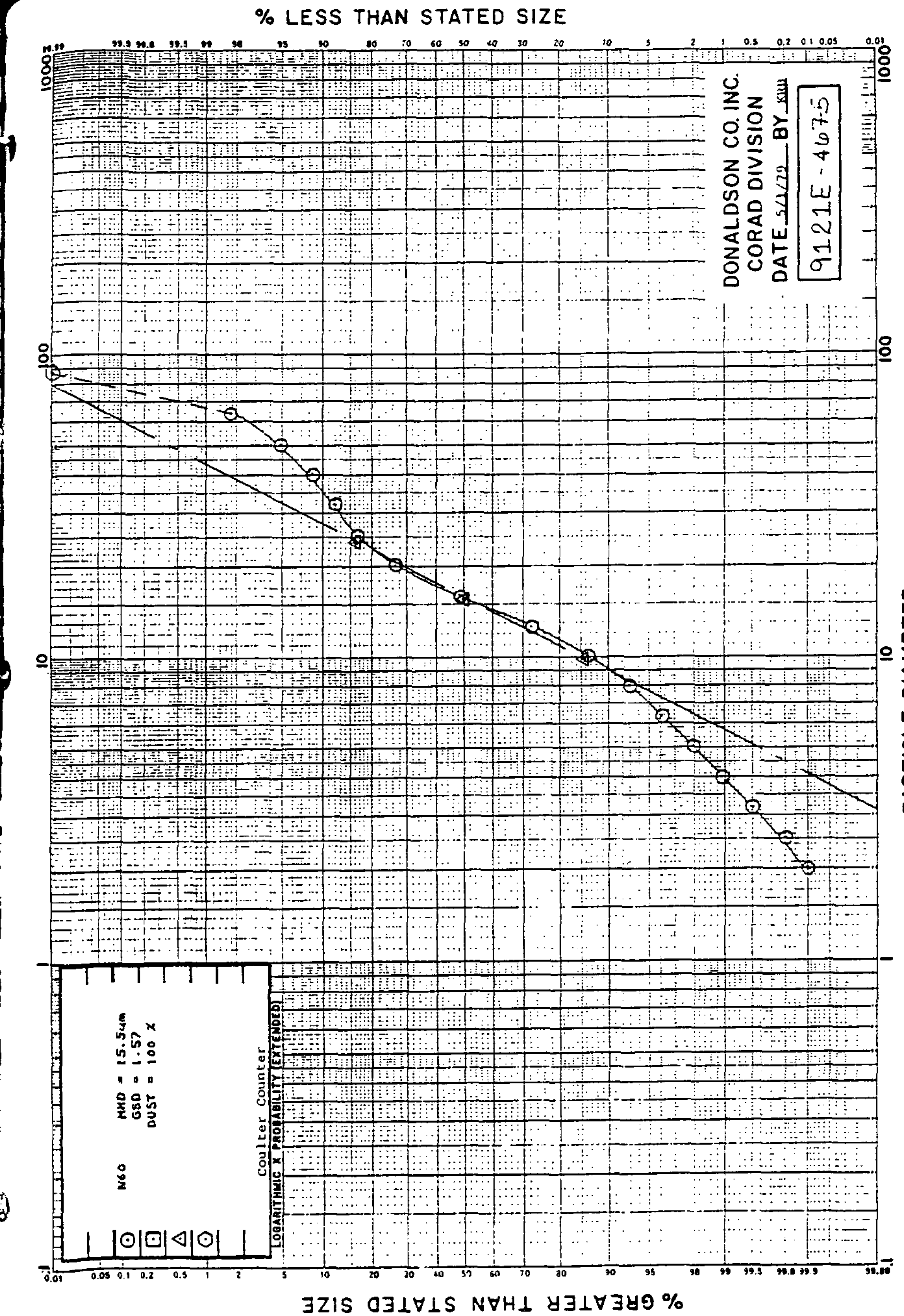

Cargill Grain Dust
N57
MMD = 17.7um
GSD = 1.76
DUST = 75.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4681
00-922



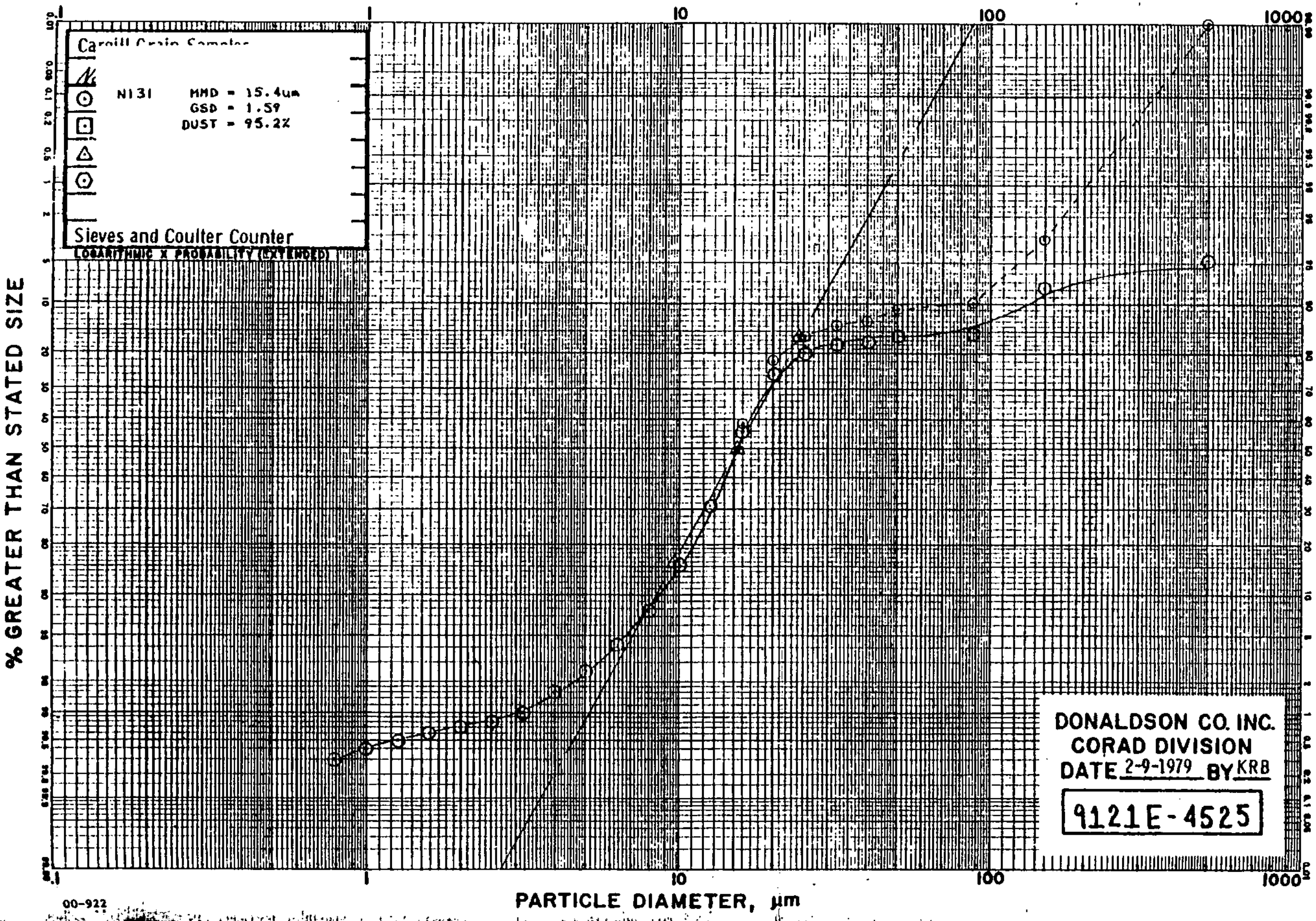
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4674
PARTICLE DIAMETER, µm
NSB
MMD = 20.8um
GSD = 2.72
DUST = 71.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

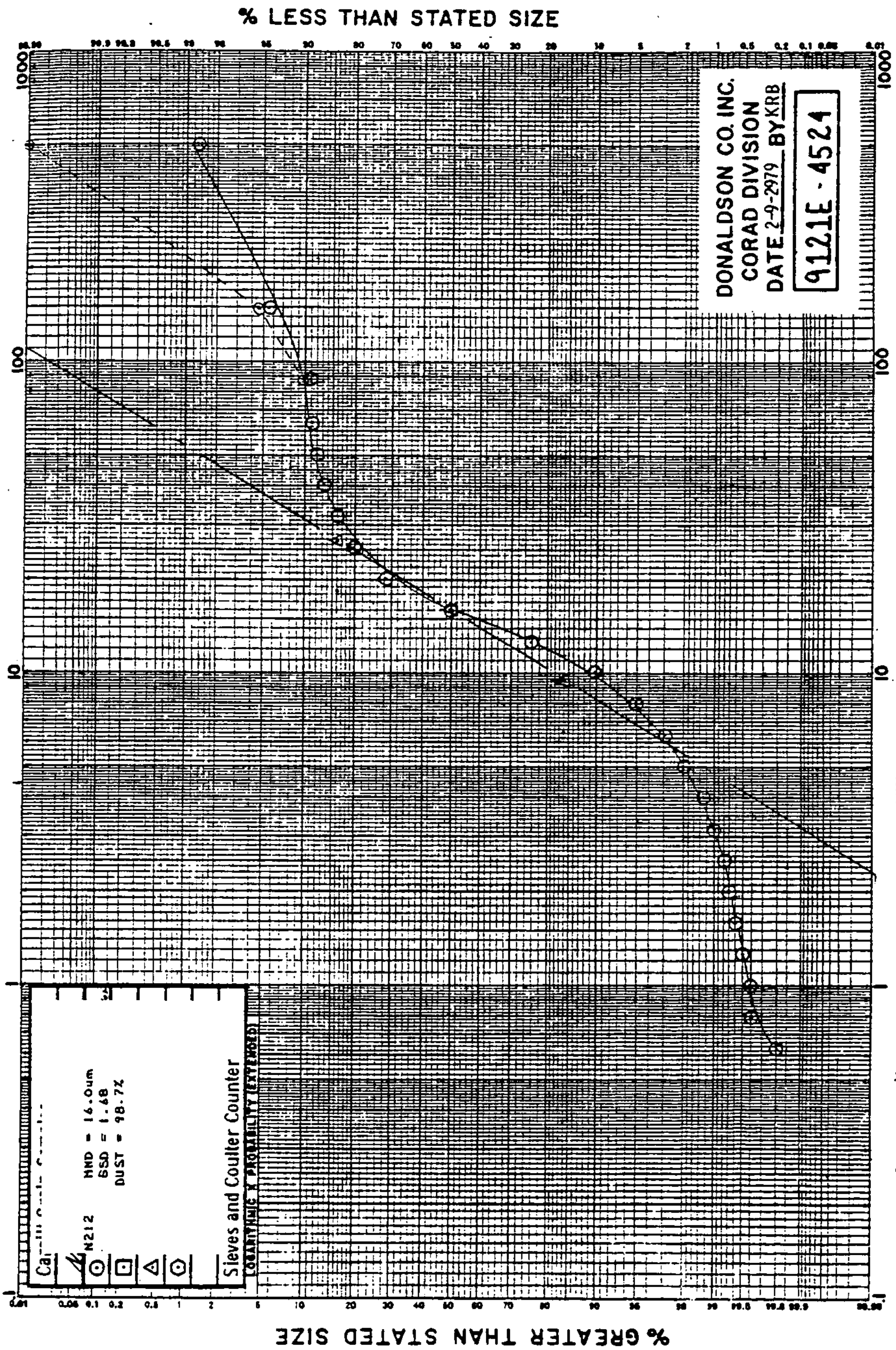


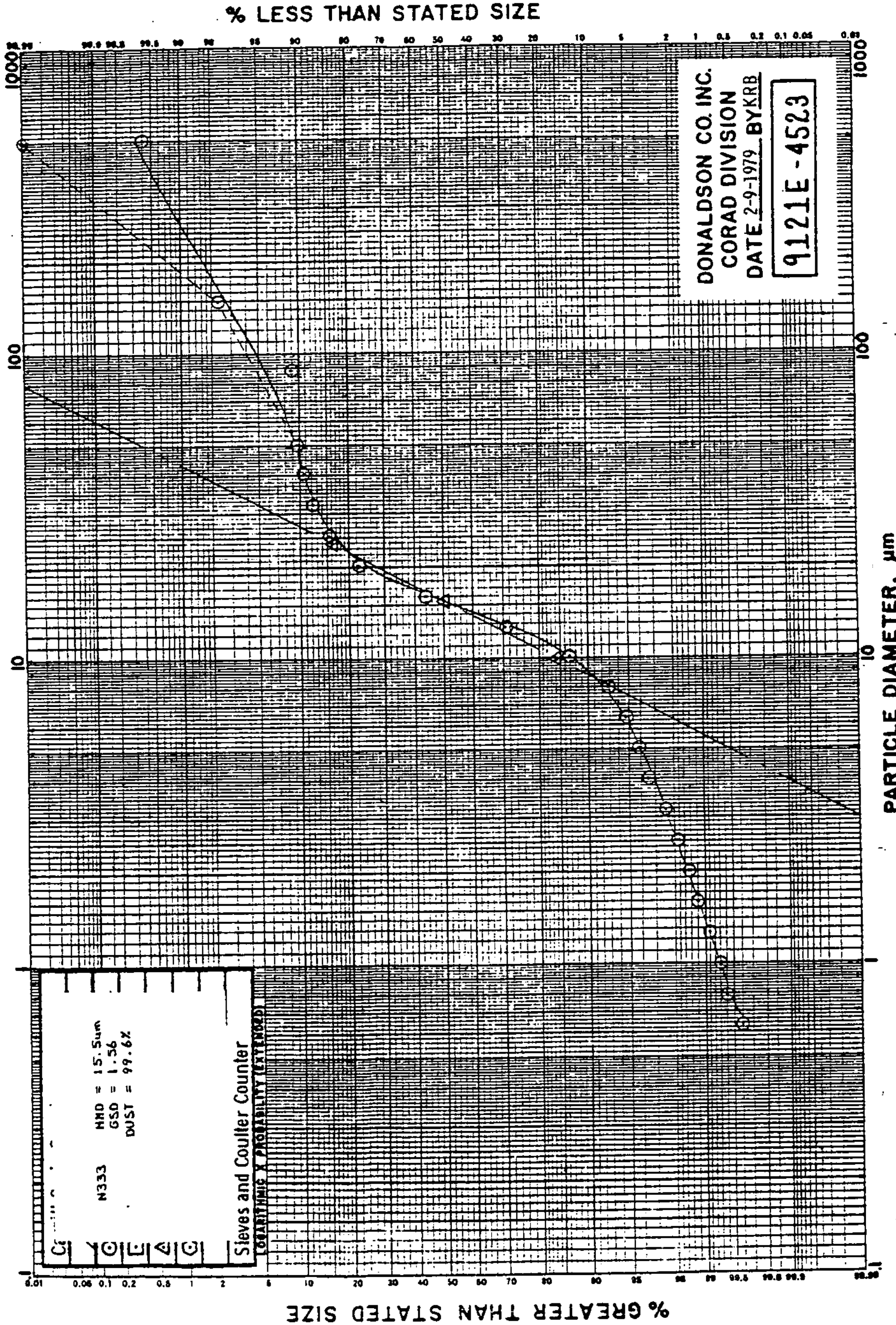
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E-4670
PARTICLE DIAMETER, µm
MMD = 16.0µm
GSD = 1.42
DUST = 100 %
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
NSG
% GREATER THAN STATED SIZE
00-922



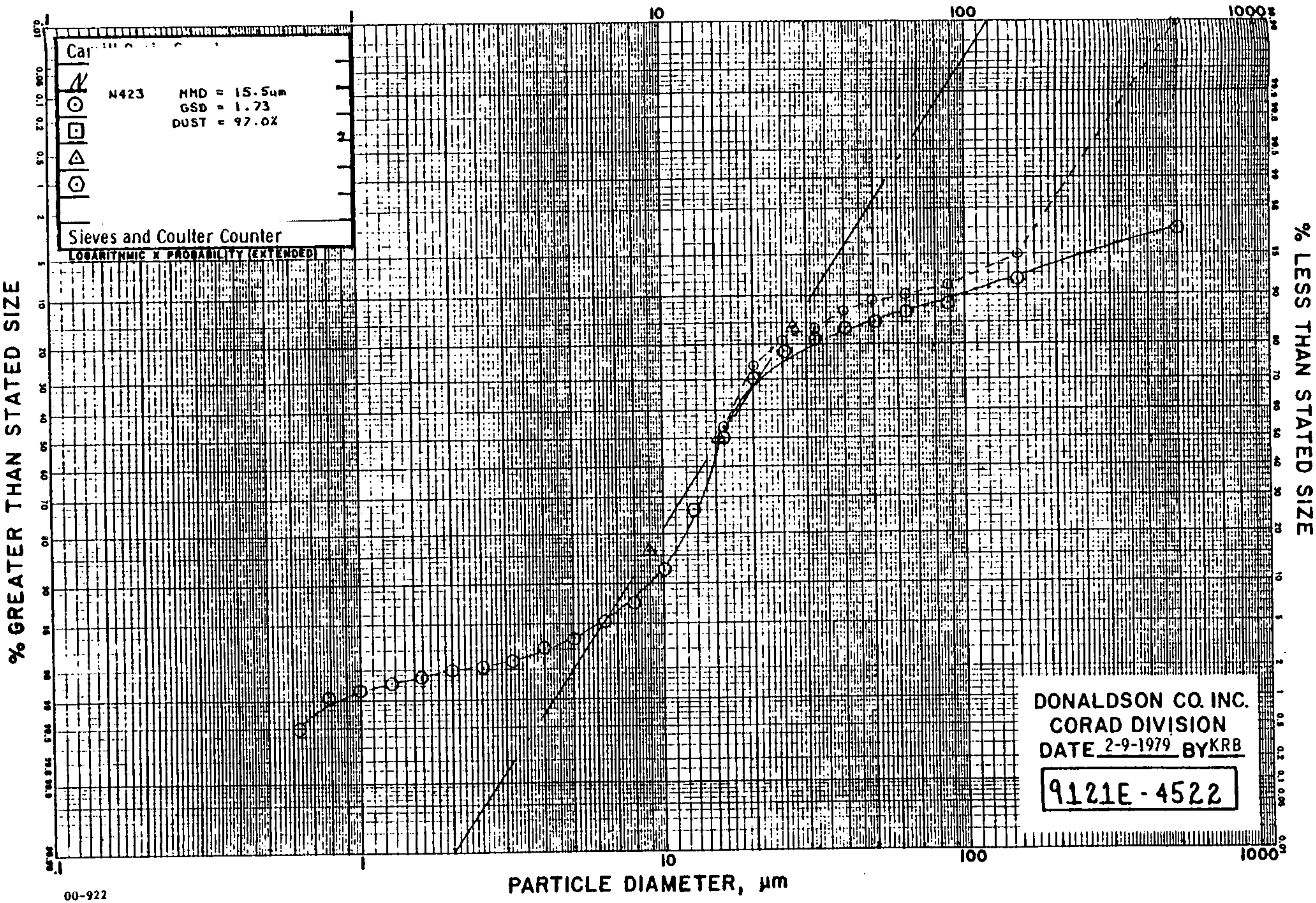
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY
9121E-4675
PARTICLE DIAMETER, µm
N60
MMD = 15.5µm
GSD = 1.57
DUST = 100 X
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

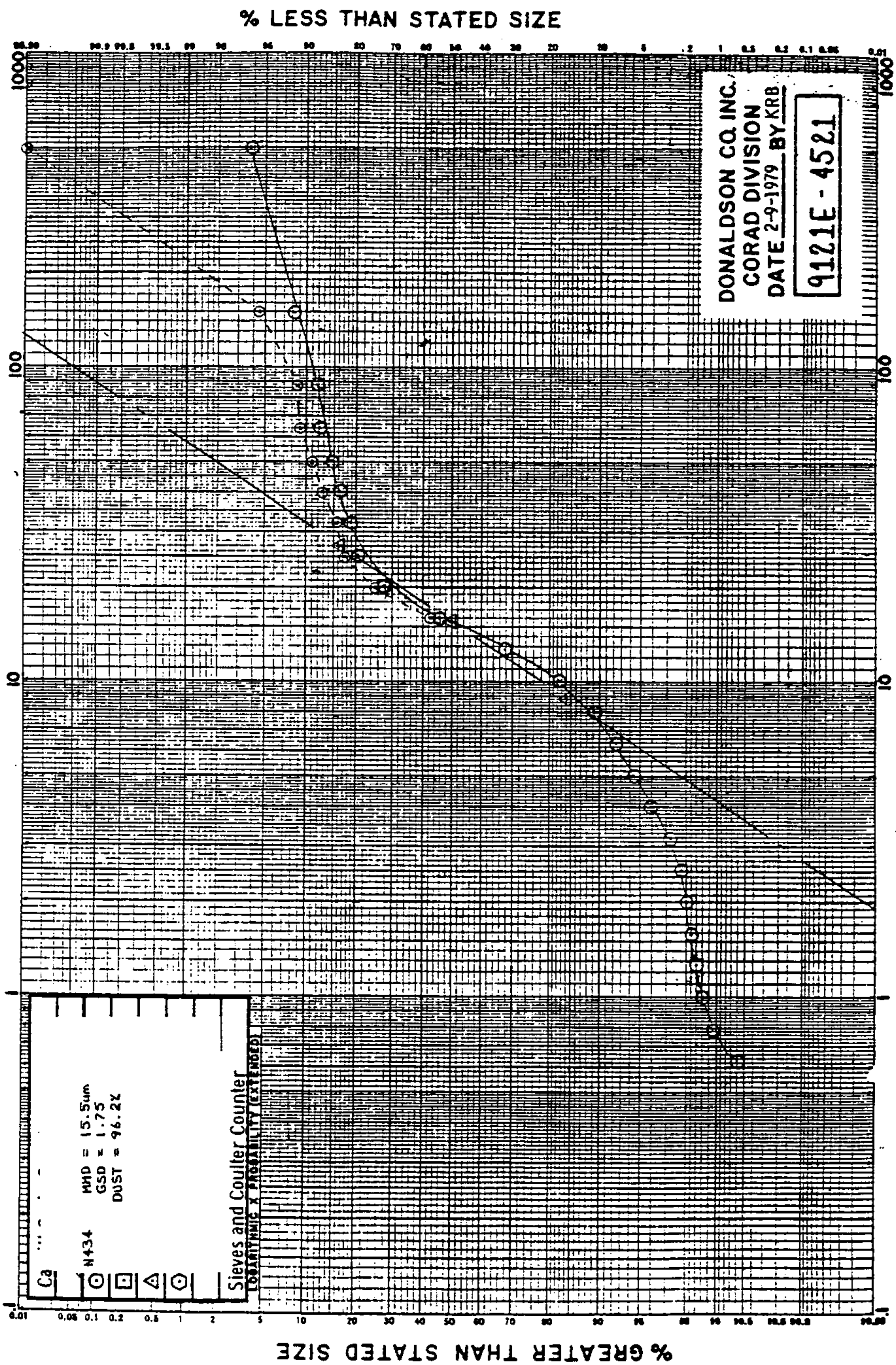

Cargill Grain Sampler
N131 MMD = 15.4um
GSD = 1.59
DUST = 95.2%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4525
00-922

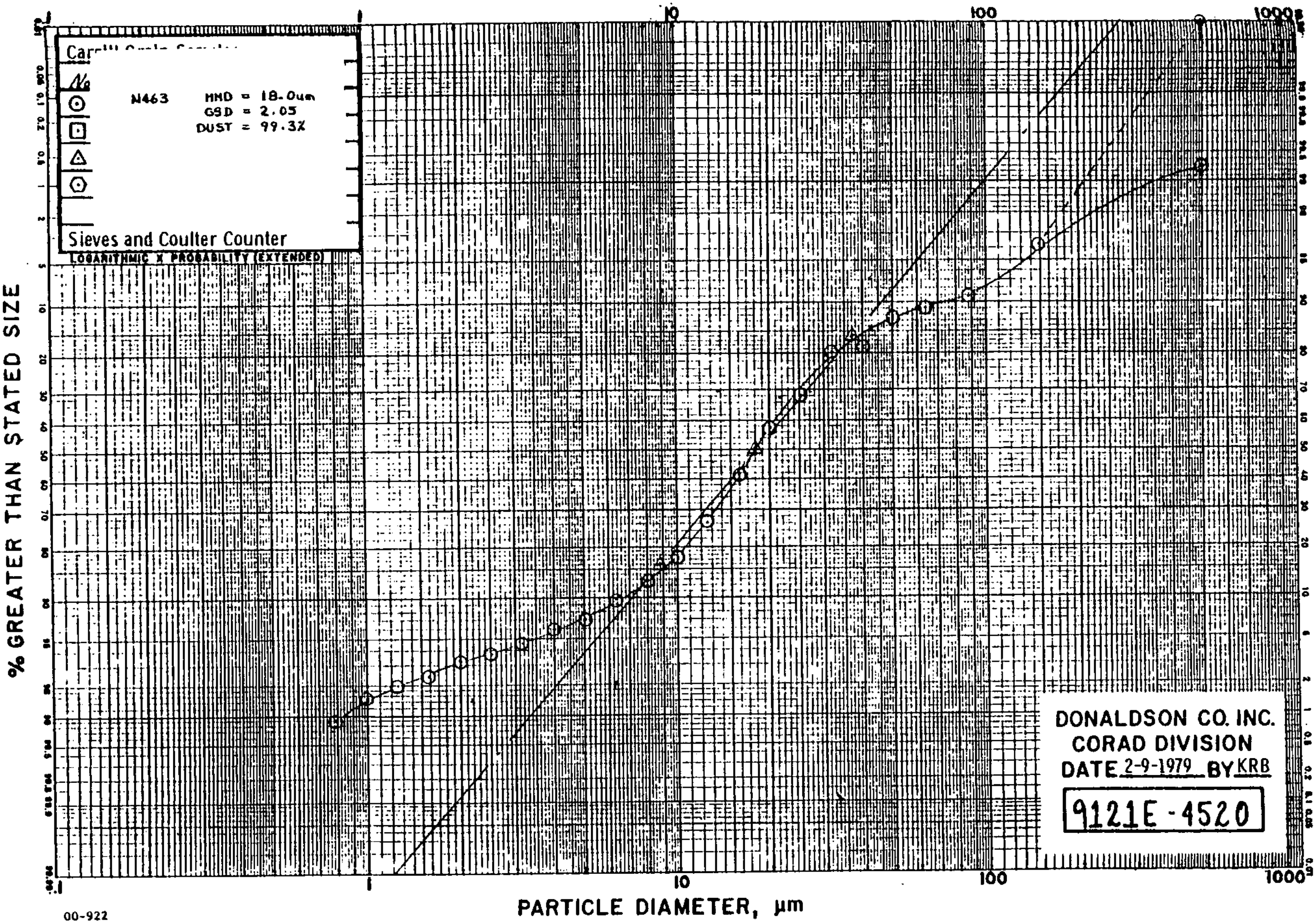

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-2979 BY KRB
9121E - 4524
PARTICLE DIAMETER, µm
N212
MMD = 16.0um
GSD = 1.68
DUST = 98.7%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

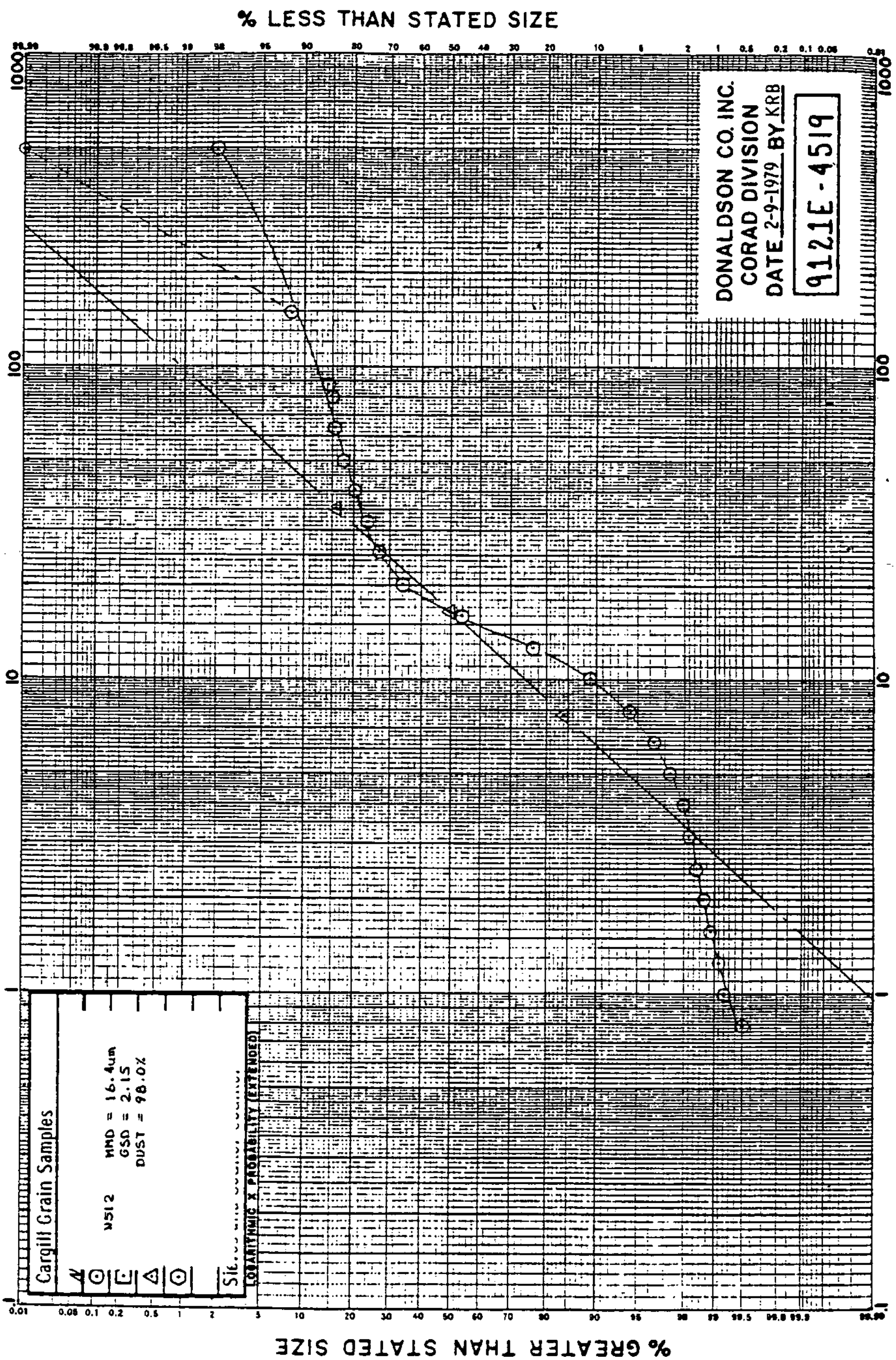


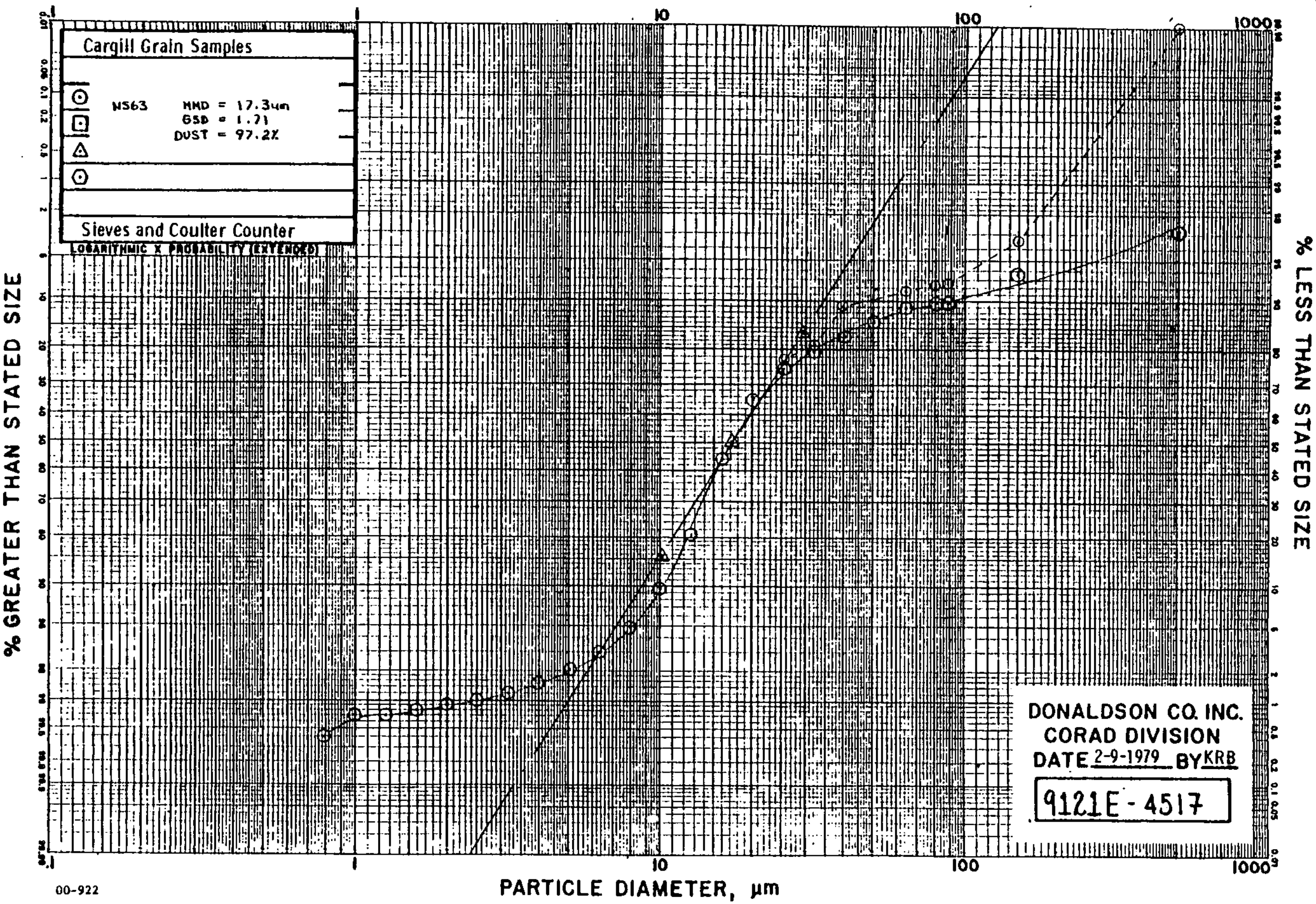
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4523
PARTICLE DIAMETER, μm
N333
MMD = 15.5um
GSD = 1.56
DUST = 99.6%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
DO-922


Sieves and Coulter Counter
N423
MMD = 15.5um
GSD = 1.73
DUST = 97.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4522
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E - 4521
Ca
N434
MMD = 15.5um
GSD = 1.75
DUST = 96.2%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-923

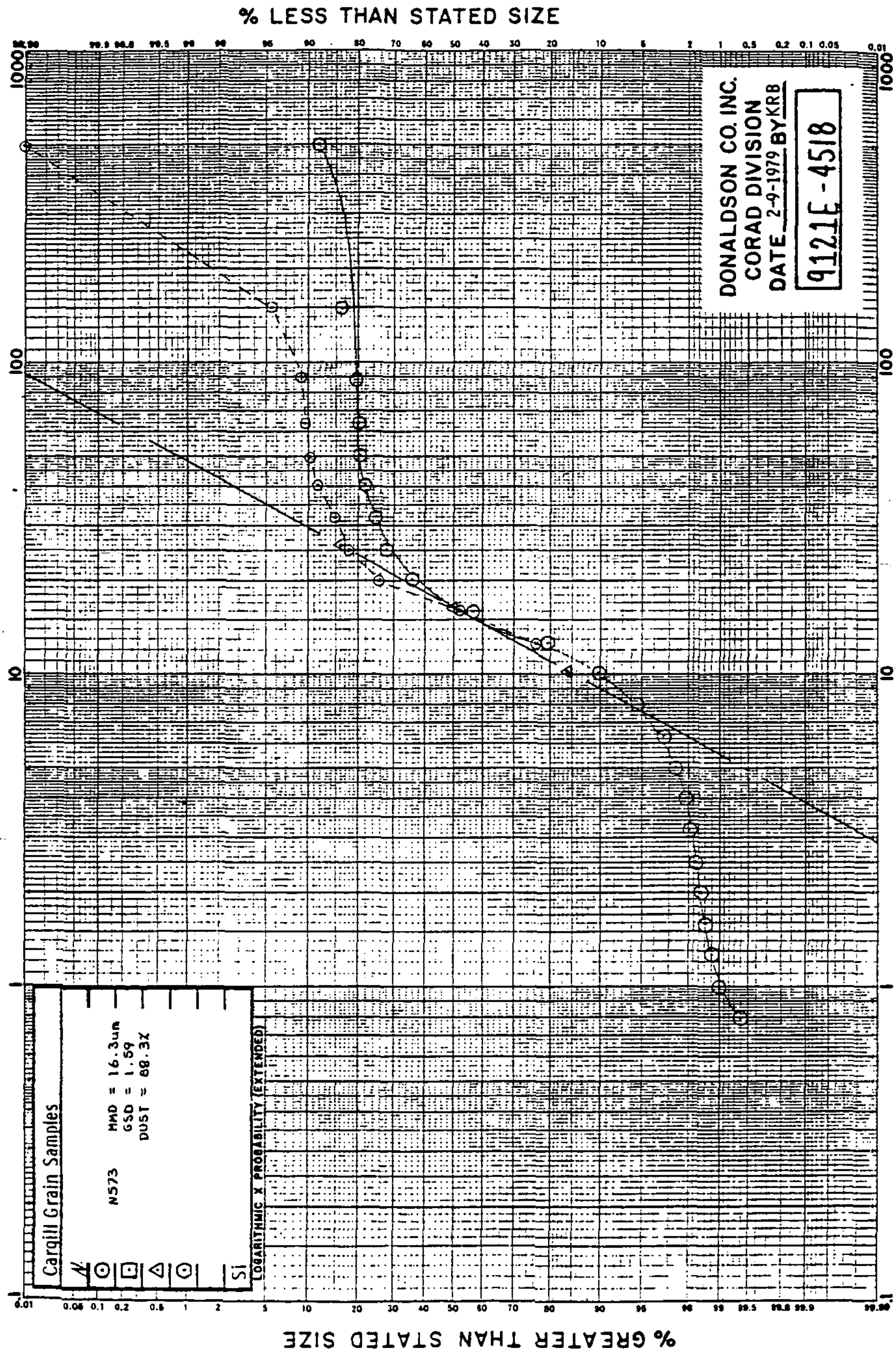

N463
MMD = 18.0um
GSD = 2.05
DUST = 99.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4520
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4519
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
Cargill Grain Samples
W512
MMD = 16.4um
GSD = 2.15
DUST = 98.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

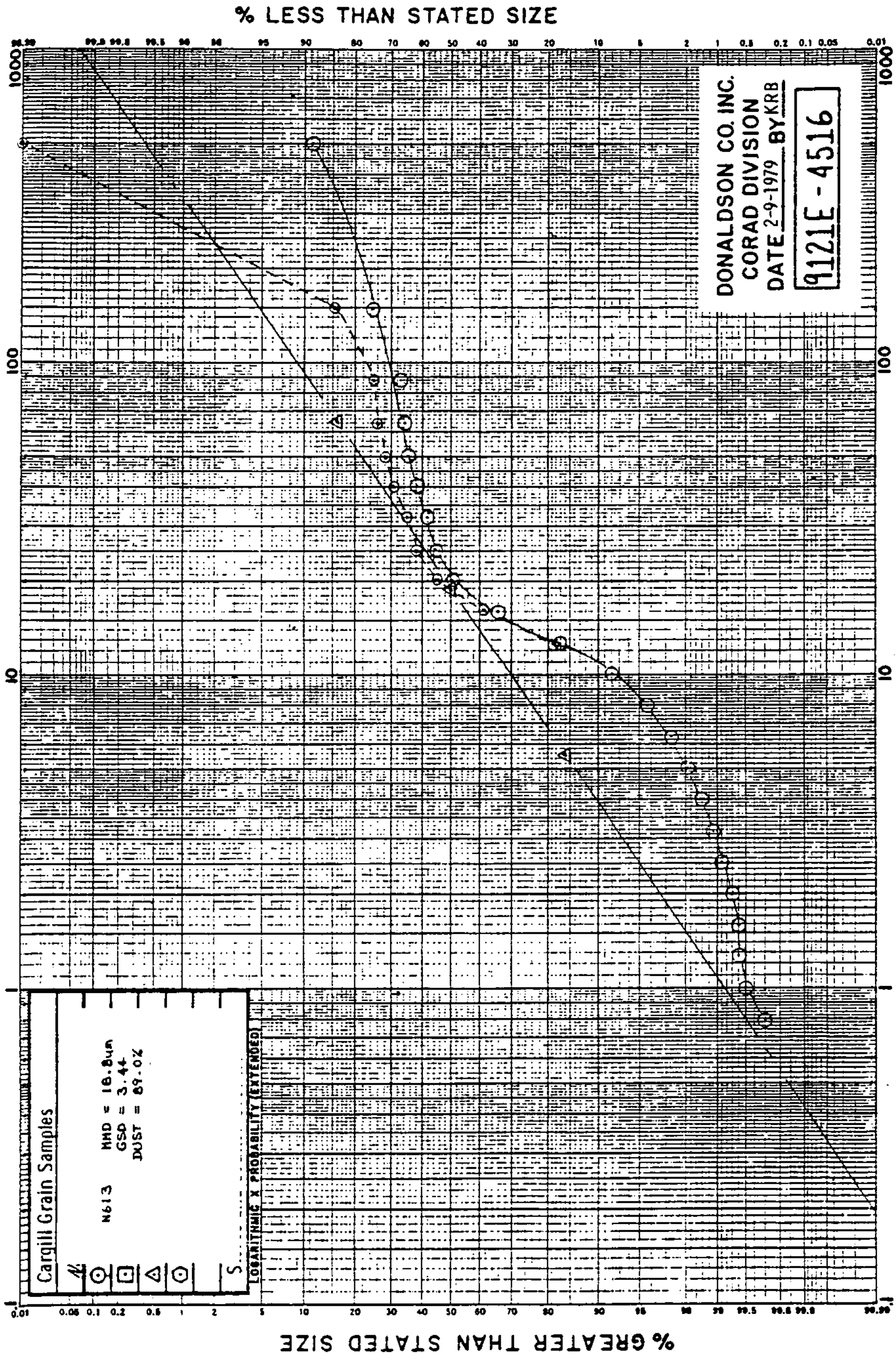


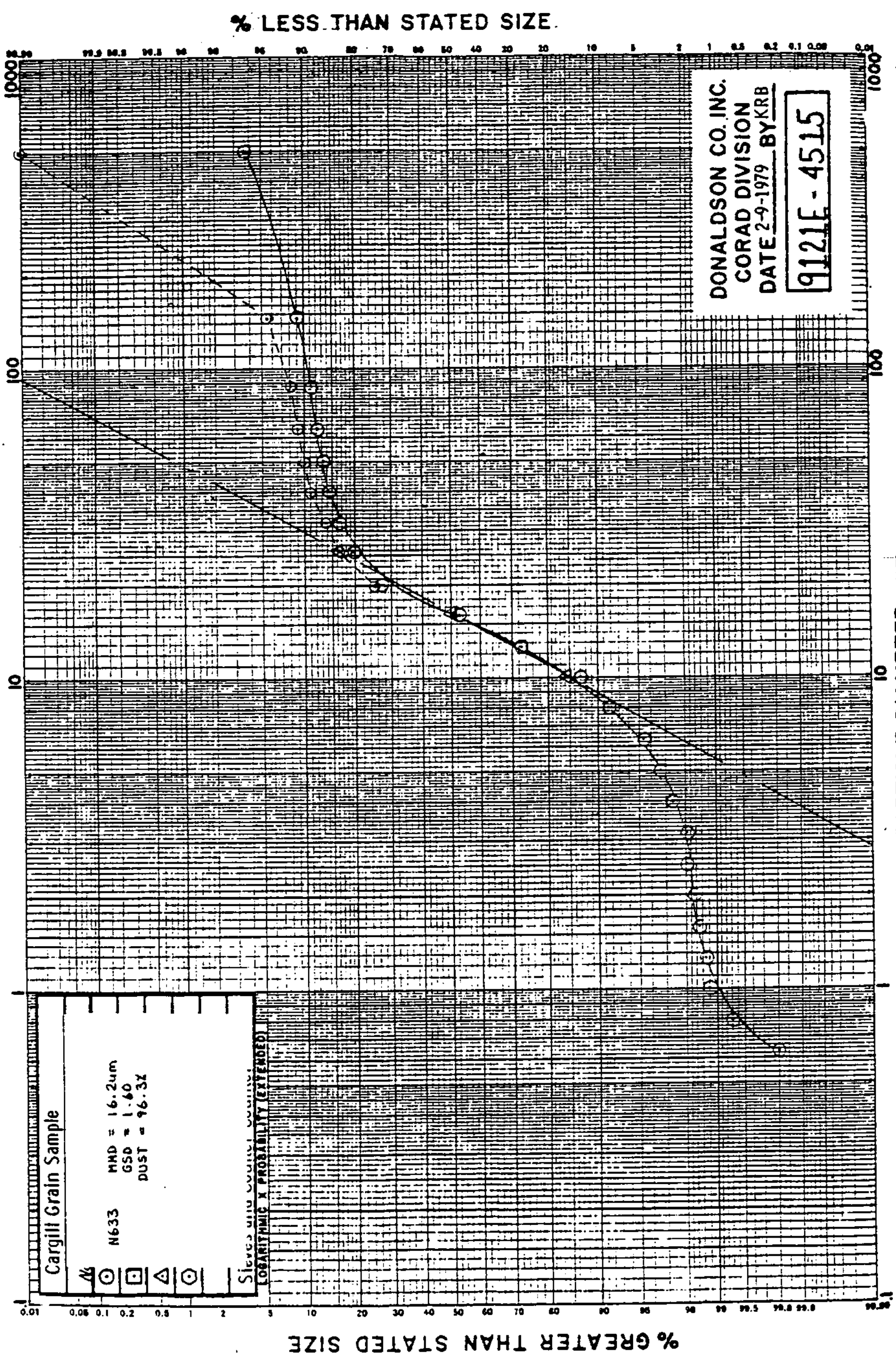
Cargill Grain Samples
NS63 MMD = 17.3um
GSD = 1.71
DUST = 97.2%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4517

00-922

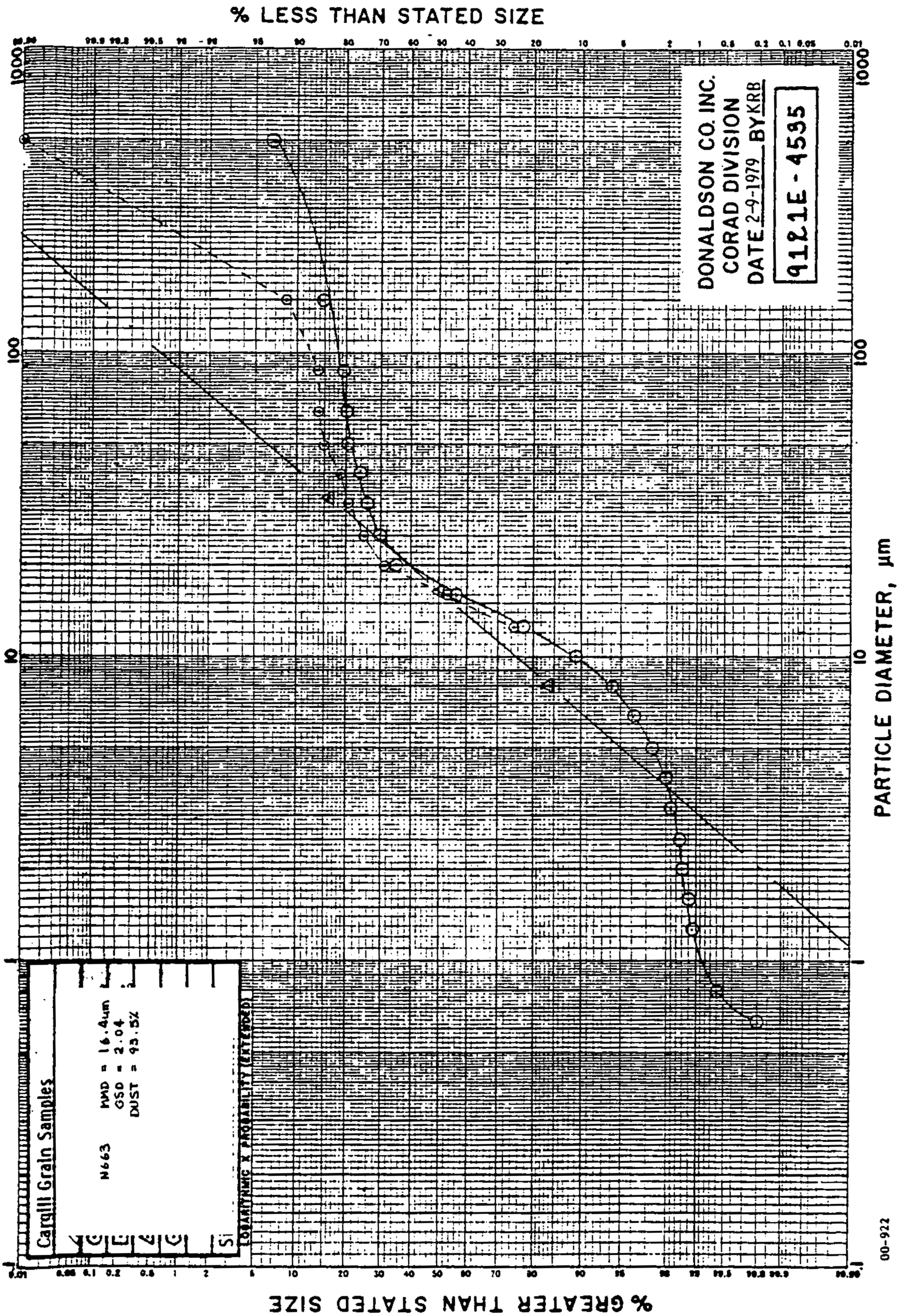


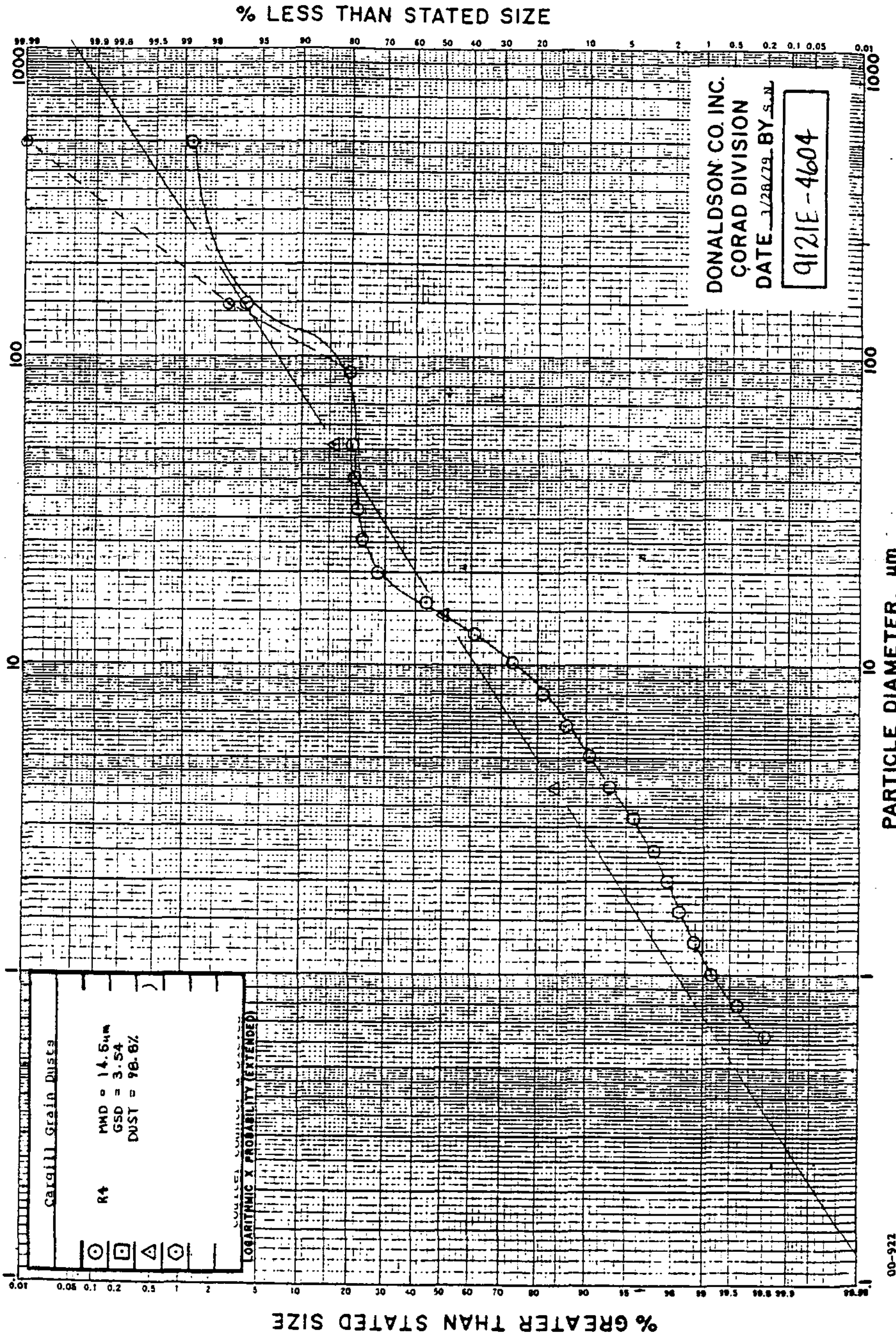
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4518
PARTICLE DIAMETER, µm
Cargill Grain Samples
N573
MMD = 16.3um
GSD = 1.59
DUST = 88.3%
Si
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

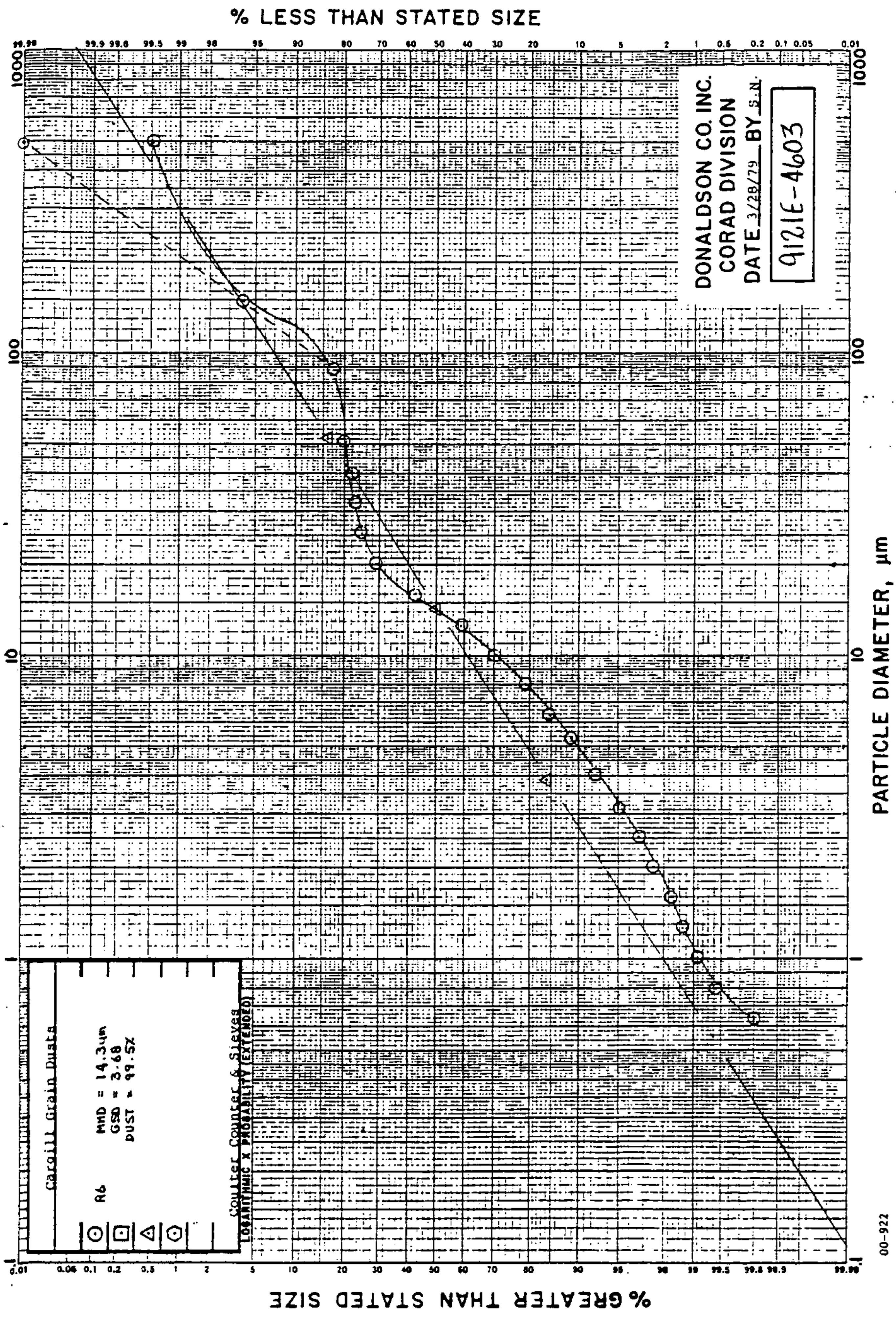

% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4516
Cargill Grain Samples
N613
MMD = 18.8μm
GSD = 3.44
DUST = 89.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

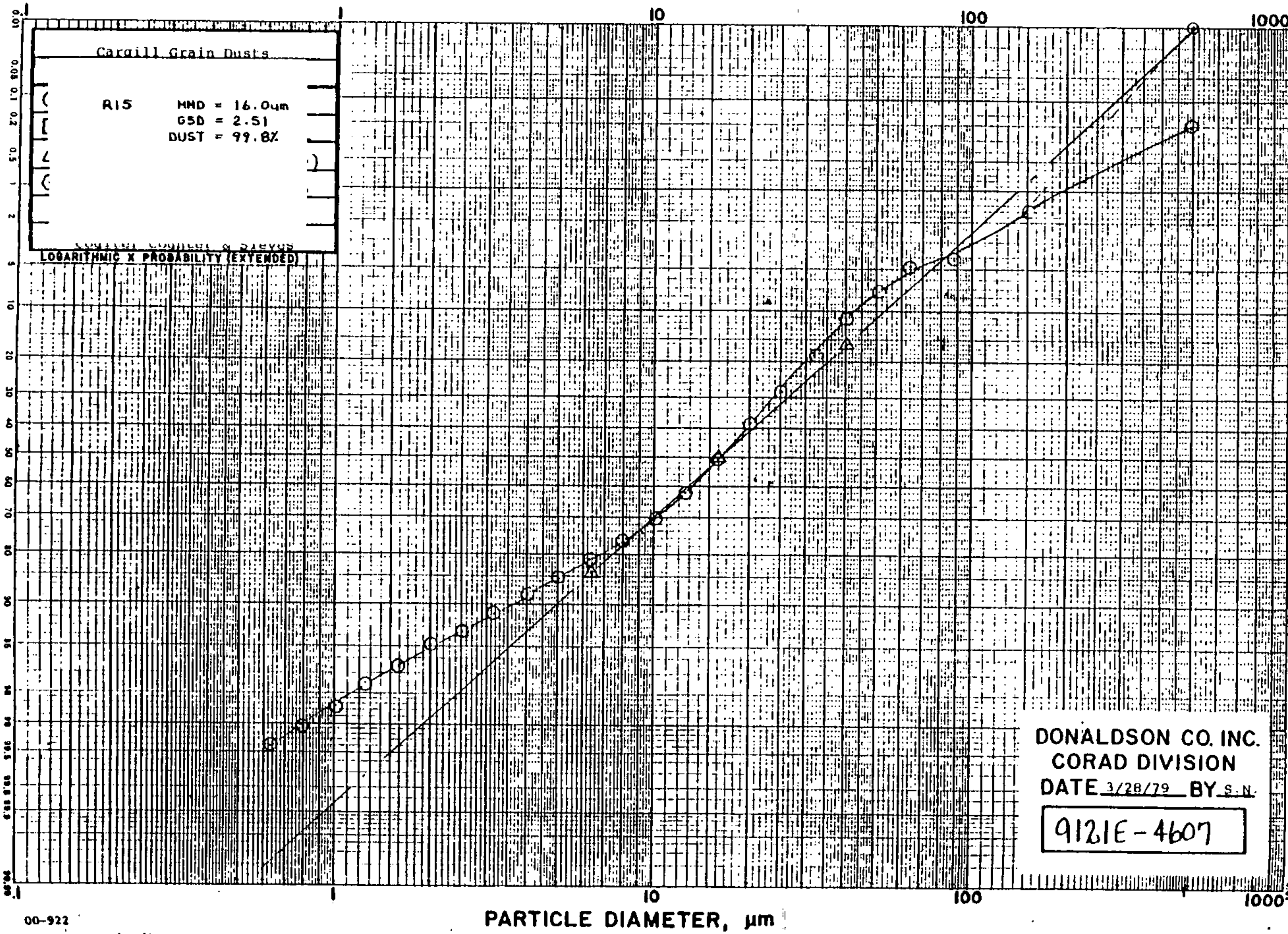


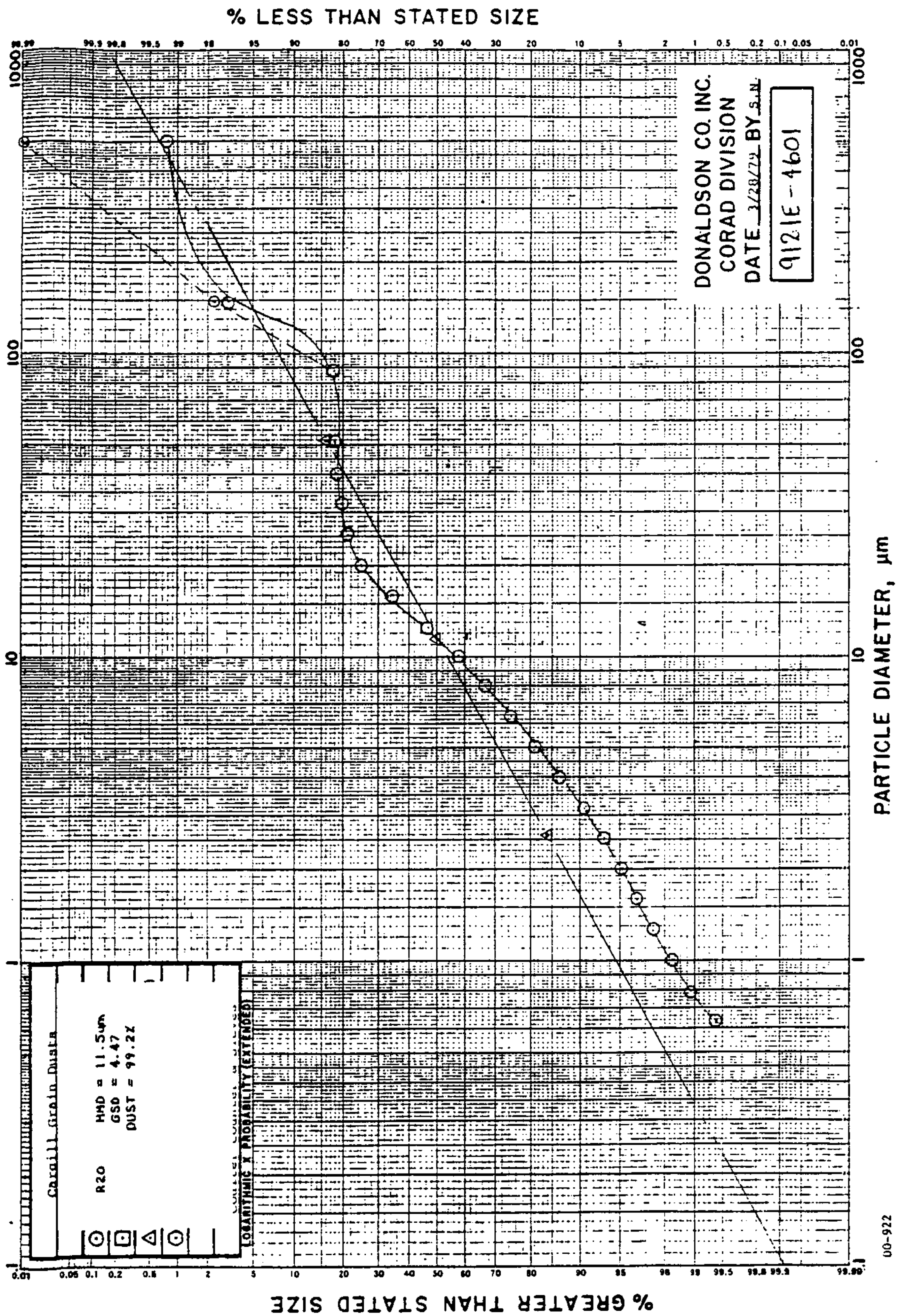
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E - 4515
PARTICLE DIAMETER, µm
Cargill Grain Sample
N633
MMD = 16.2um
GSD = 1.60
DUST = 96.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

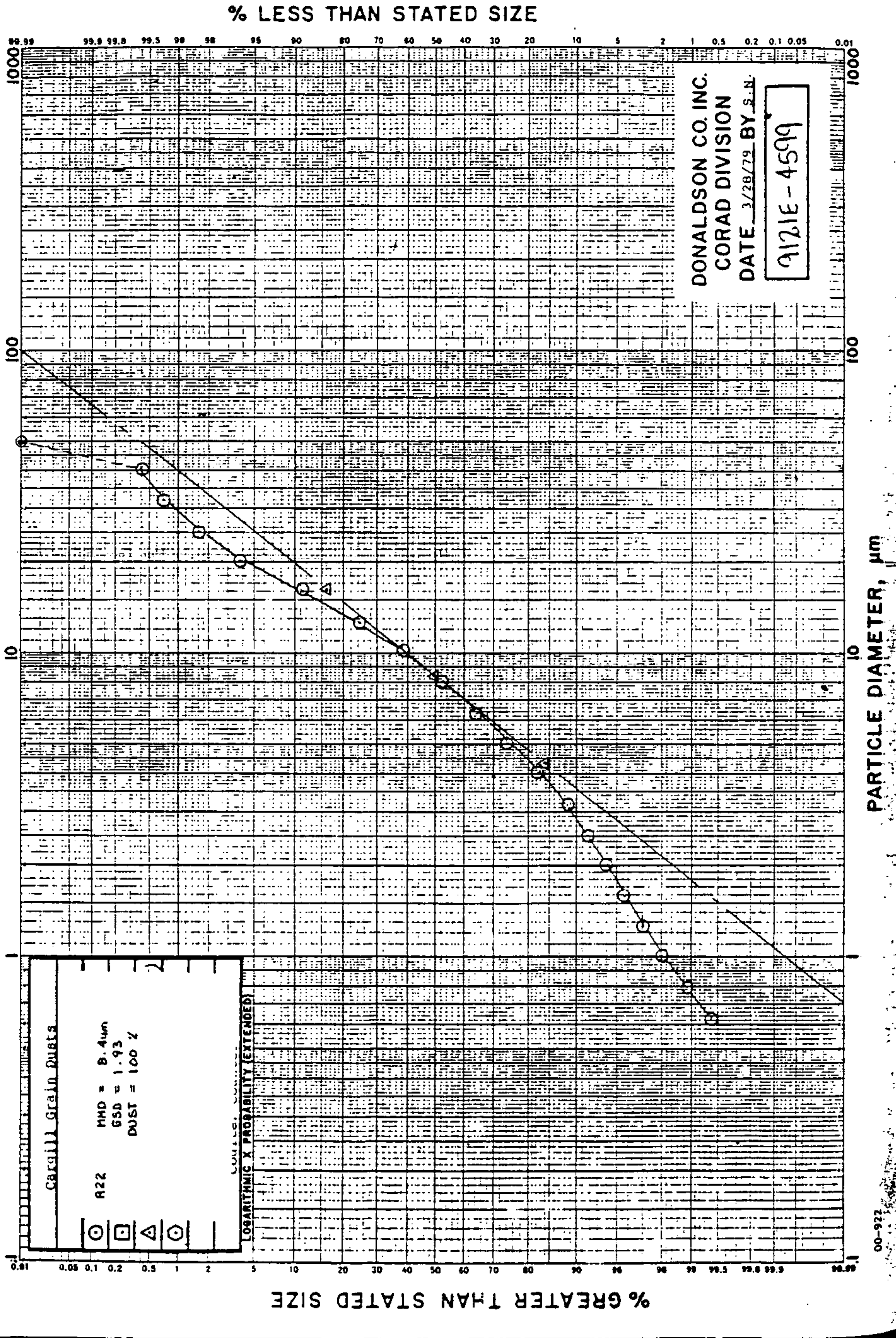

% LESS THAN STATED SIZE
1000
100
10
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-9-1979 BY KRB
9121E-4595
Cargill Grain Samples
N663 MMD = 16.4um
GSD = 2.04
DUST = 93.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

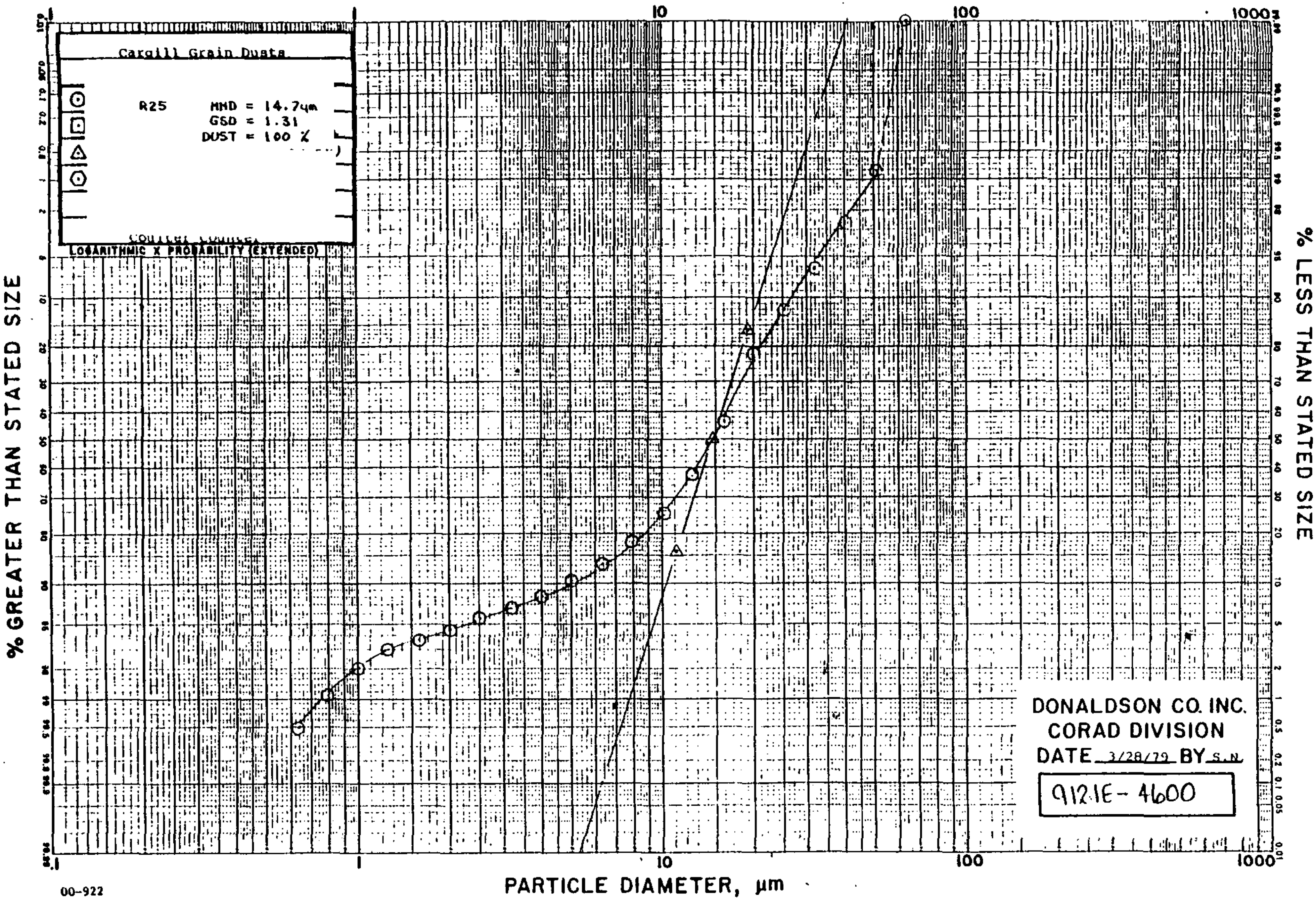

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 1/28/79 BY S.N
9121E-4604
Cargill Grain Dusts
R4
MMD = 14.5µm
GSD = 3.54
DUST = 98.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

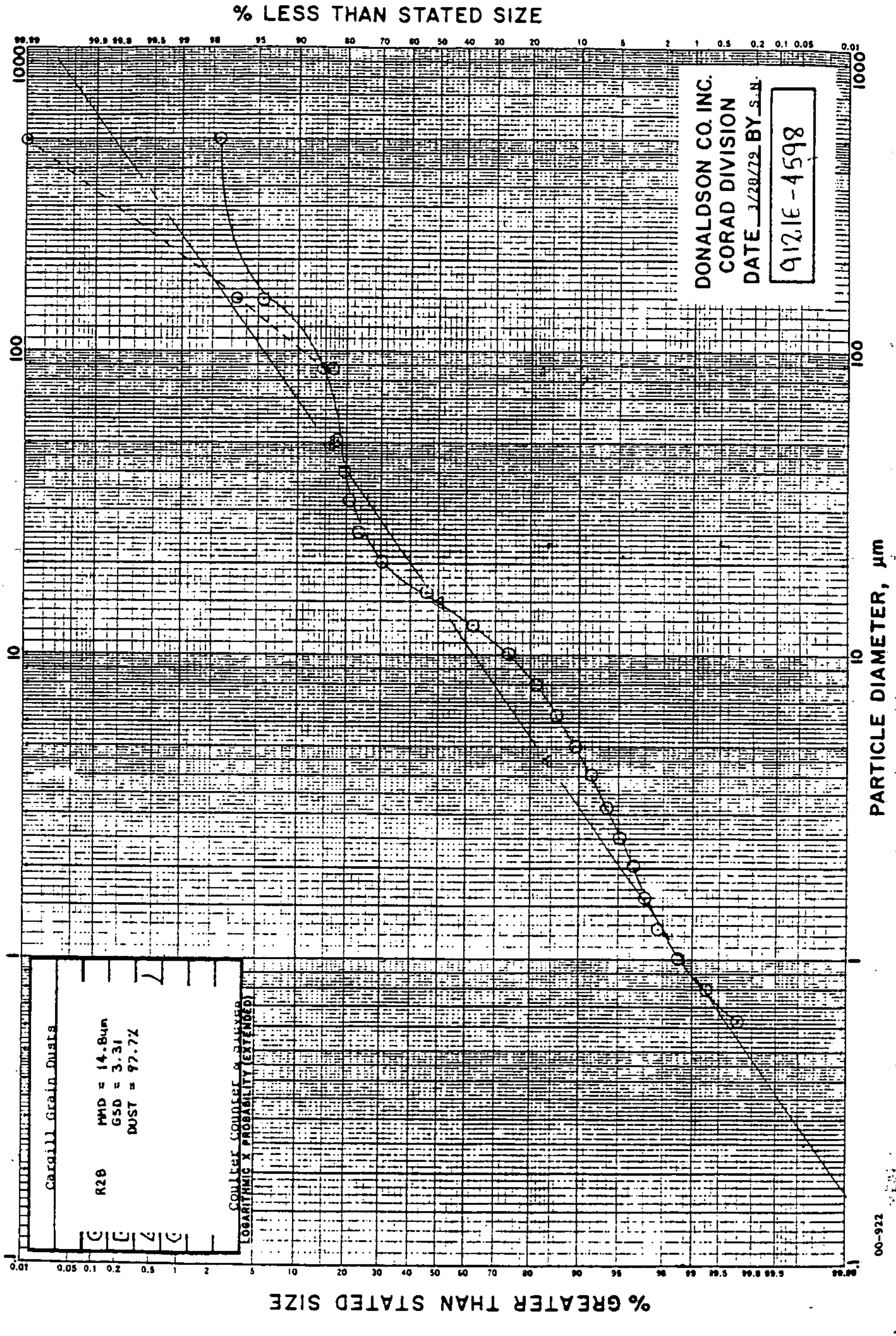

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4603
PARTICLE DIAMETER, µm
Cargill Grain Dusts
R6
MMD = 14.3µm
GSD = 3.68
DUST = 99.5%
Coulter Counter & Sieves
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

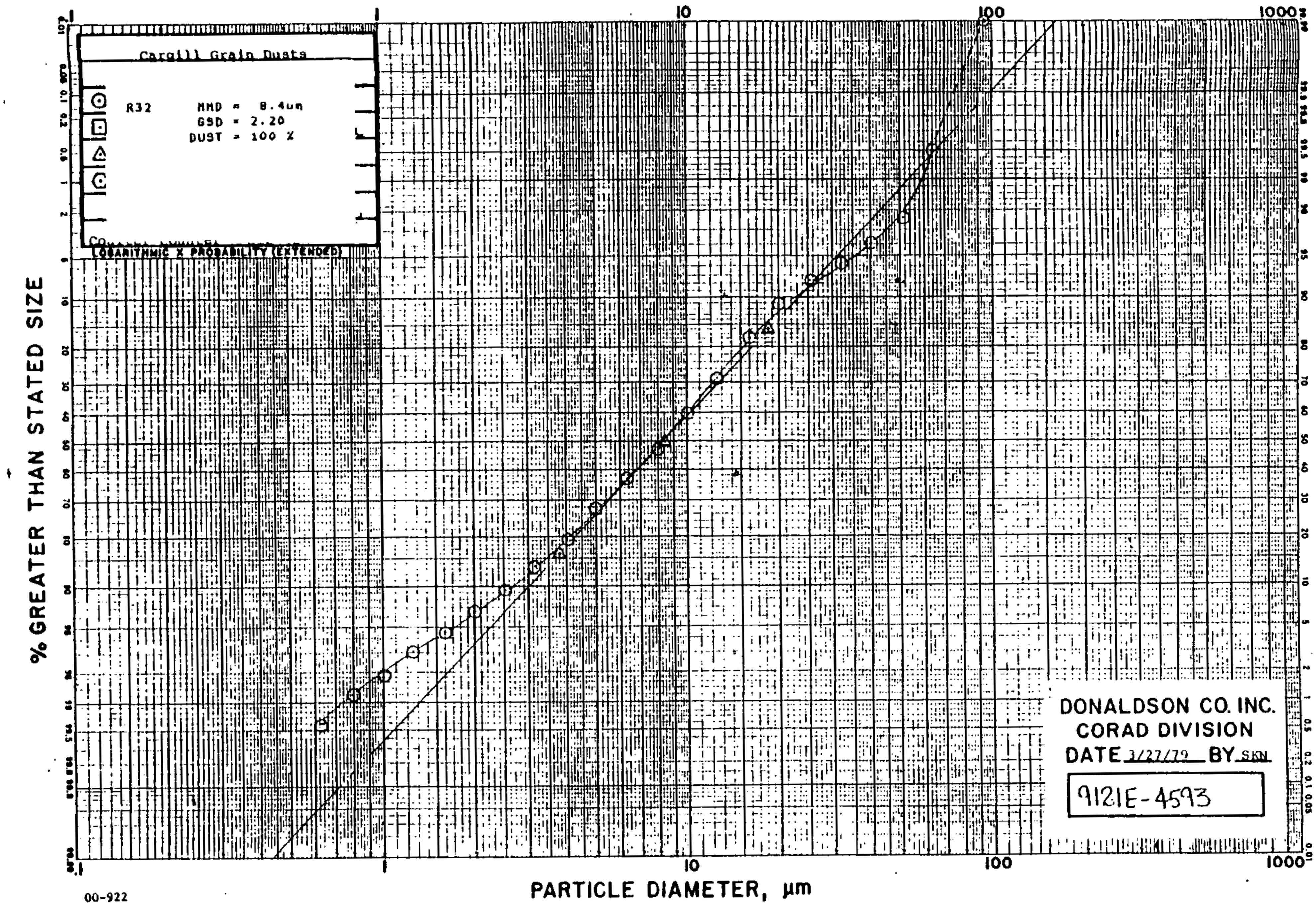

Cargill Grain Dusts
R15
MMD = 16.0um
GSD = 2.51
DUST = 99.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4607
00-922

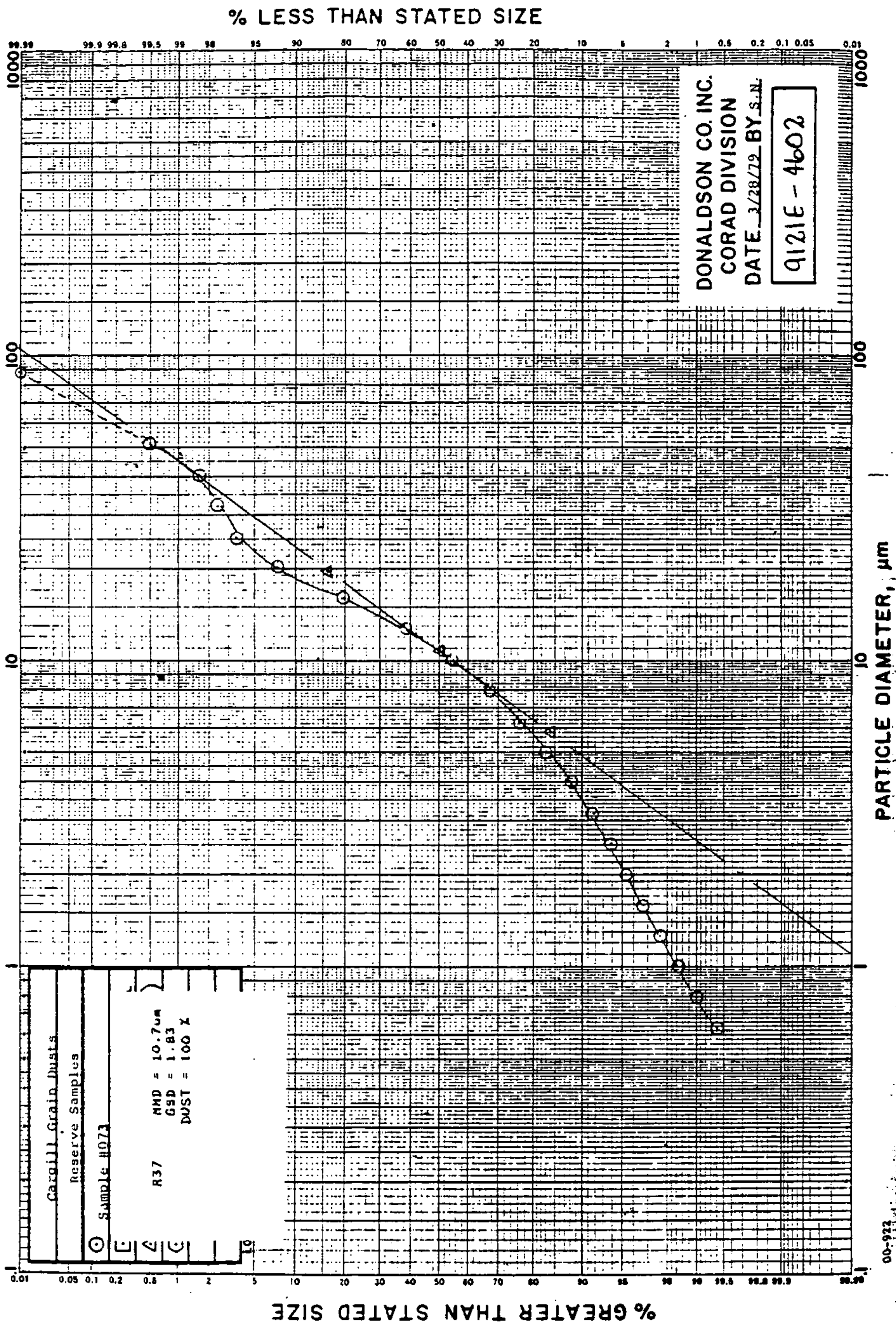

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N
9121E-4601
PARTICLE DIAMETER, µm
Cargill Grain Dusts
R20
MMD = 11.5µm
GSD = 4.47
DUST = 99.2%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4599
Cargill Grain Dusts
A22
MMD = 8.4um
GSD = 1.93
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

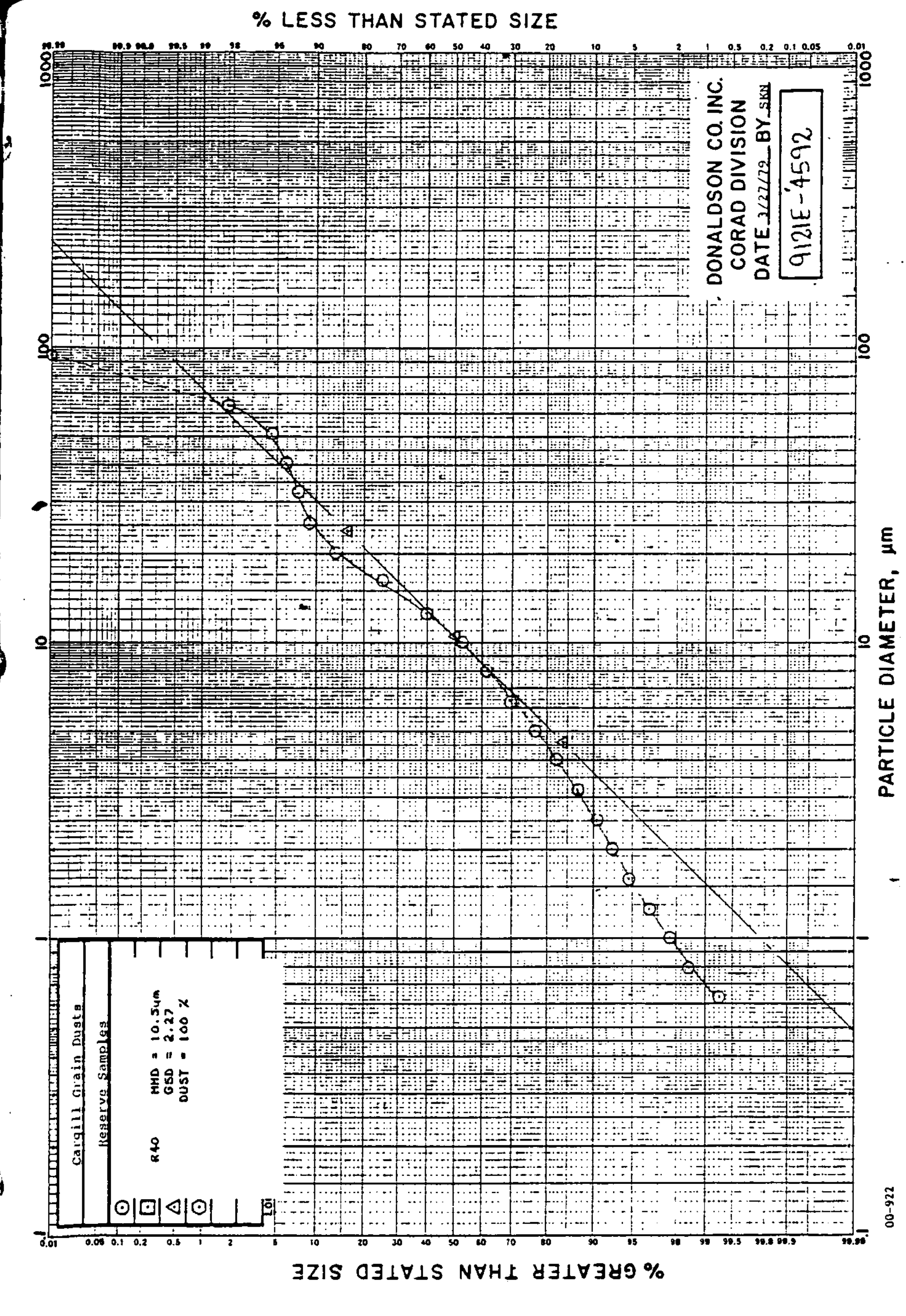

Cargill Grain Dusts
R25
MMD = 14.7µm
GSD = 1.31
DUST = 100 %
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4600
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4598
Cargill Grain Dusts
R28
MMD = 14.8µm
GSD = 3.31
DUST = 97.7%
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

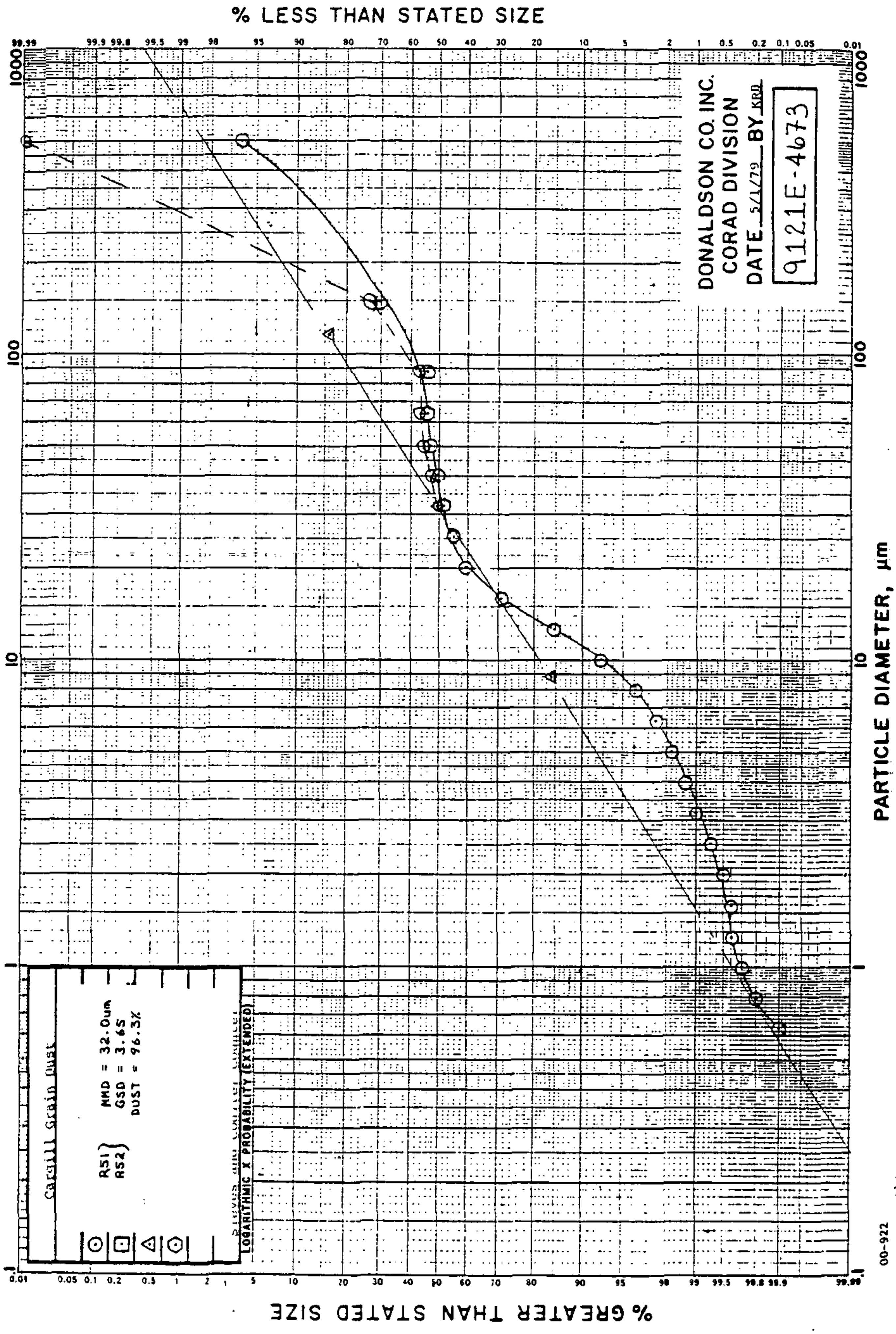

Cargill Grain Dusts
R32
MMD = 8.4um
GSD = 2.20
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/27/79 BY SKN
9121E-4593
00-922

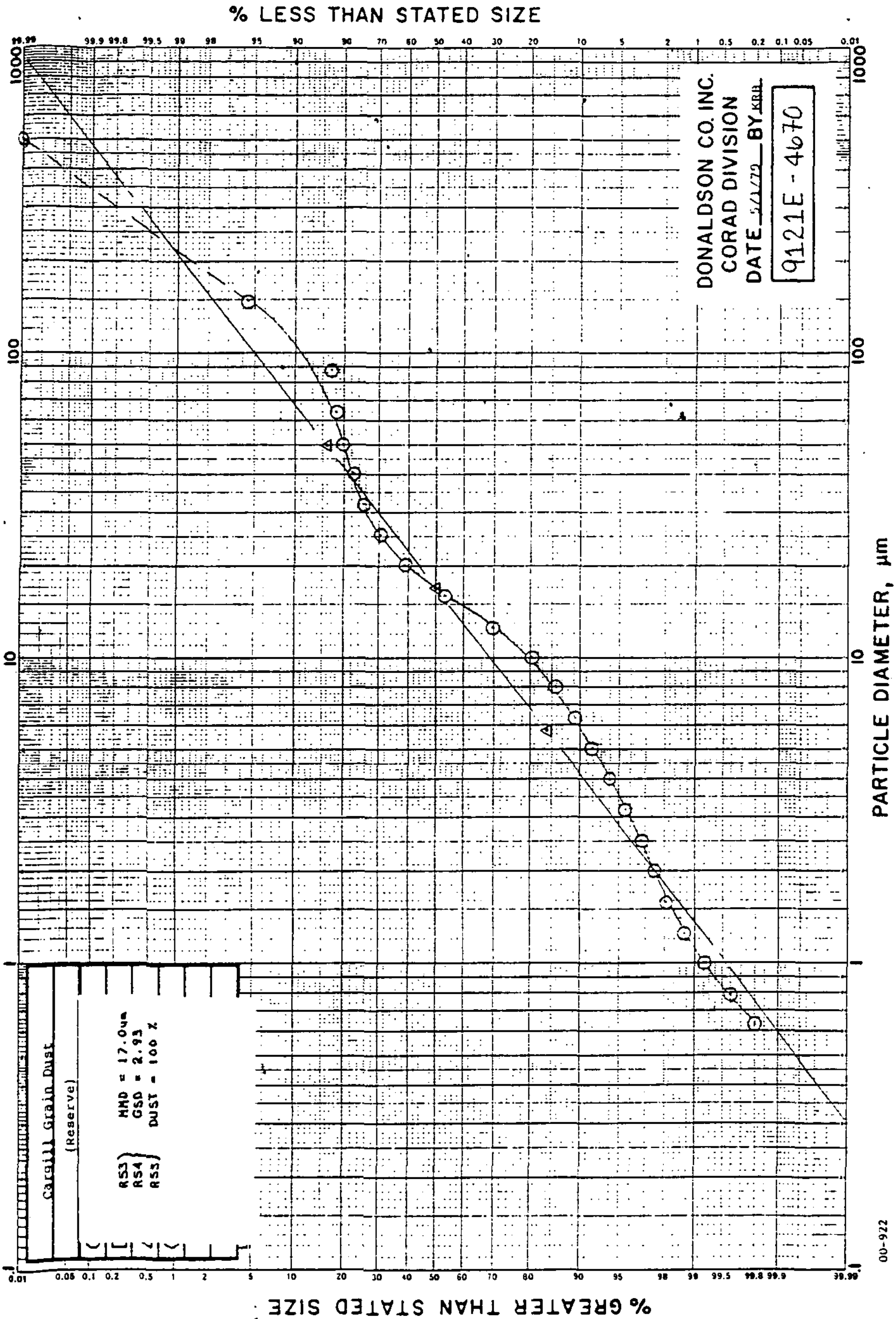


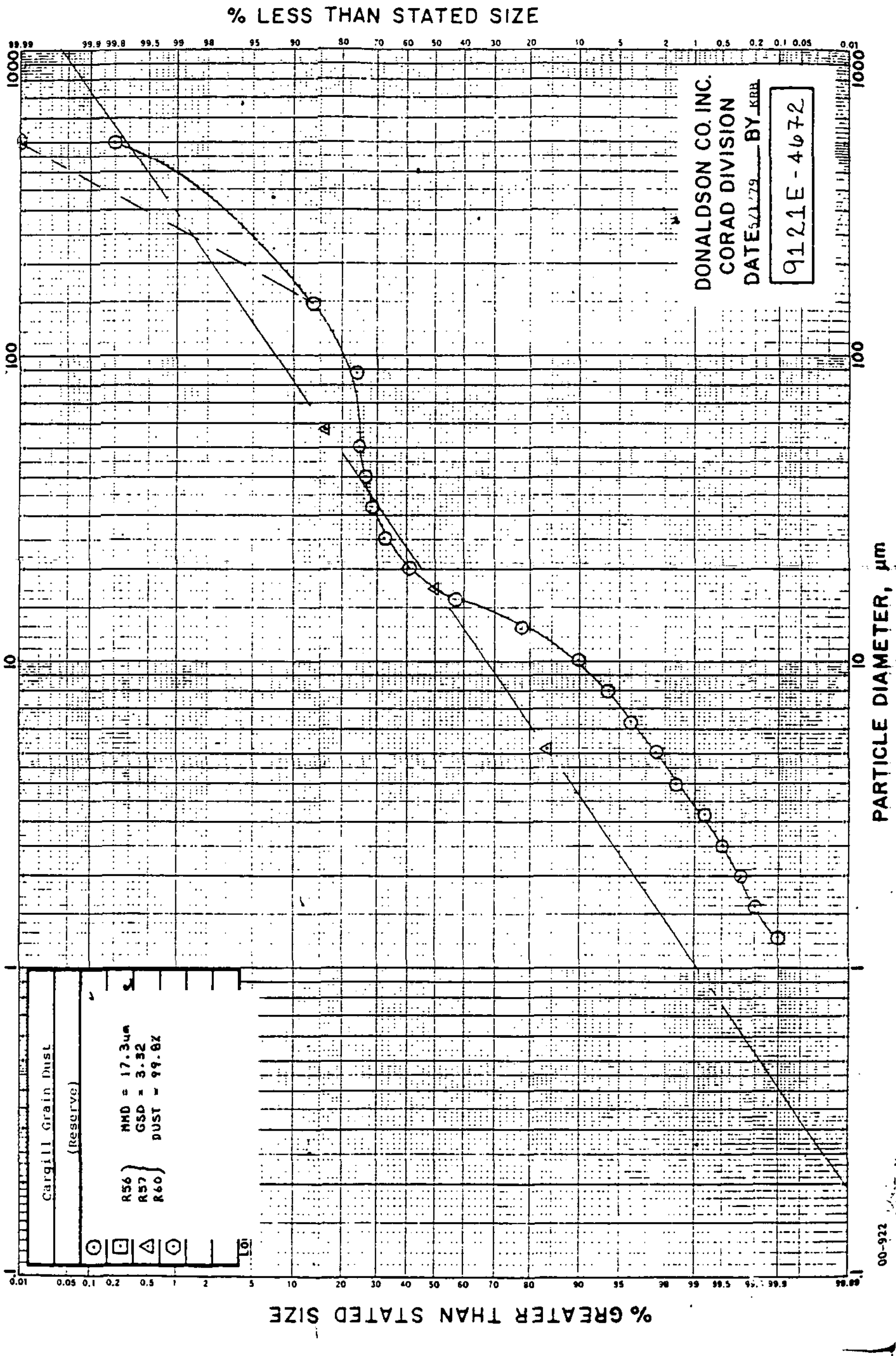
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4602
Cargill Grain Dusts
Reserve Samples
Sample #073
R37
MMD = 10.7um
GSD = 1.83
DUST = 100 %
00-922



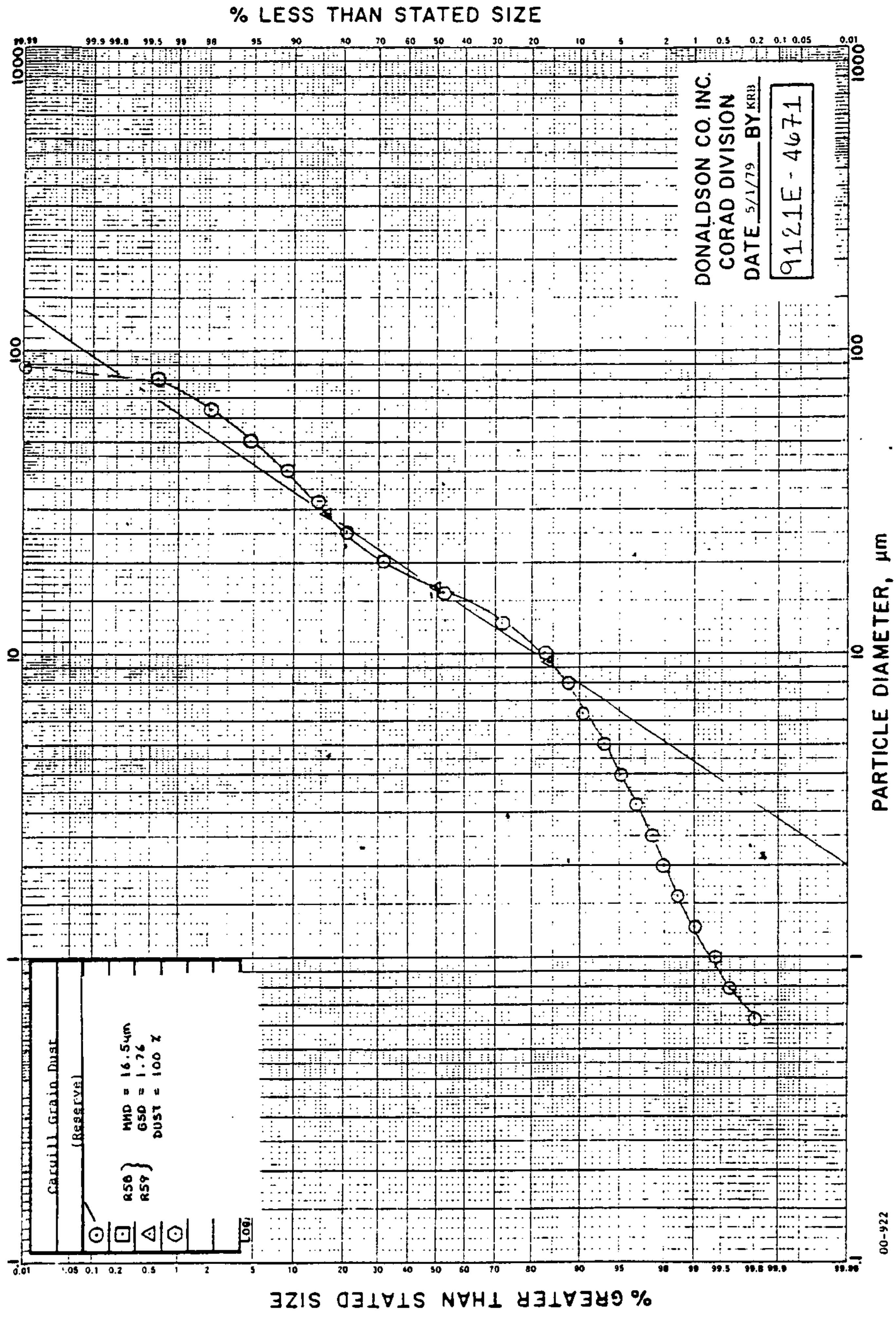
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/27/79 BY SKN
9121E-4592
PARTICLE DIAMETER, µm
Cargill Grain Dusts
Reserve Samples
R40
MMD = 10.5µm
GSD = 2.27
DUST = 100 %
% GREATER THAN STATED SIZE
00-922

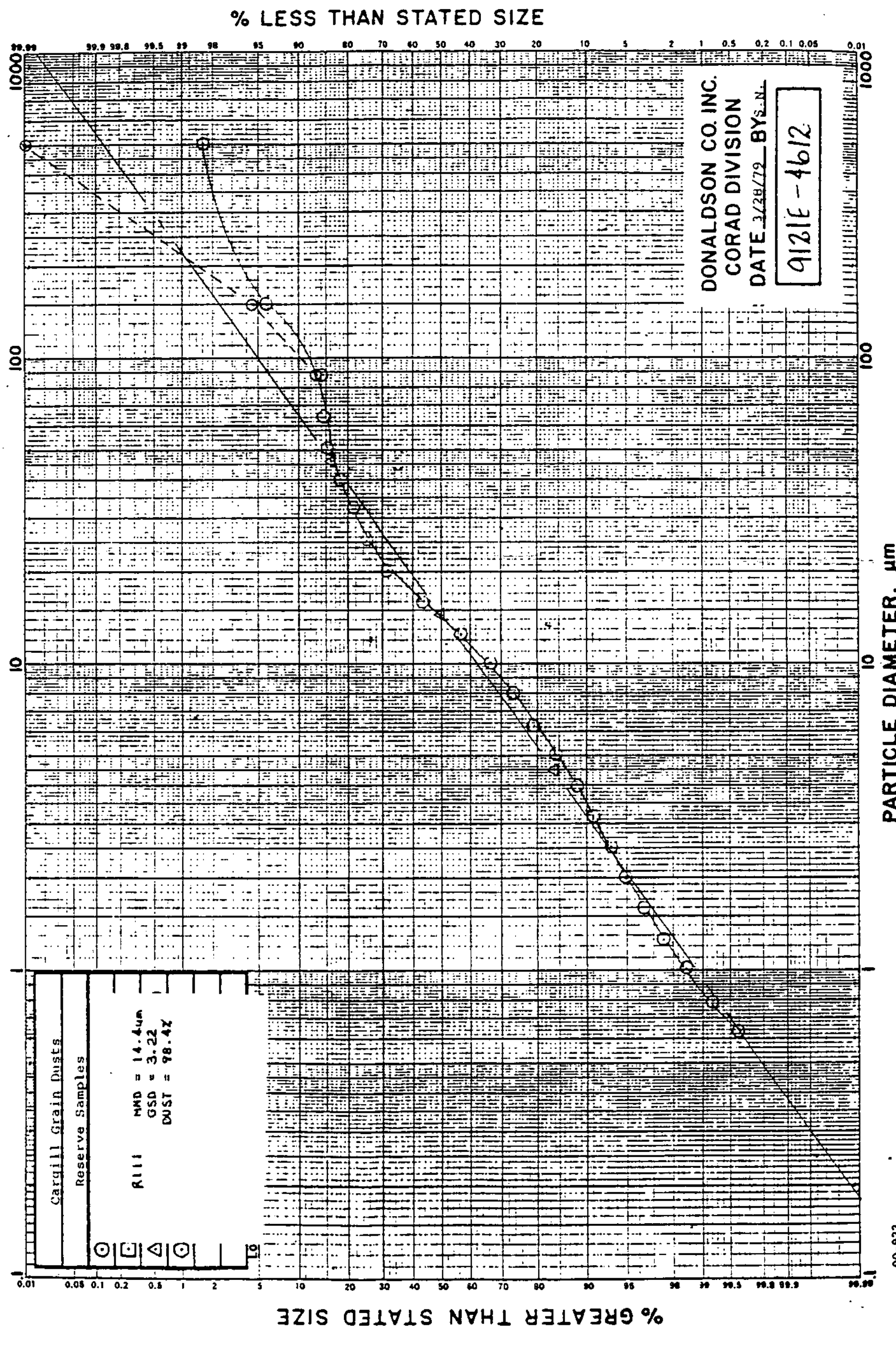

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/11/79 BY KRB
9121E-4673
PARTICLE DIAMETER, µm
Cargill Grain Dust
R51
R52
MMD = 32.0um
GSD = 3.65
DUST = 96.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY KRB
9121E - 4670
Cargill Grain Dust
(Reserve)
RS3
RS4
RS5
MMD = 17.0um
GSD = 2.93
DUST = 100 %
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

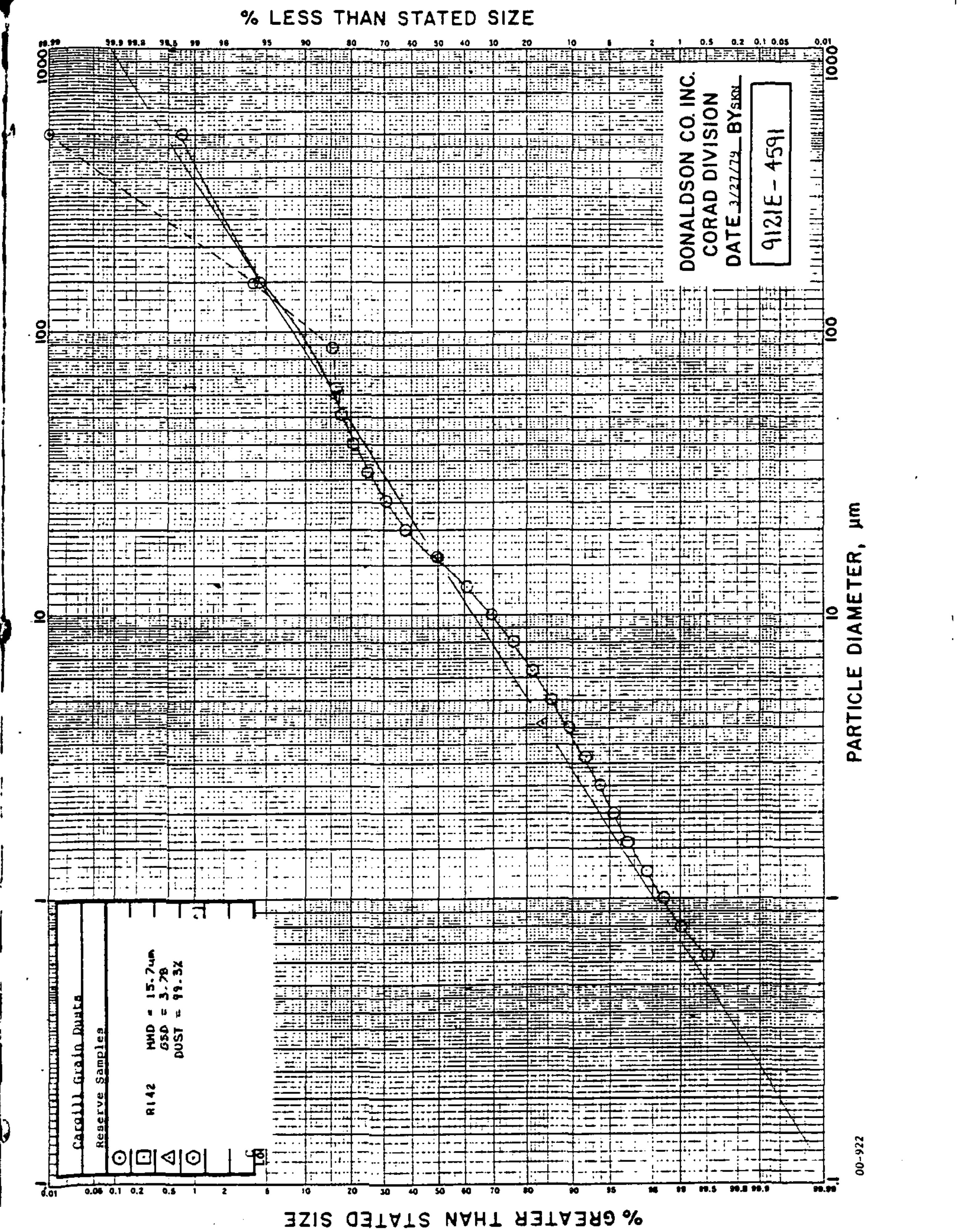


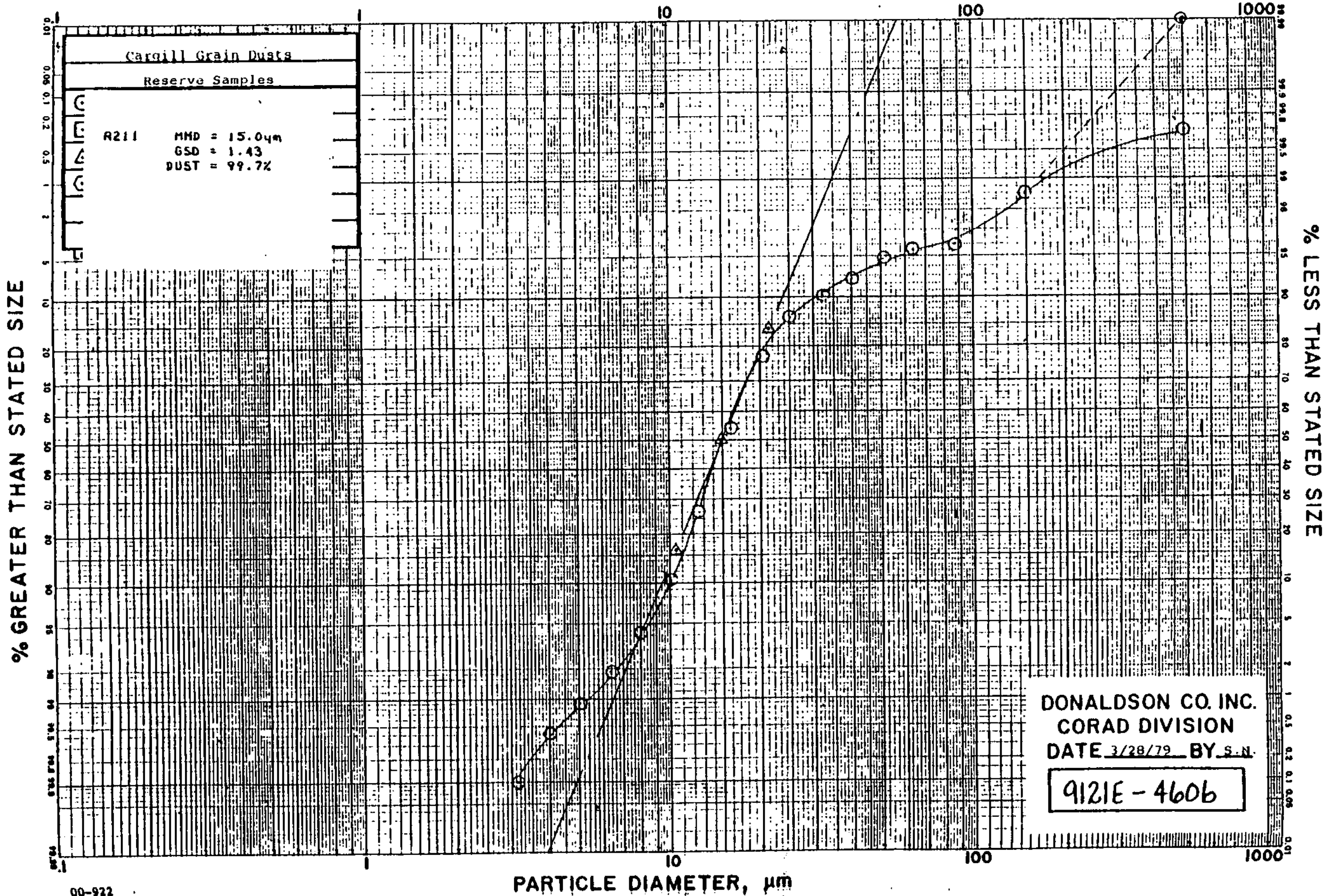
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRH
9121E-4672
Cargill Grain Dust
(Reserve)
R56
R57
R60
MMD = 17.3um
GSD = 3.32
DUST = 99.8%
00-922

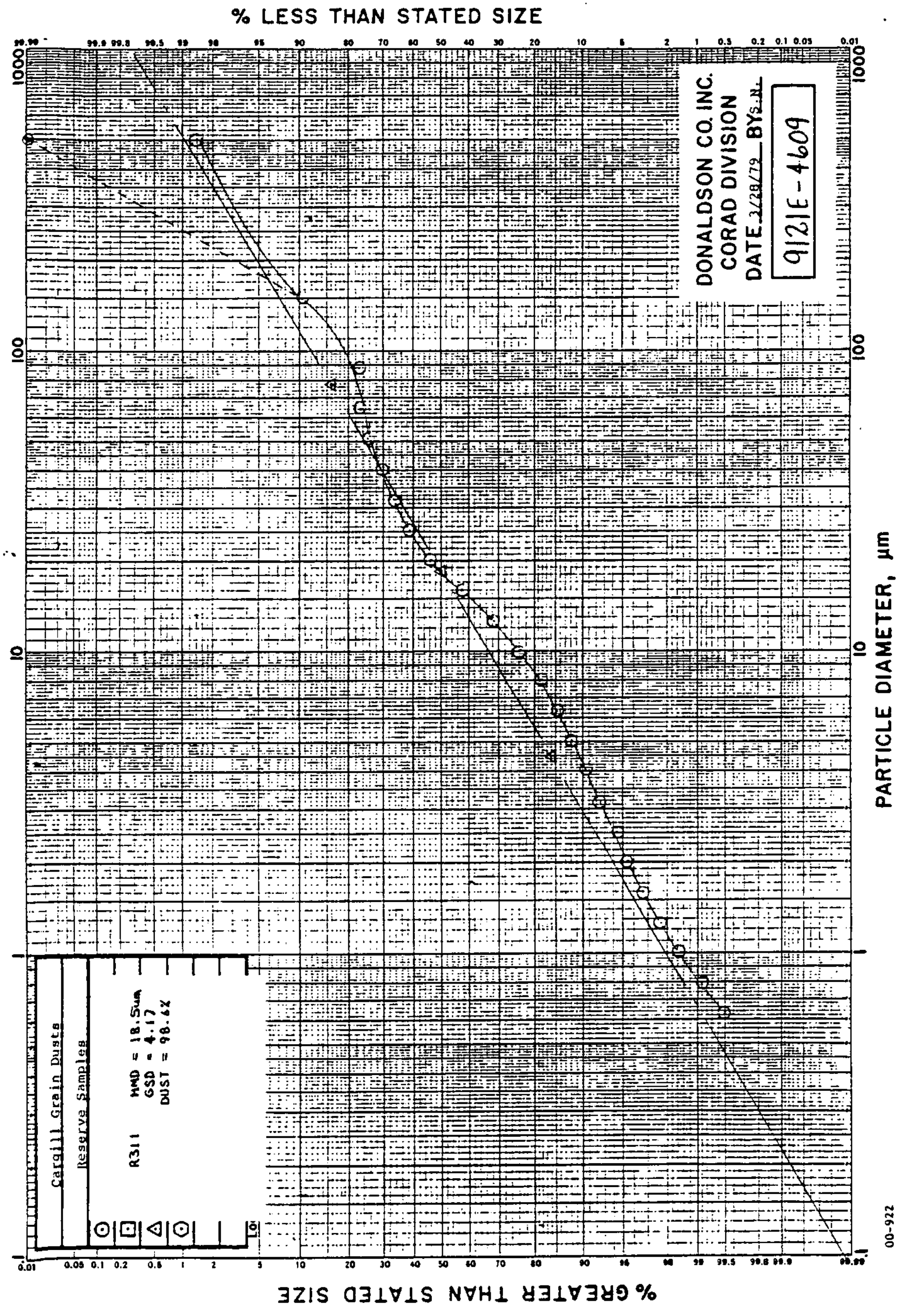

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5/1/79 BY KRB
9121E - 4671
PARTICLE DIAMETER, µm
Cargill Grain Dust
(Reserve)
RS8
RS9
MMD = 16.5µm
GSD = 1.76
DUST = 100 %
% GREATER THAN STATED SIZE
00-922

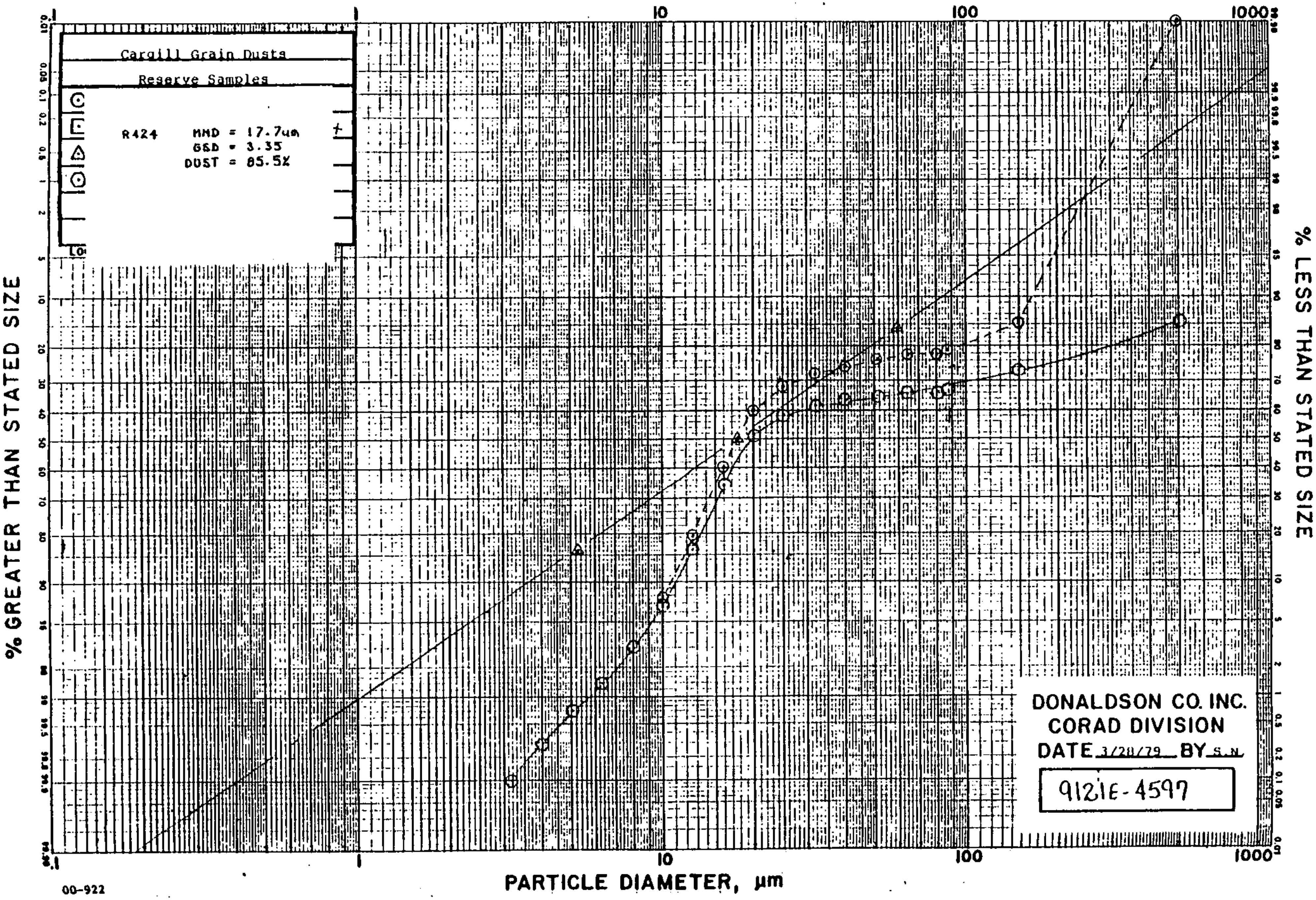


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4612
Cargill Grain Dusts
Reserve Samples
R111
MMD = 14.4um
GSD = 3.22
DUST = 98.4%
00-922

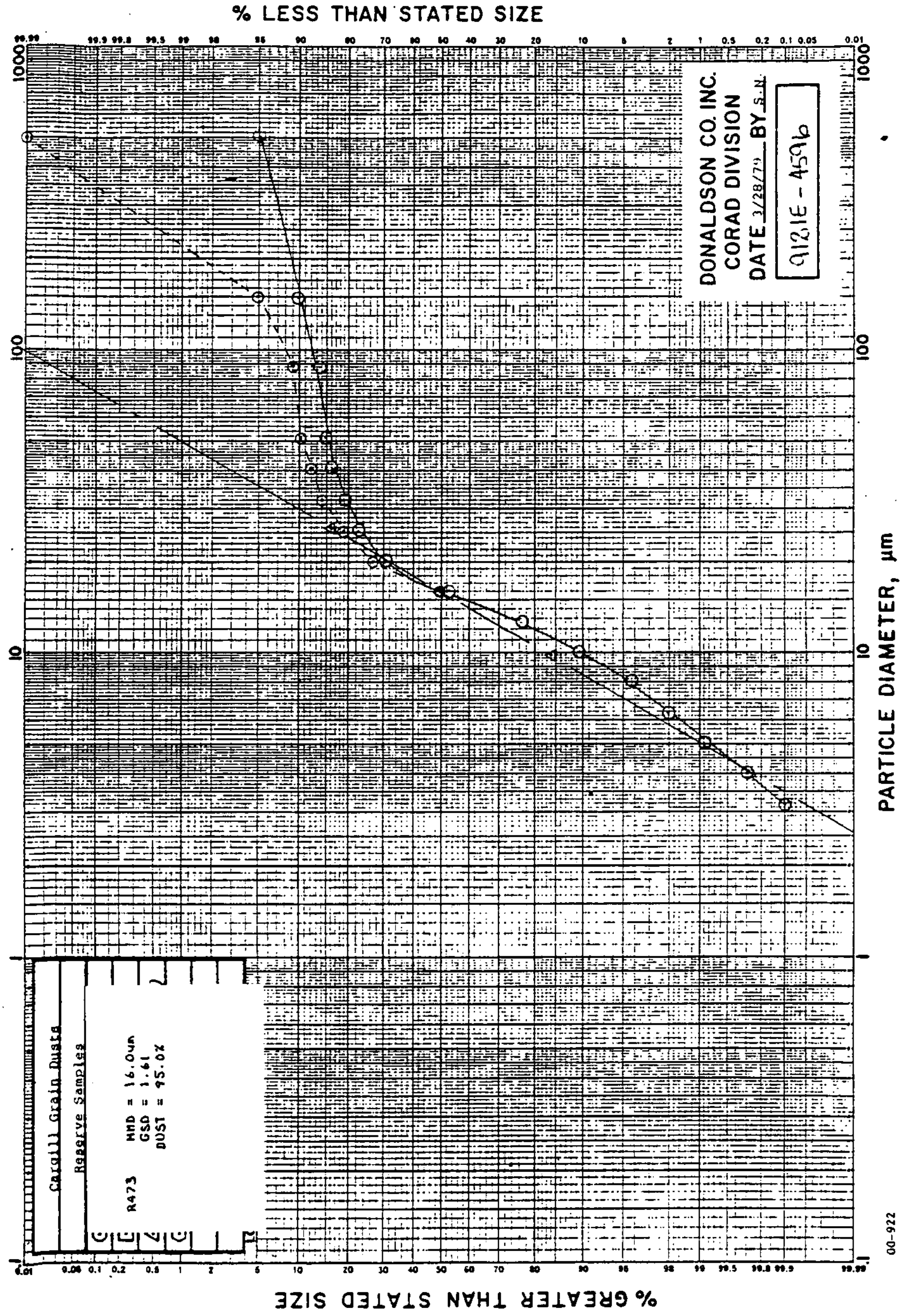

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/27/79 BY SKN
9121E - 4591
Cargill Grain Dusts
Reserve Samples
R142
MMD = 15.7um
GSD = 3.78
DUST = 99.3%
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

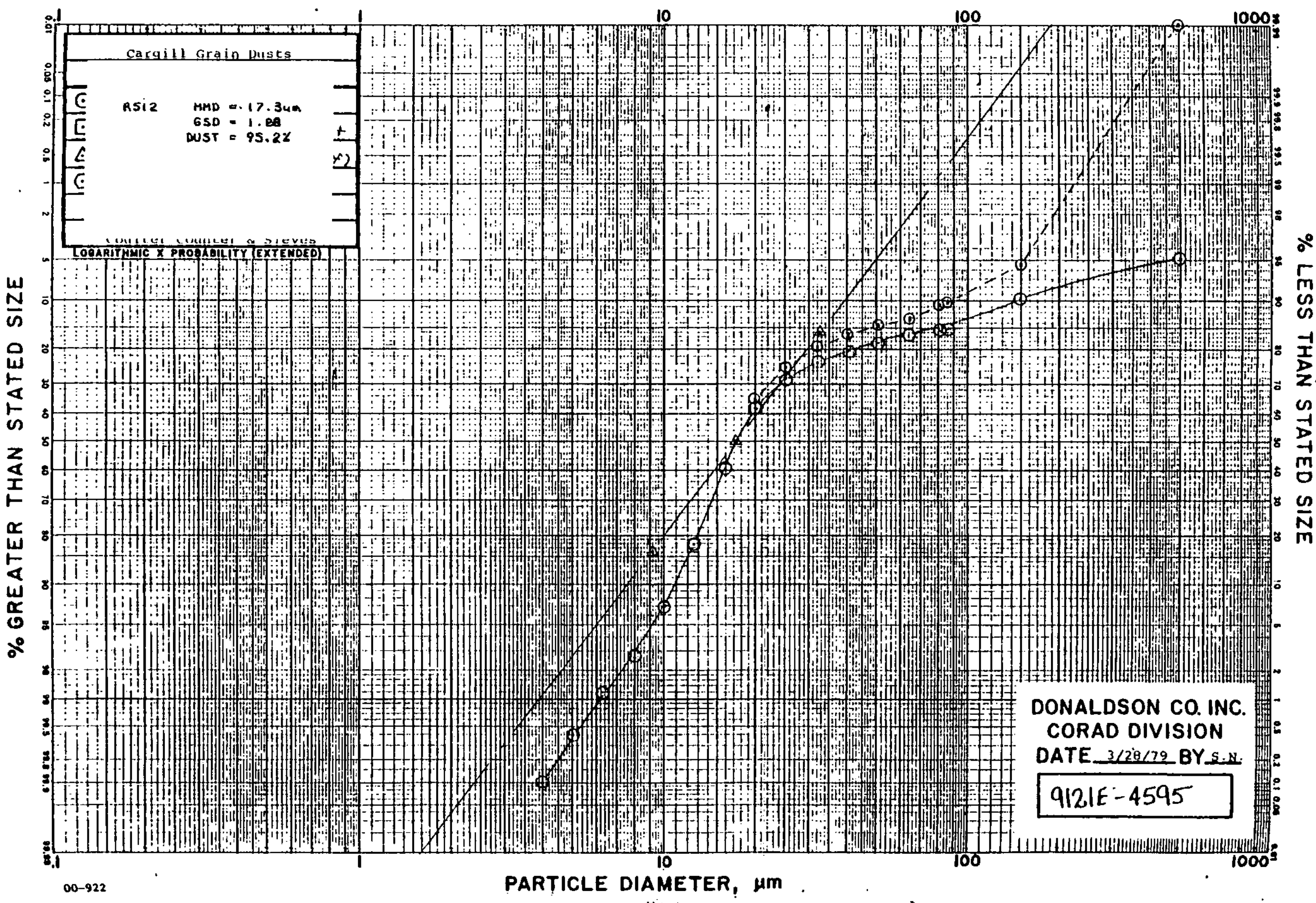

Cargill Grain Dusts
Reserve Samples
R211 MMD = 15.0μm
GSD = 1.43
DUST = 99.7%
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E - 4606
00-922

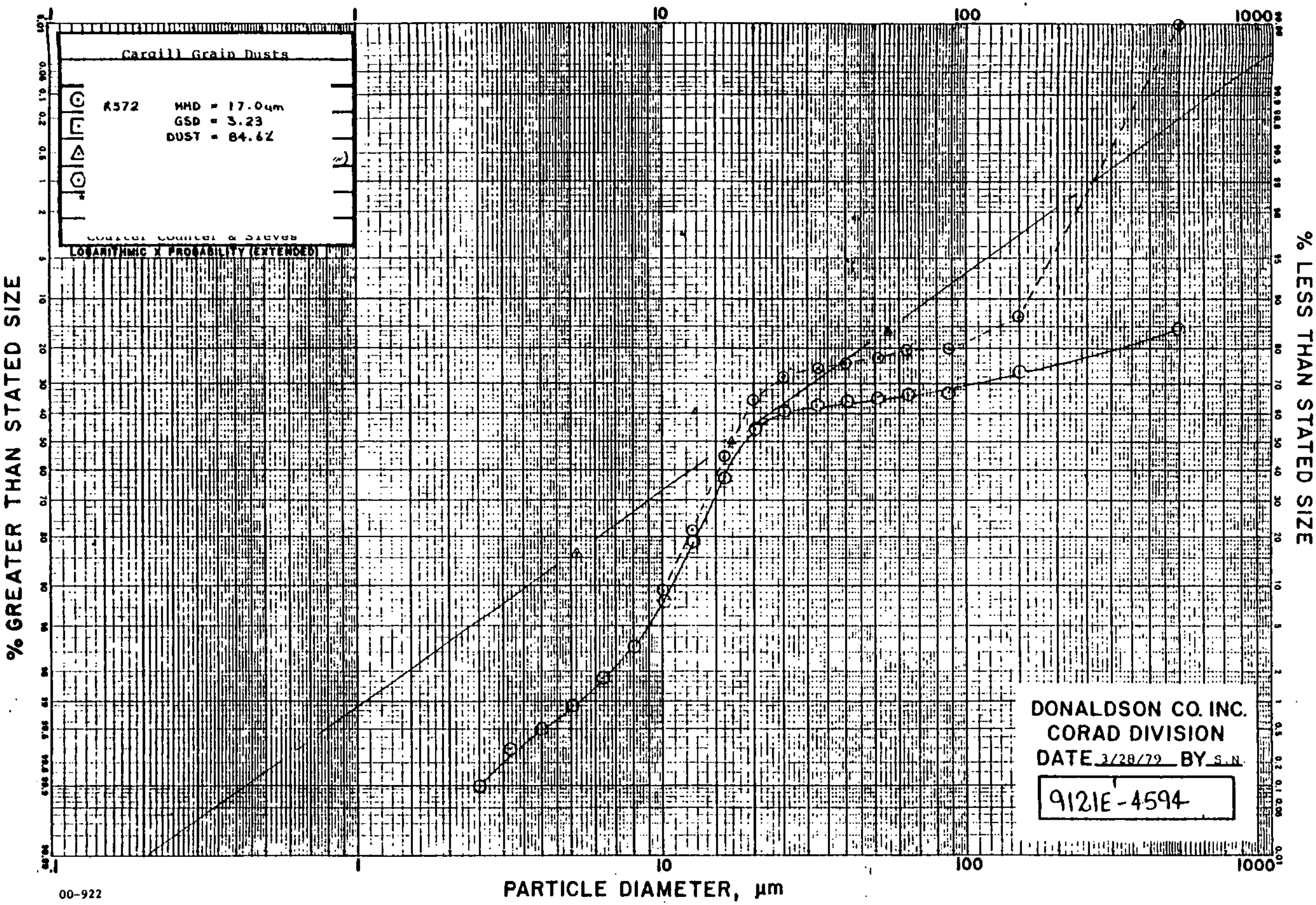

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4609
Cargill Grain Dusts
Reserve Samples
R311
MMD = 18.5um
GSD = 4.17
DUST = 98.6%
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
00-922

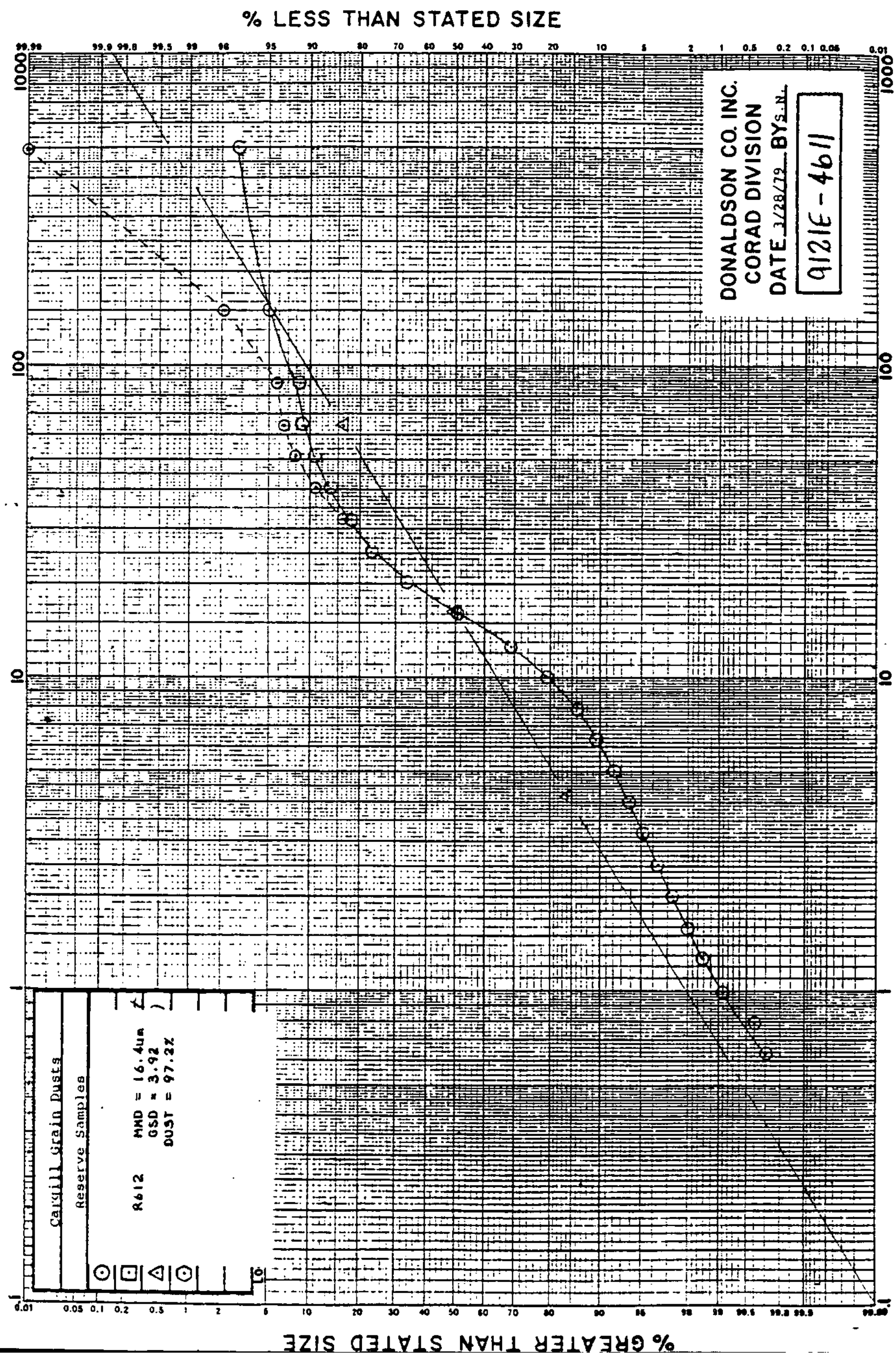


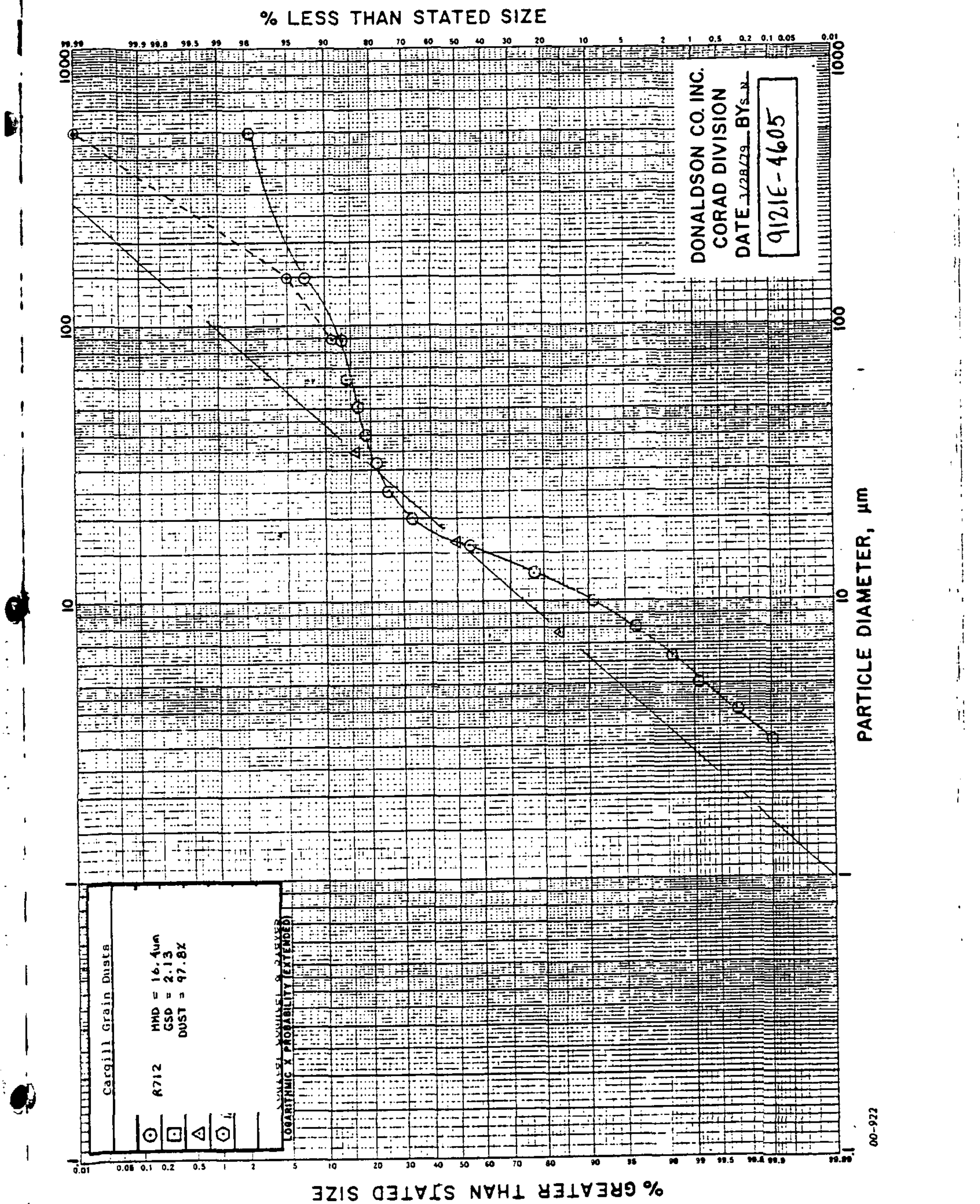
Cargill Grain Dusts
Reserve Samples
R424
MMD = 17.7um
GSD = 3.35
DUST = 85.5%
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4597
00-922

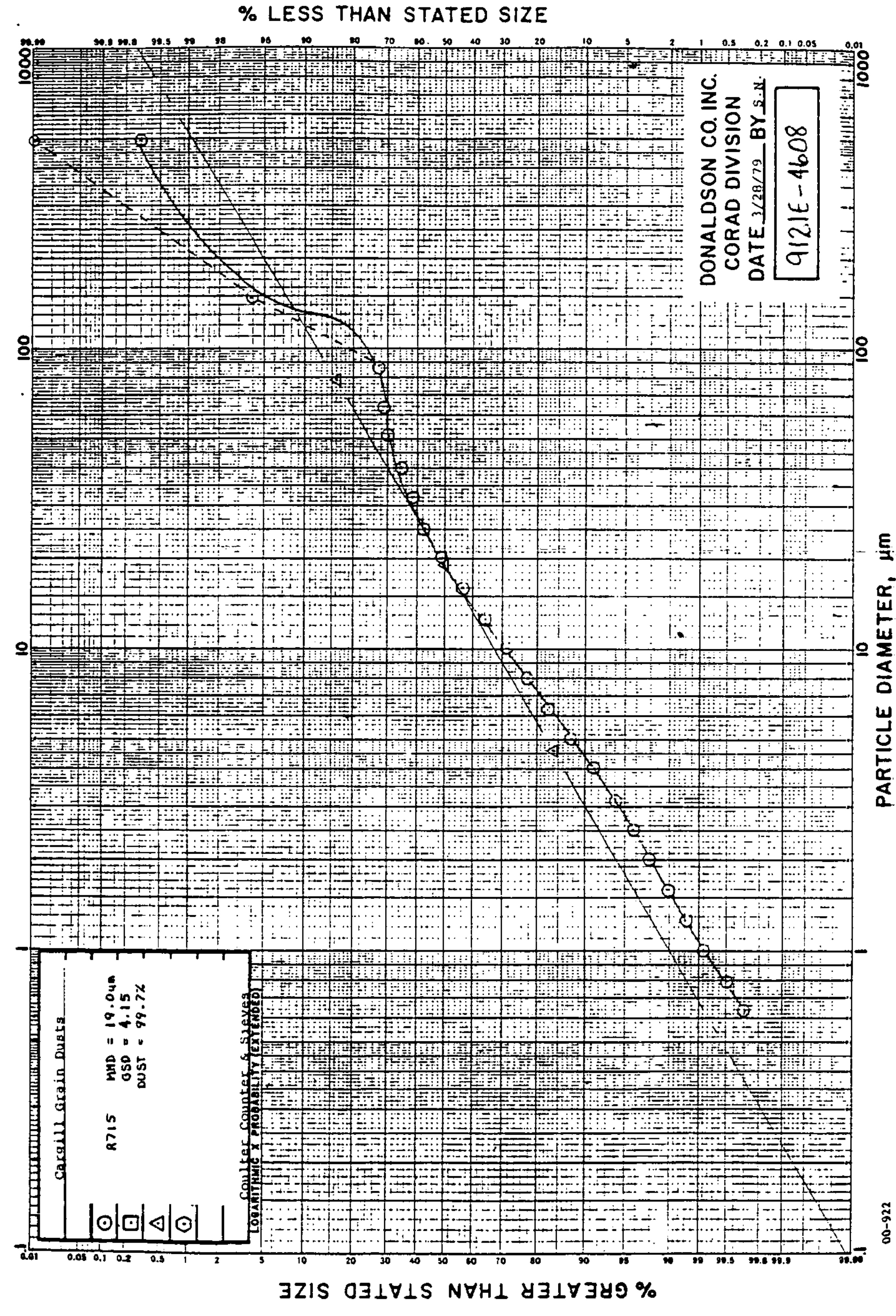

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E - 4596
PARTICLE DIAMETER, µm
Cargill Grain Dusts
Reserve Samples
R473
MMD = 16.0um
GSD = 1.61
DUST = 95.0%
% GREATER THAN STATED SIZE
00-922

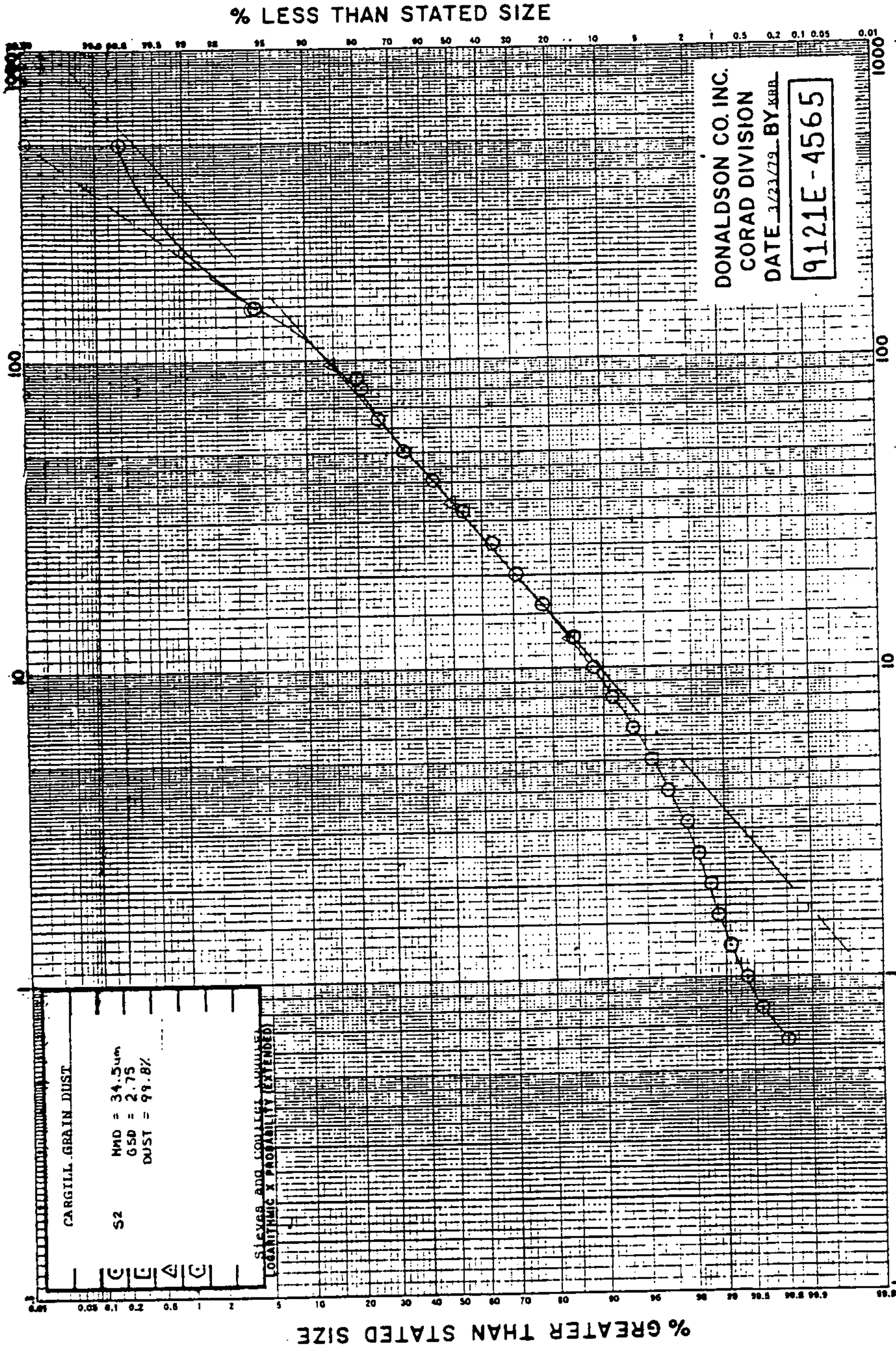

Cargill Grain Dusts
AS12
MMD = 17.3um
GSD = 1.88
DUST = 95.2%
Coulter Counter & Sieves
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4595
00-922


Cargill Grain Dusts
R572 MMD = 17.0µm
GSD = 3.23
DUST = 84.6%
Coulter Counter & Sieves
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4594
00-922

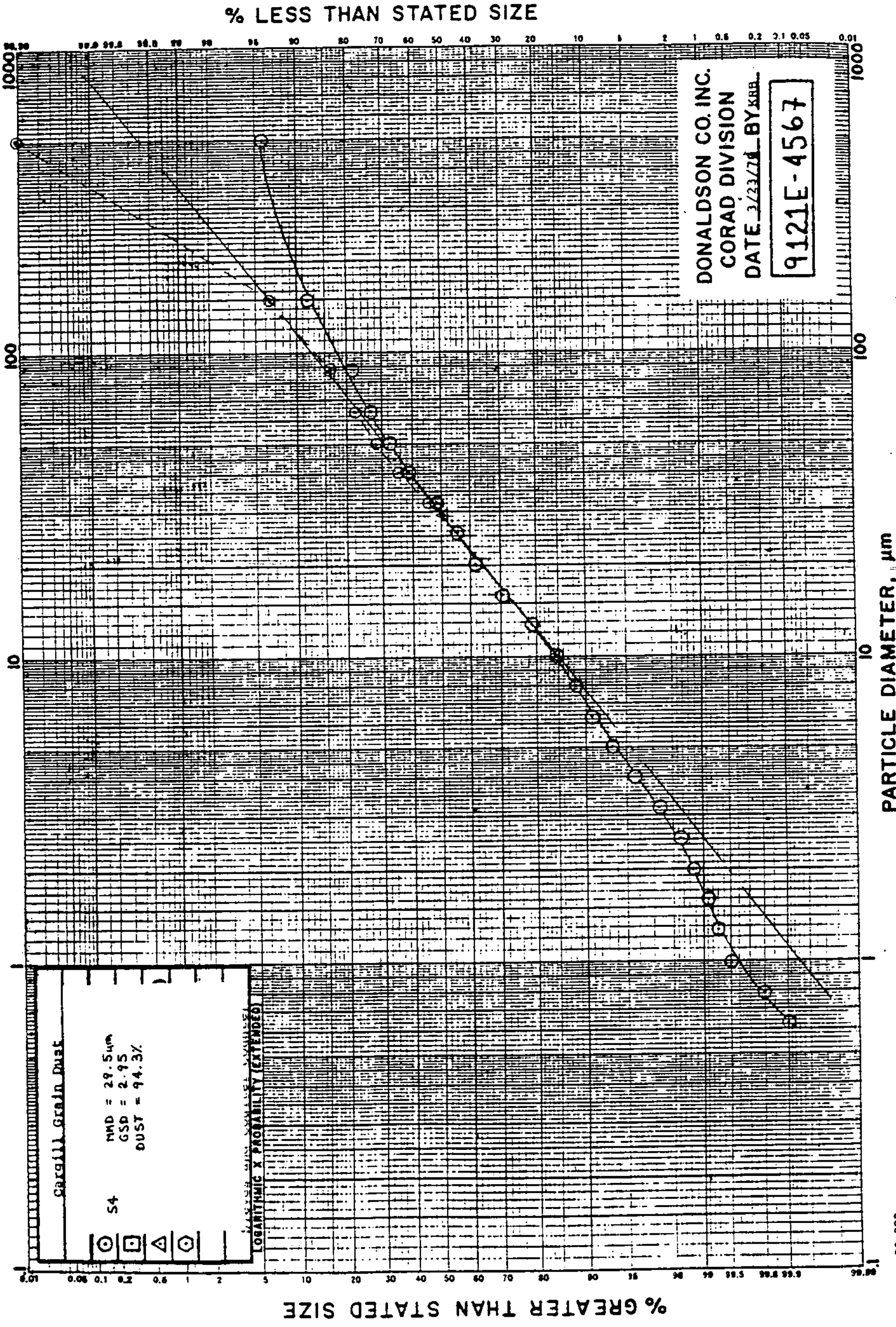

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4611
PARTICLE DIAMETER, µm
Cargill Grain Dusts
Reserve Samples
R612
MMD = 16.4um
GSD = 3.92
DUST = 97.2%
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N
9121E-4605
PARTICLE DIAMETER, µm
Cargill Grain Dusts
R712
MMD = 16.4um
GSD = 2.13
DUST = 97.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

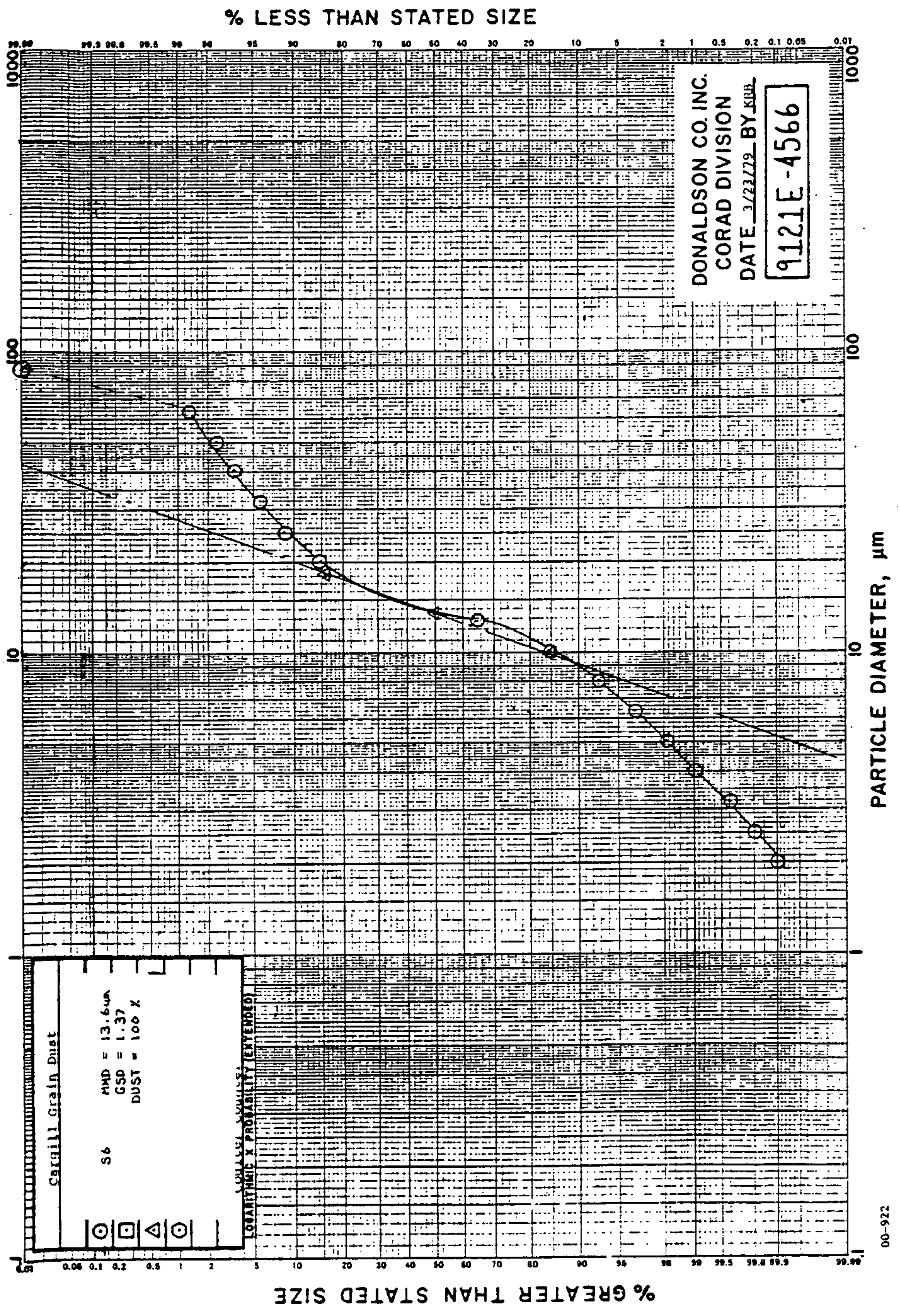

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/28/79 BY S.N.
9121E-4608
PARTICLE DIAMETER, µm
Cargill Grain Dusts
R715
MMD = 19.0um
GSD = 4.15
DUST = 99.7%
Coulter Counter & Sieves
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

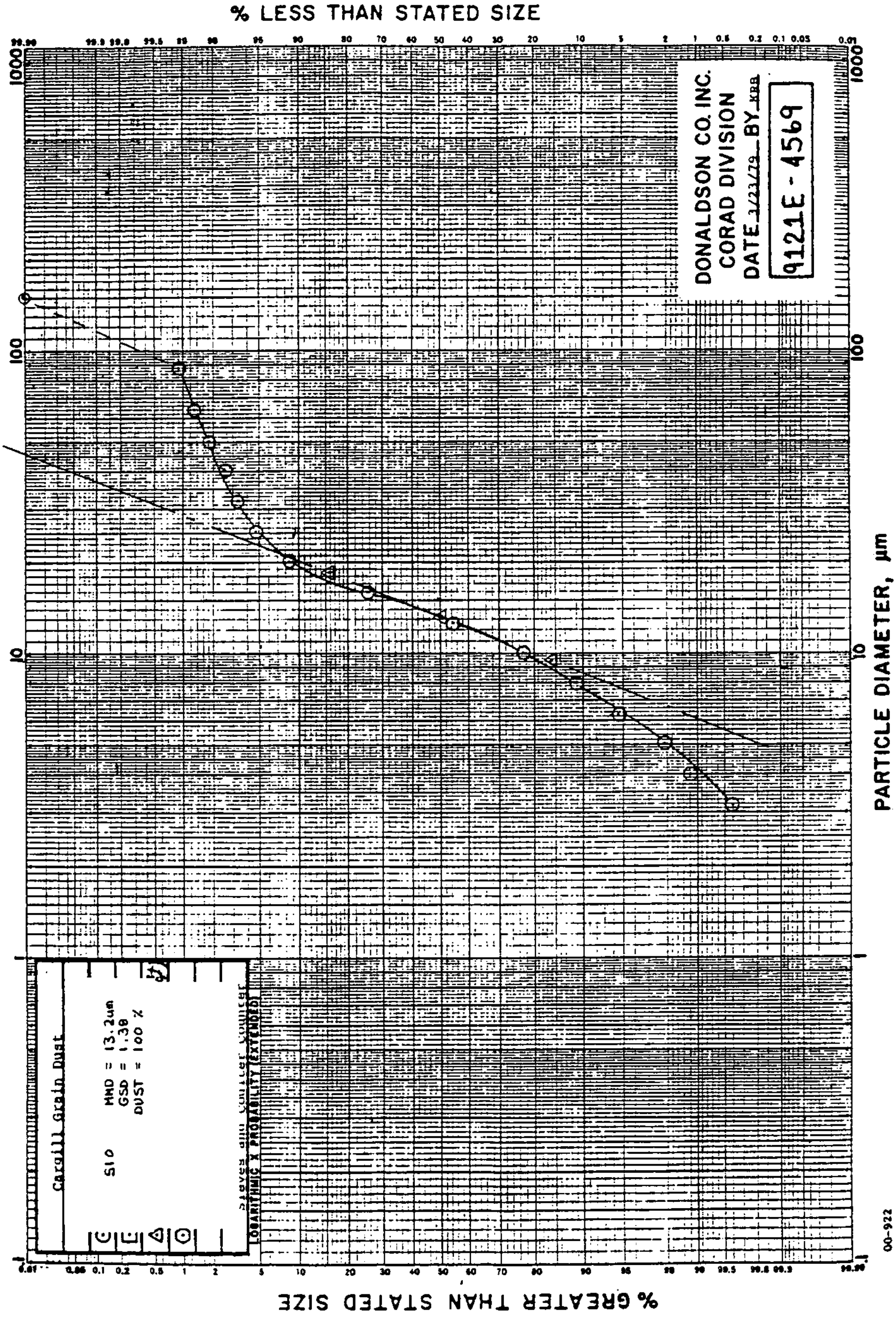


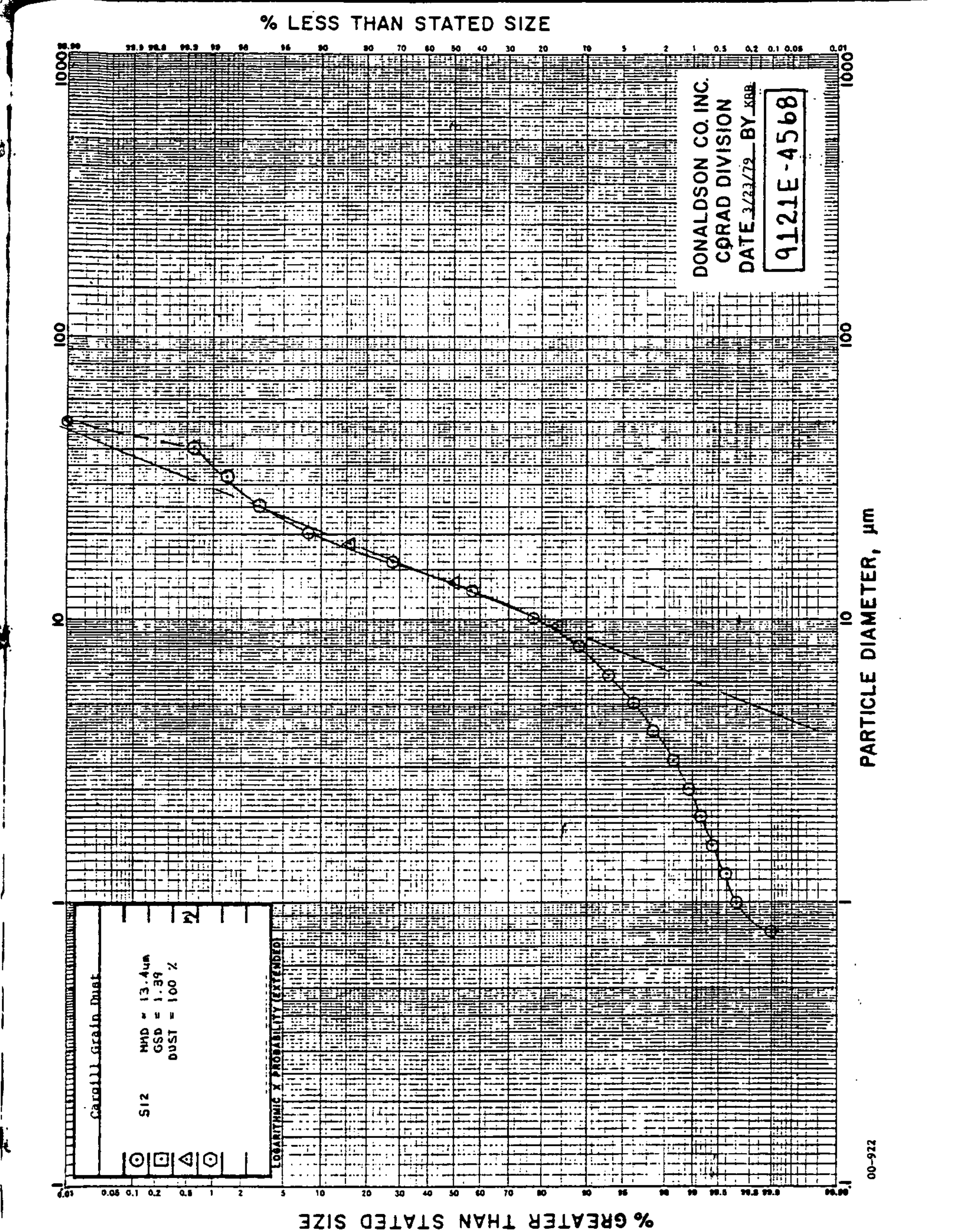
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KBB
9121E-4565
PARTICLE DIAMETER, µm
CARGILL GRAIN DUST
S2
MMD = 34.5um
GSD = 2.75
DUST = 99.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

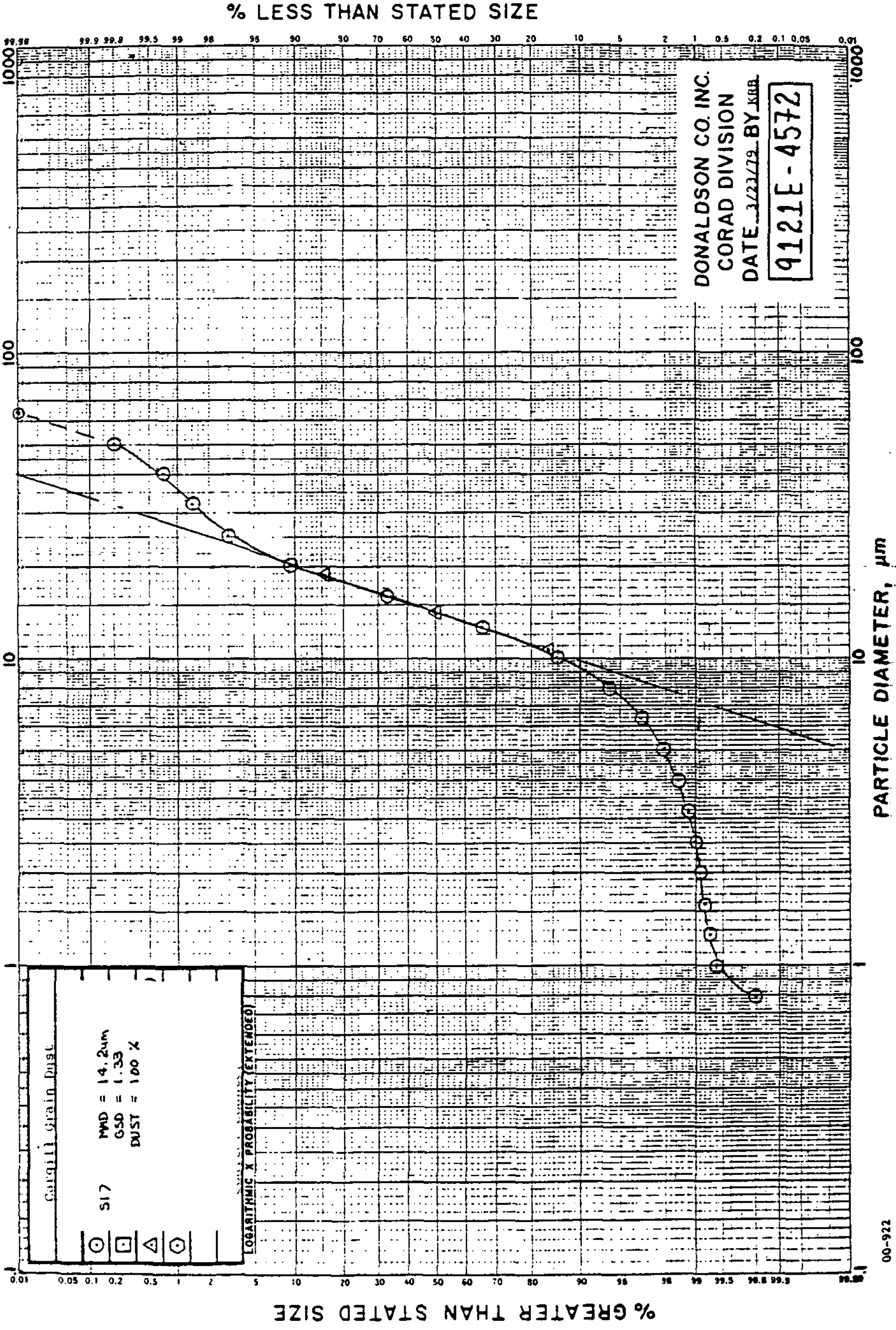


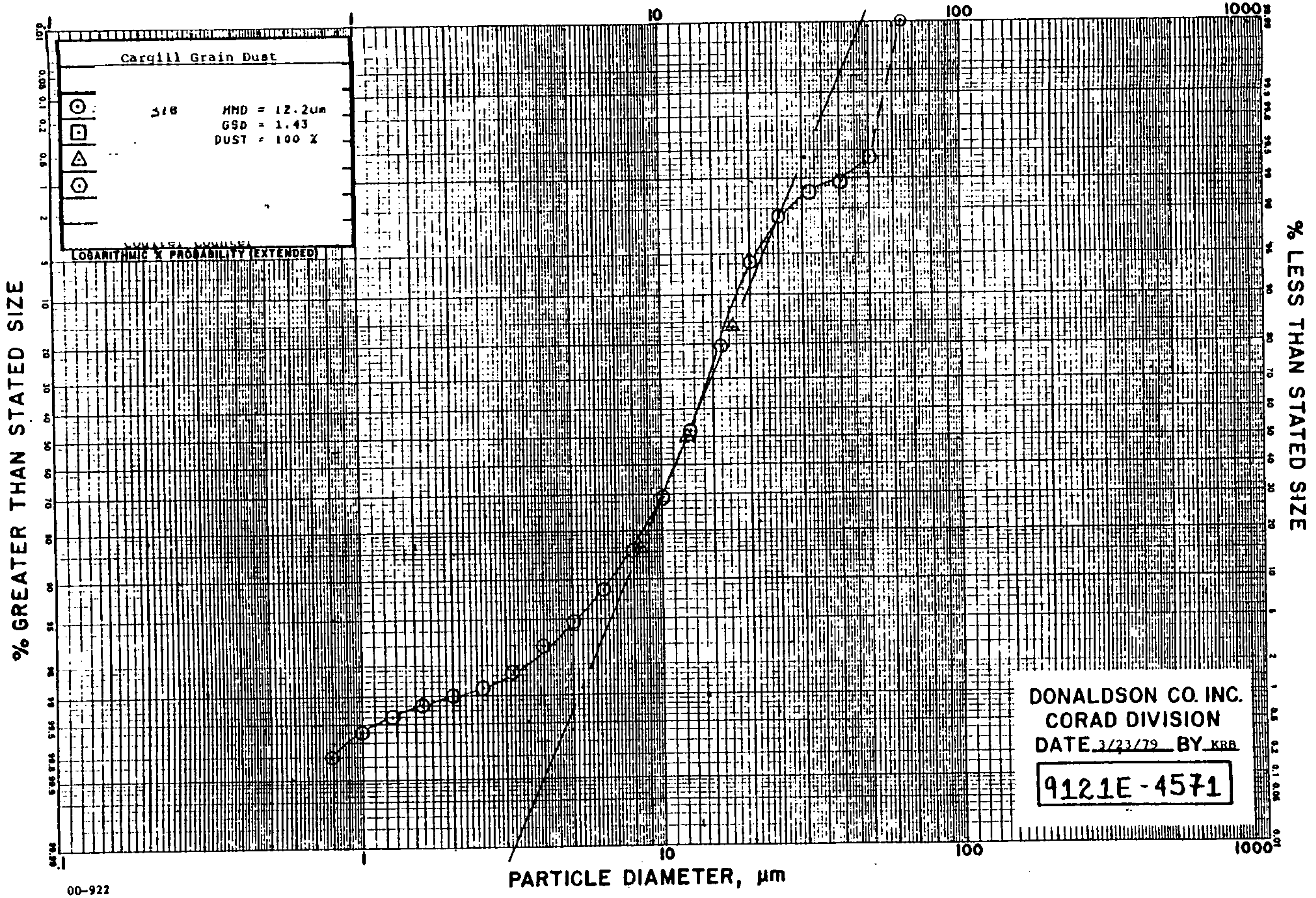
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/7 BY KRB
9121E-4567
PARTICLE DIAMETER, µm
Cargill Grain Dust
S4
MMD = 29.5µm
GSD = 2.95
DUST = 94.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KDB
9121E-4566
PARTICLE DIAMETER, µm
Cargill Grain Dust
S6
MMD = 13.6µm
GSD = 1.37
DUST = 100 X
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

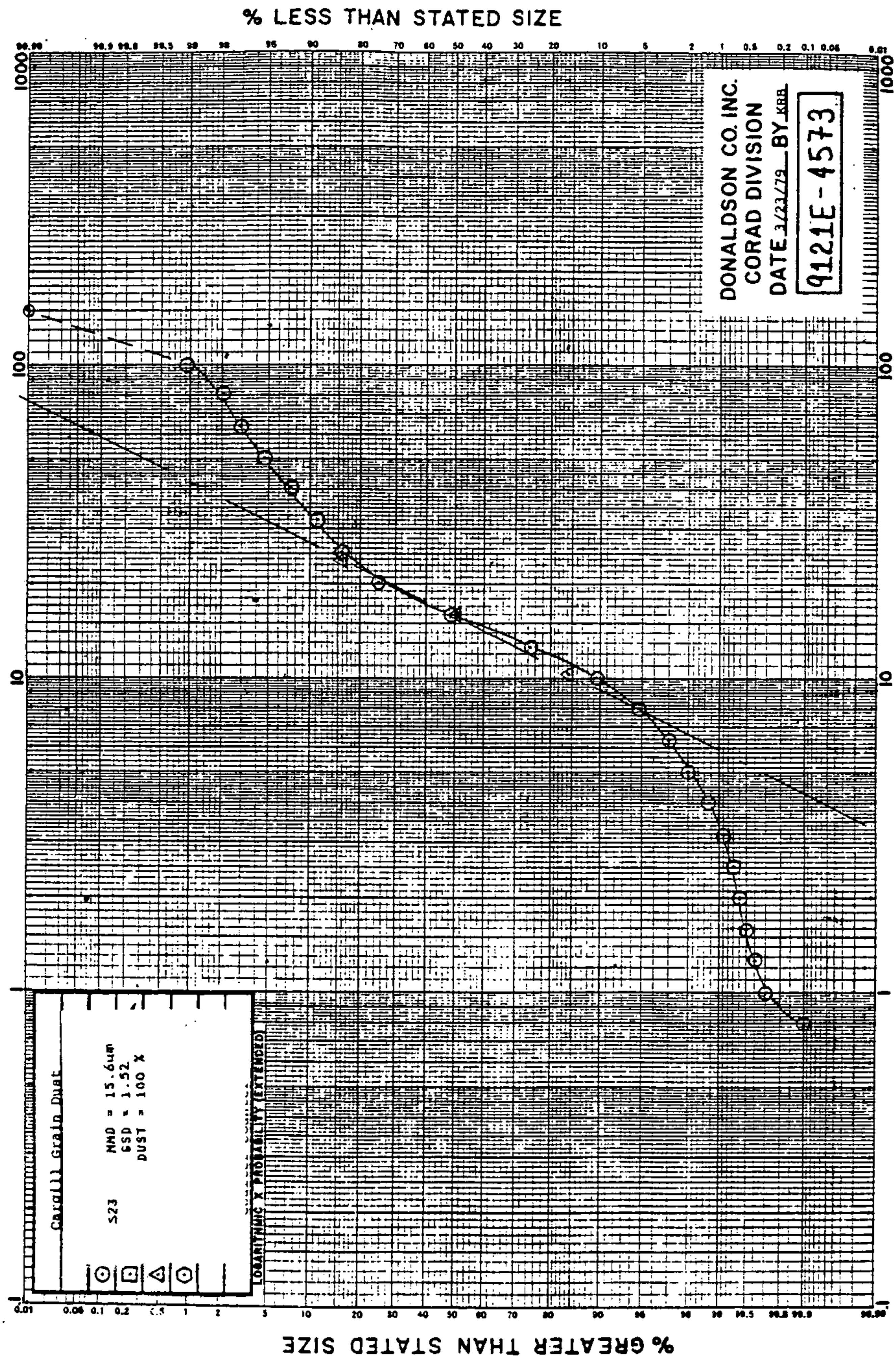

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E - 4569
PARTICLE DIAMETER, µm
Cargill Grain Dust
SIO
MMD = 13.2um
GSD = 1.30
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

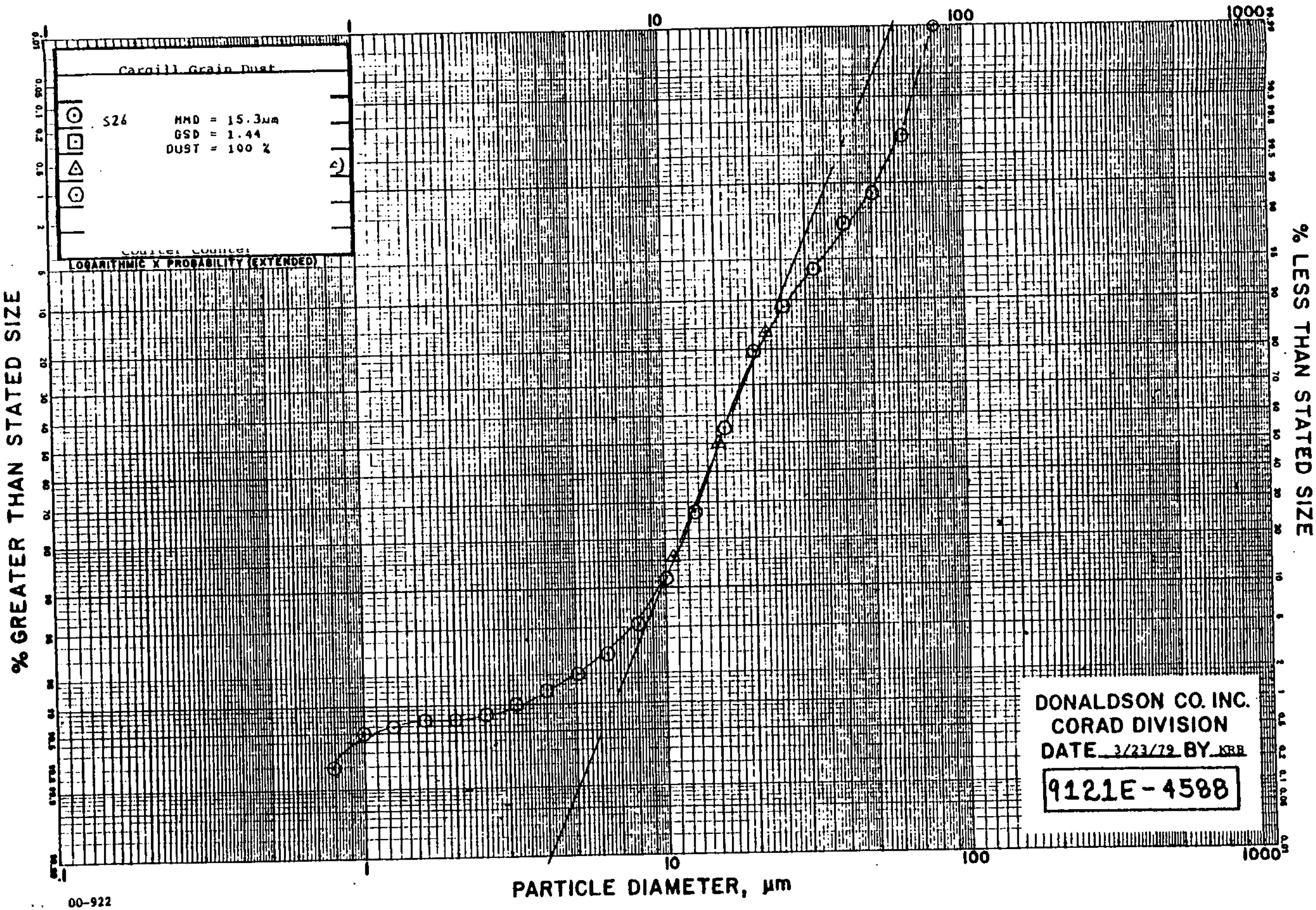

% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4568
Cargill Grain Dust
S12 MMD = 13.4um
GSD = 1.39
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4572
PARTICLE DIAMETER, μm
Cargill Grain Dust
517
MMD = 14.2um
GSD = 1.33
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

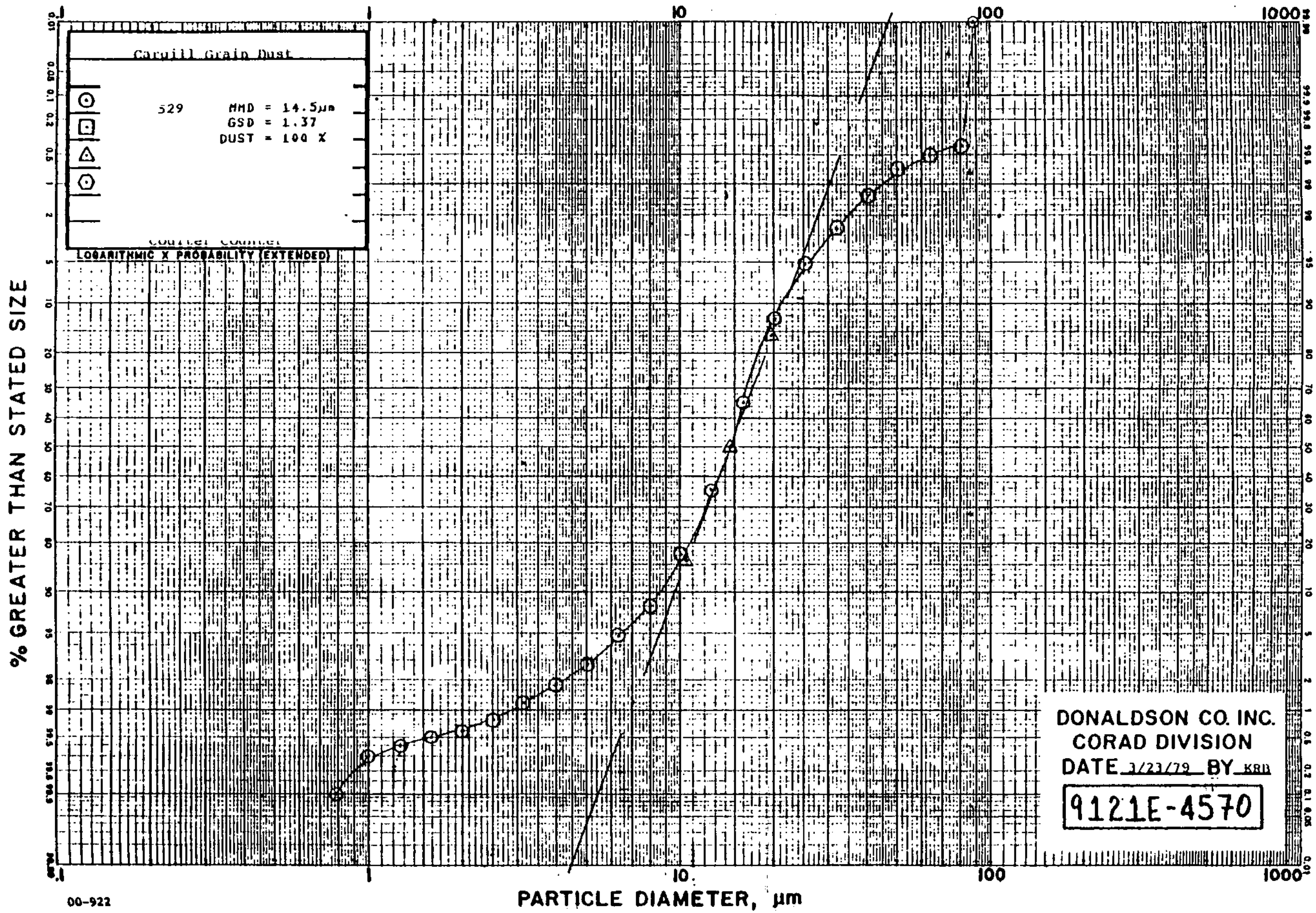


Cargill Grain Dust
518
MMD = 12.2um
GSD = 1.43
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4571
00-922

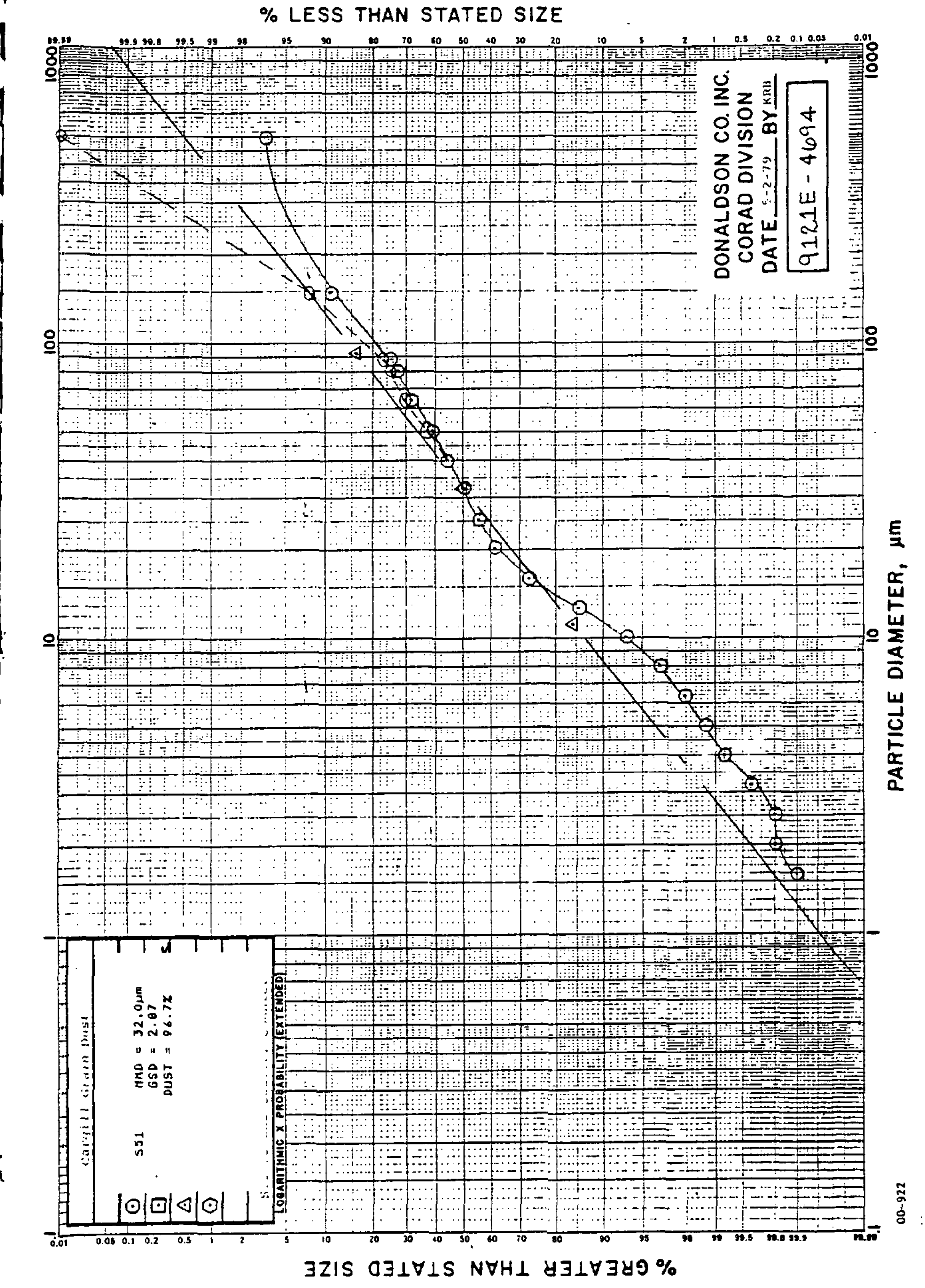

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KBB
9121E-4573
PARTICLE DIAMETER, μm
Cargill Grain Dust
S23
MMD = 15.6um
GSD = 1.52
DUST = 100 X
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



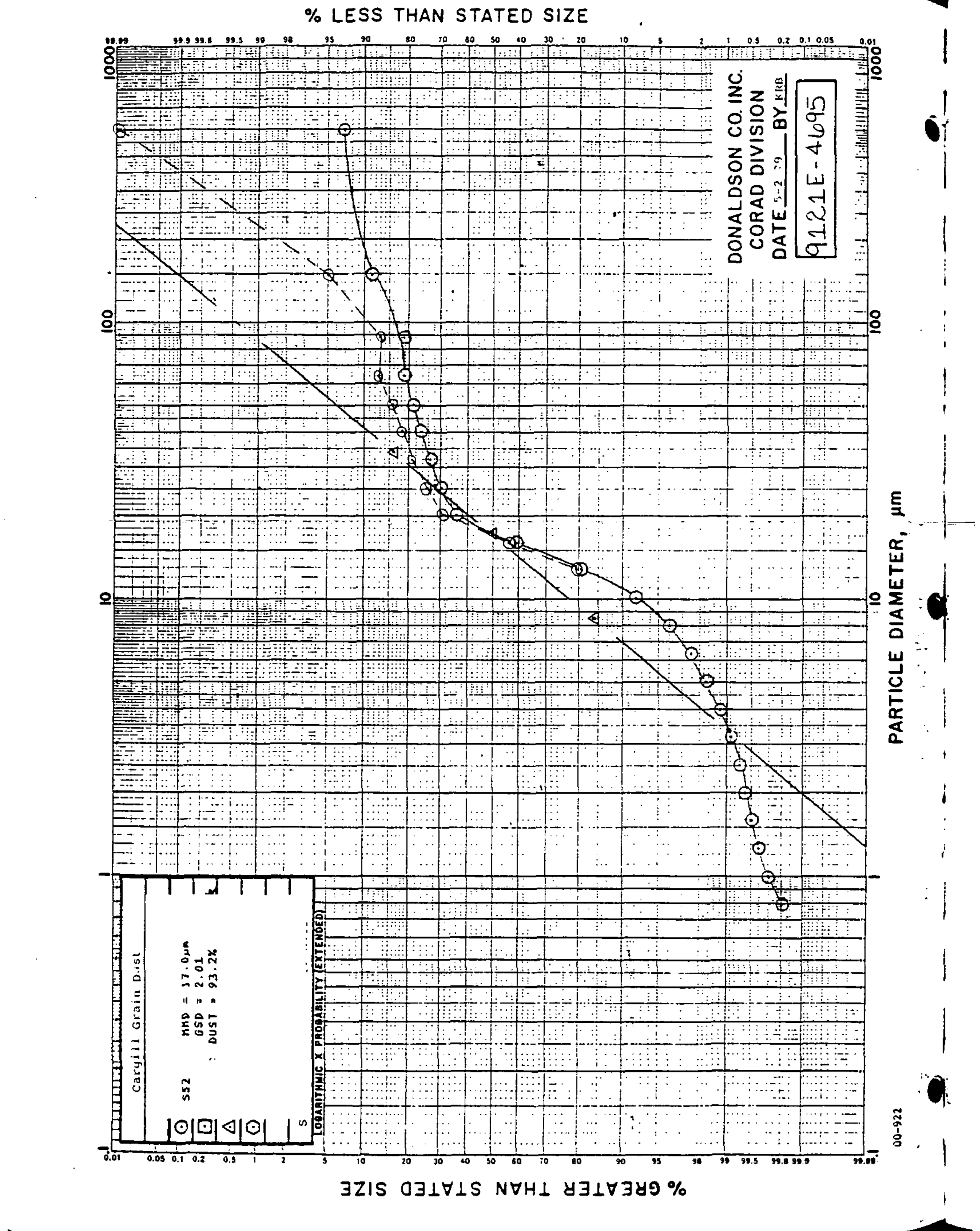
Cargill Grain Dust
S26
MMD = 15.3μm
GSD = 1.44
DUST = 100 %
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4588
00-922

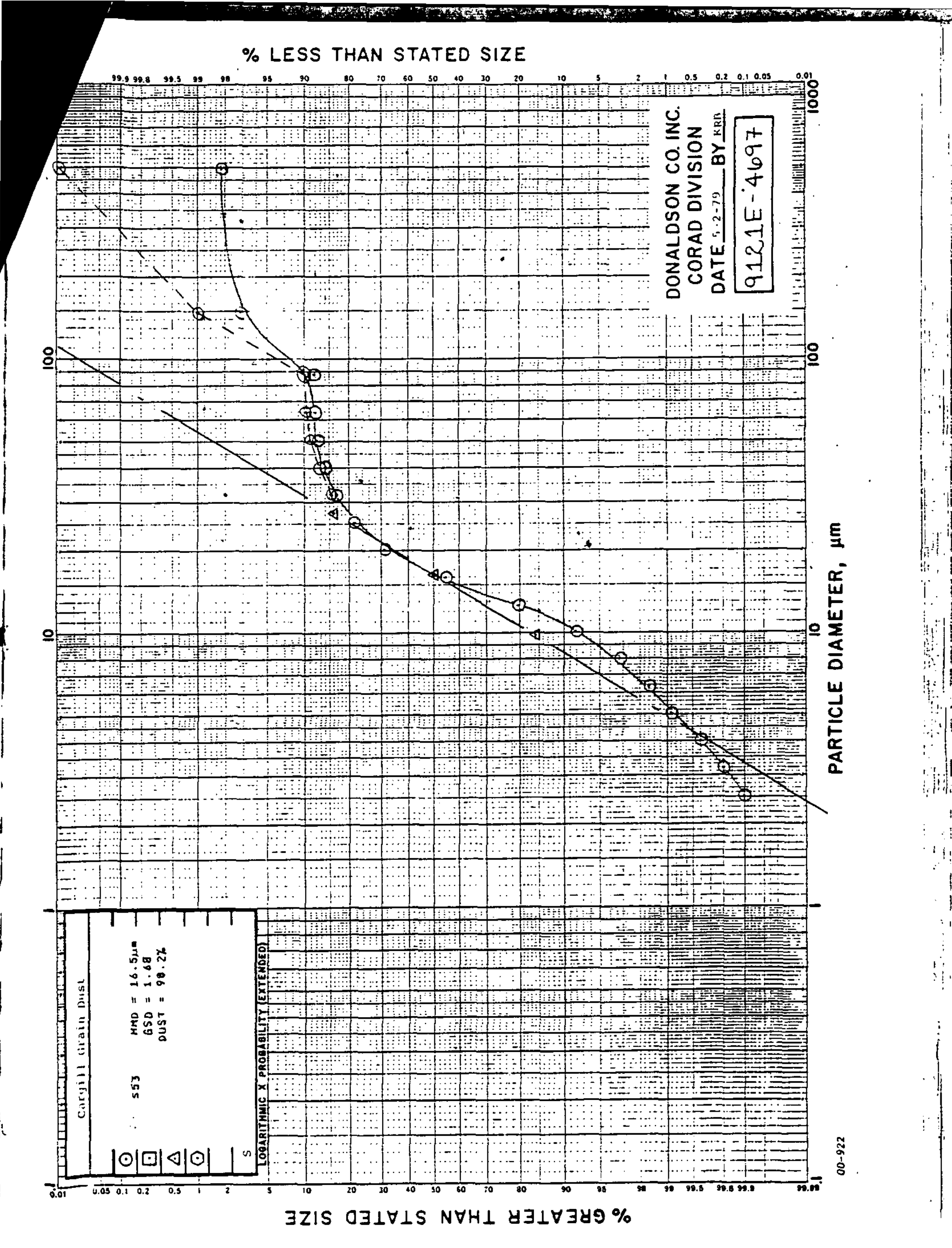


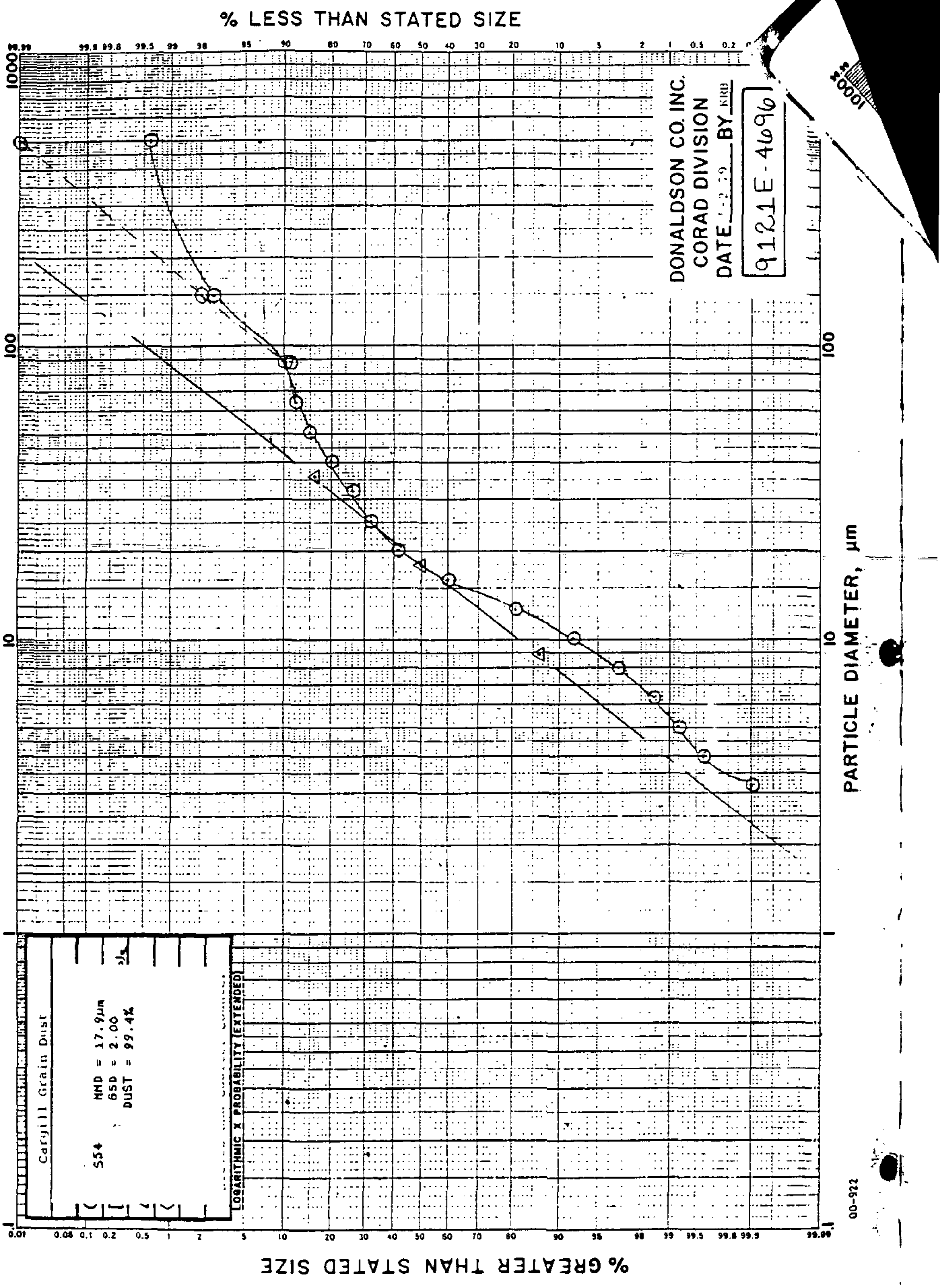
Cargill Grain Dust
529
MMD = 14.5µm
GSD = 1.37
DUST = 100 X
Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4570
00-922



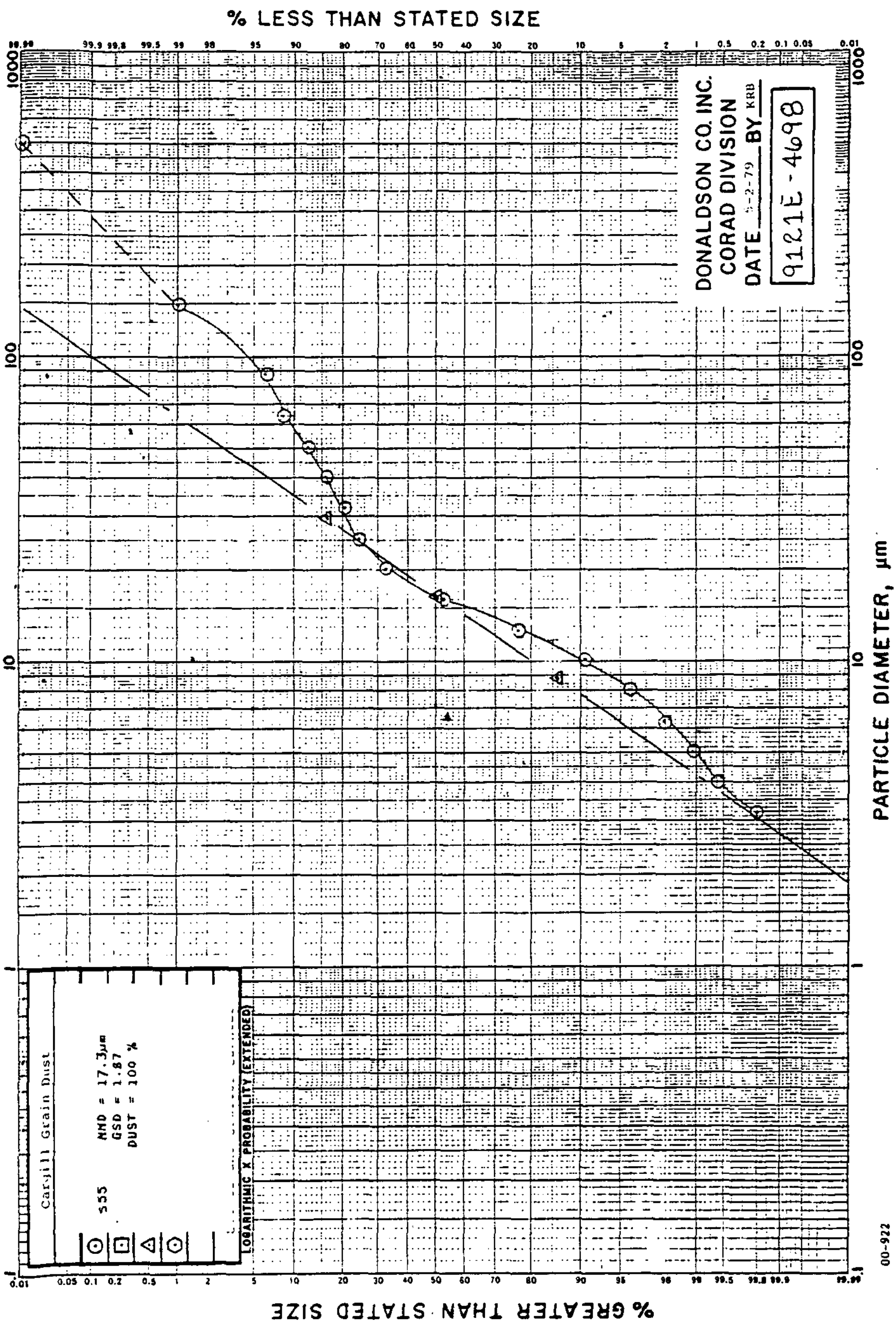
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E - 4694
PARTICLE DIAMETER, µm
Cargill Grain Dust
S51
MMD = 32.0µm
GSD = 2.87
DUST = 96.7%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E-4695
PARTICLE DIAMETER, µm
Cargill Grain Dust
SS2
MMD = 17.0µm
GSD = 2.01
DUST = 93.2%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

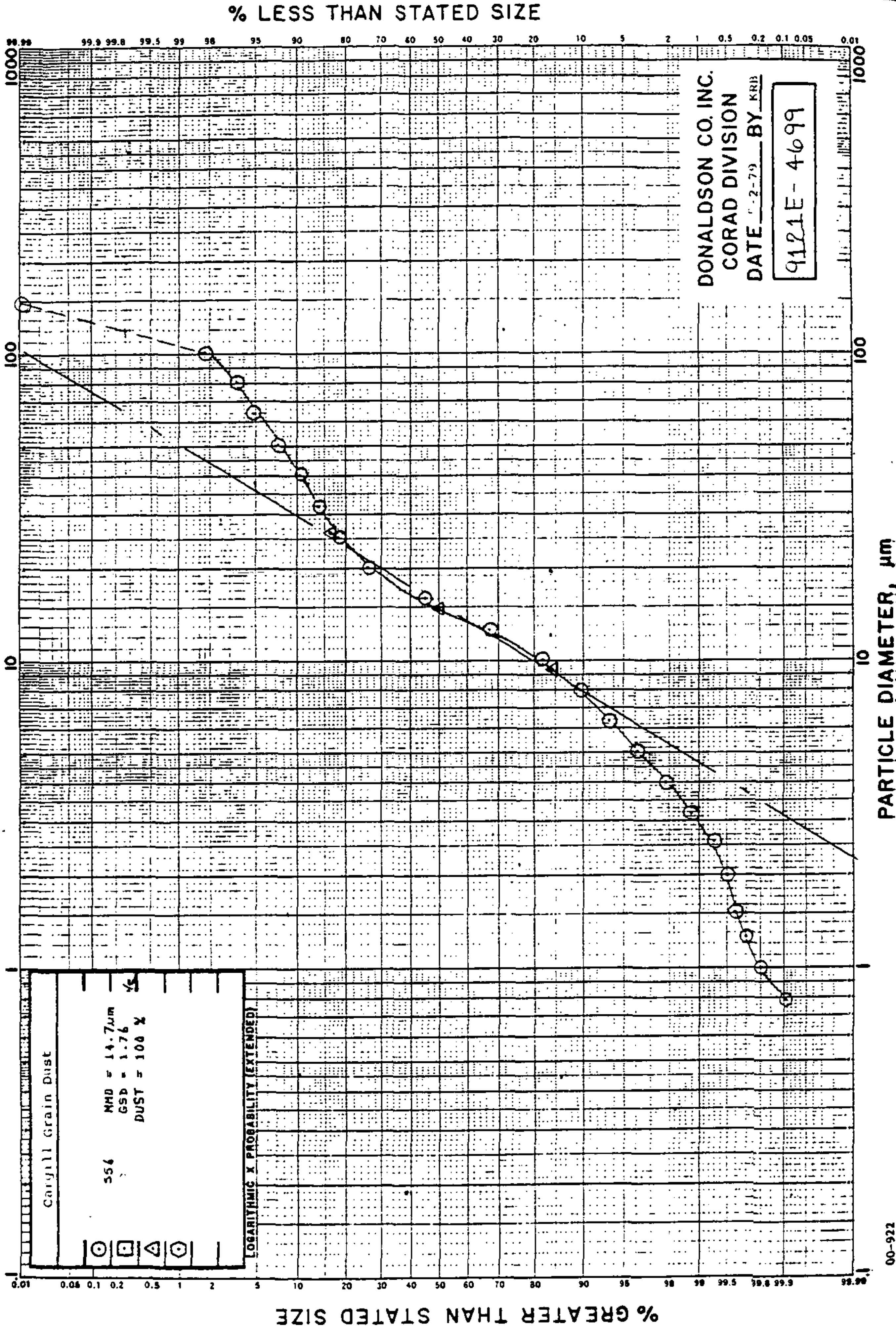

% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E-4697
Cargill Grain Dust
553
MMD = 16.5µm
GSD = 1.68
DUST = 98.2%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



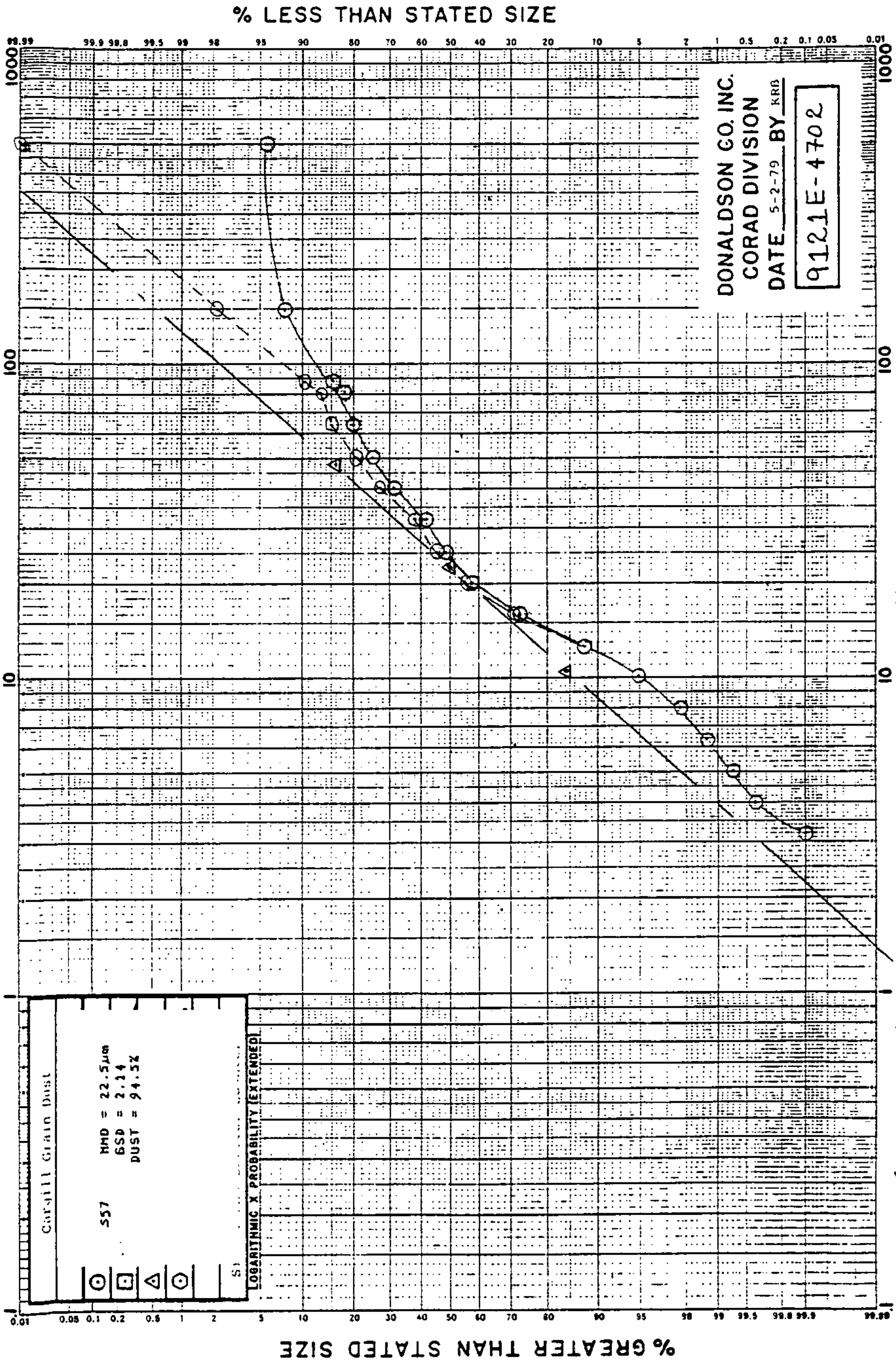
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY KRB
9121E-4696
Cargill Grain Dust
554
MMD = 17.9µm
GSD = 2.00
DUST = 99.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

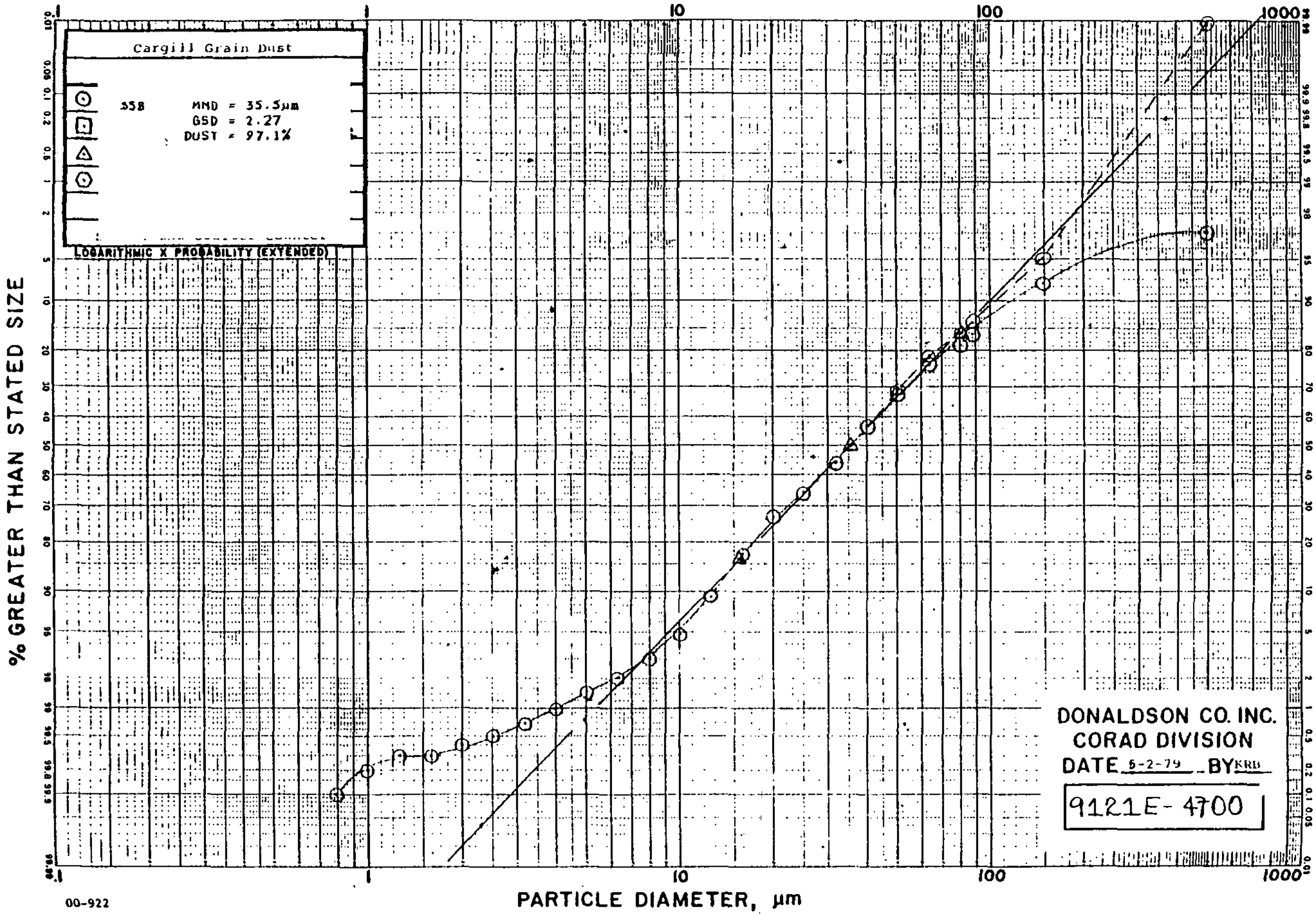


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E-4698
PARTICLE DIAMETER, µm
Cargill Grain Dust
555
MMD = 17.3µm
GSD = 1.87
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

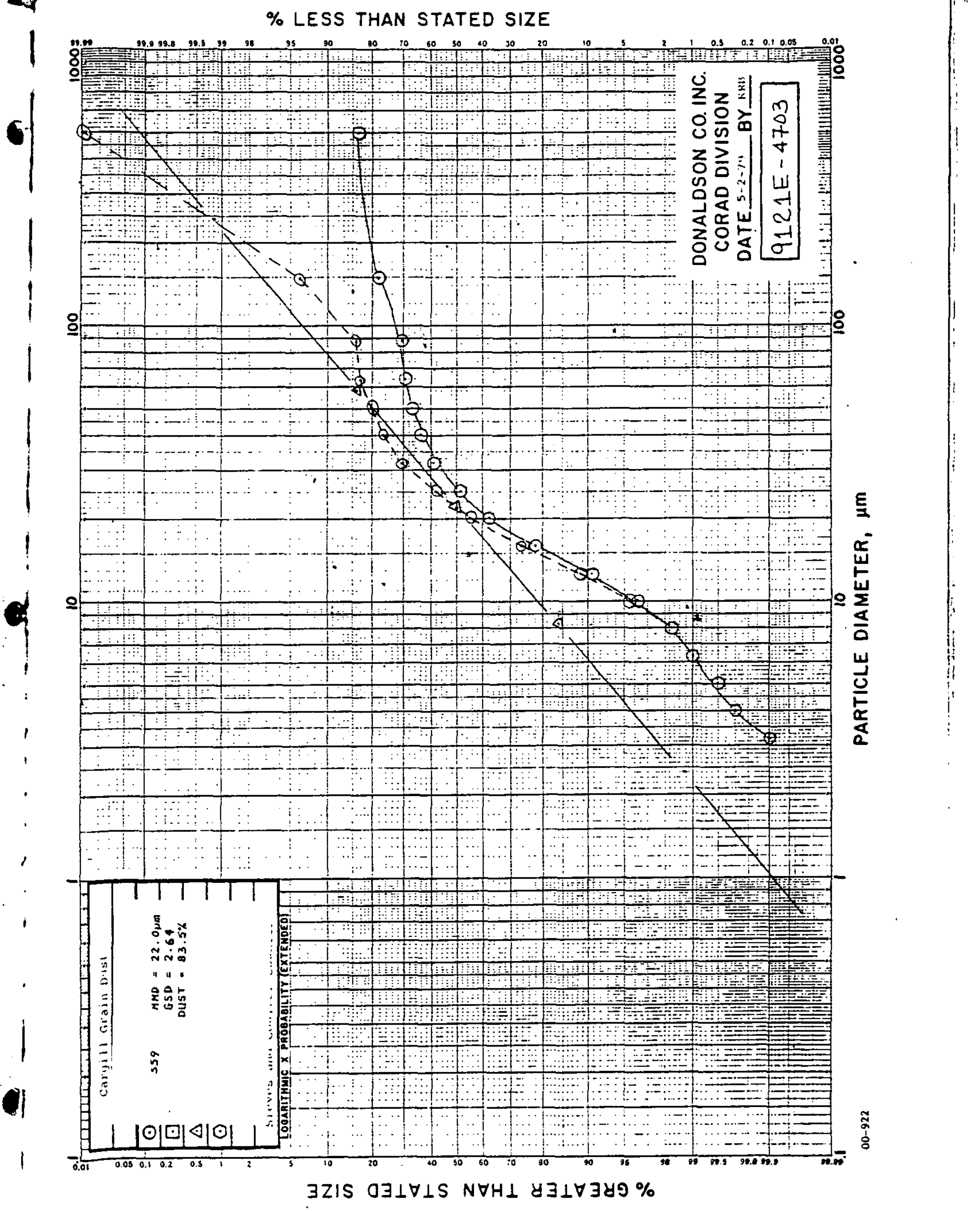


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 2-79 BY KRB
9121E-4699
PARTICLE DIAMETER, µm
Cargill Grain Dust
554
MMD = 14.7µm
GSD = 1.76
DUST = 100 %
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

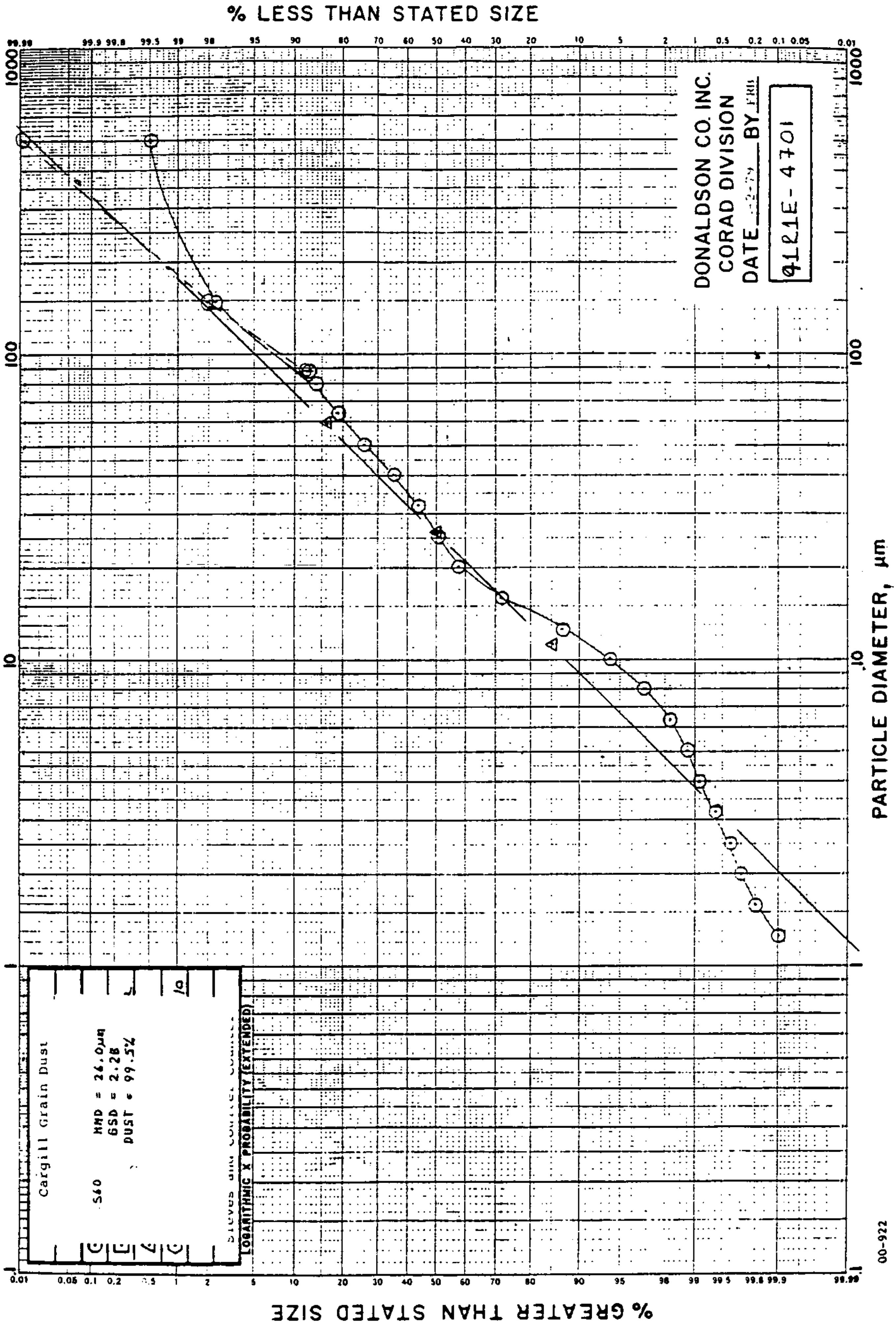

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 5-2-79 BY KRB
9121E-4702
PARTICLE DIAMETER, μm
Cargill Grain Dust
SS7
MMD = 22.5μm
GSD = 2.14
DUST = 94.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922
% GREATER THAN STATED SIZE

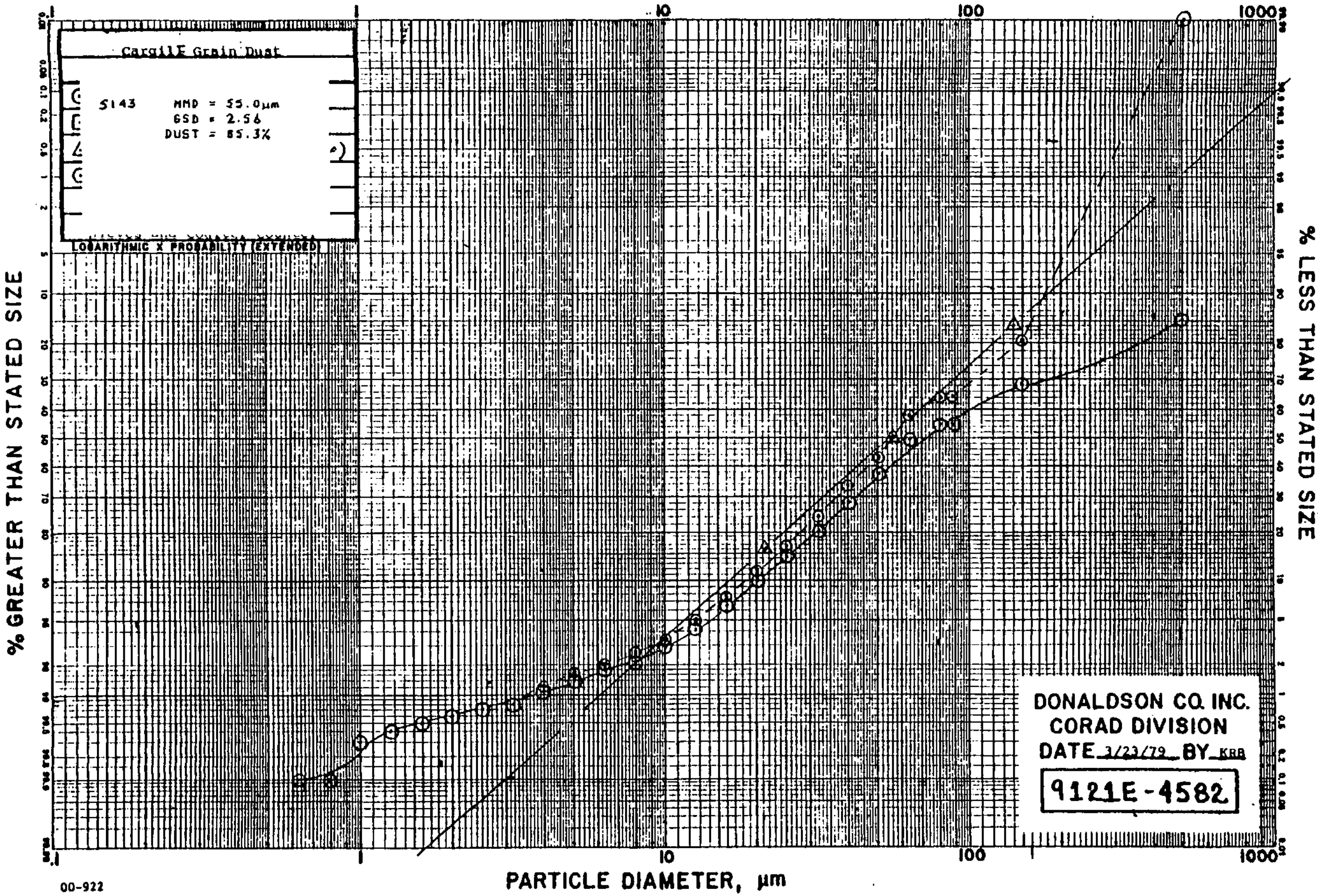


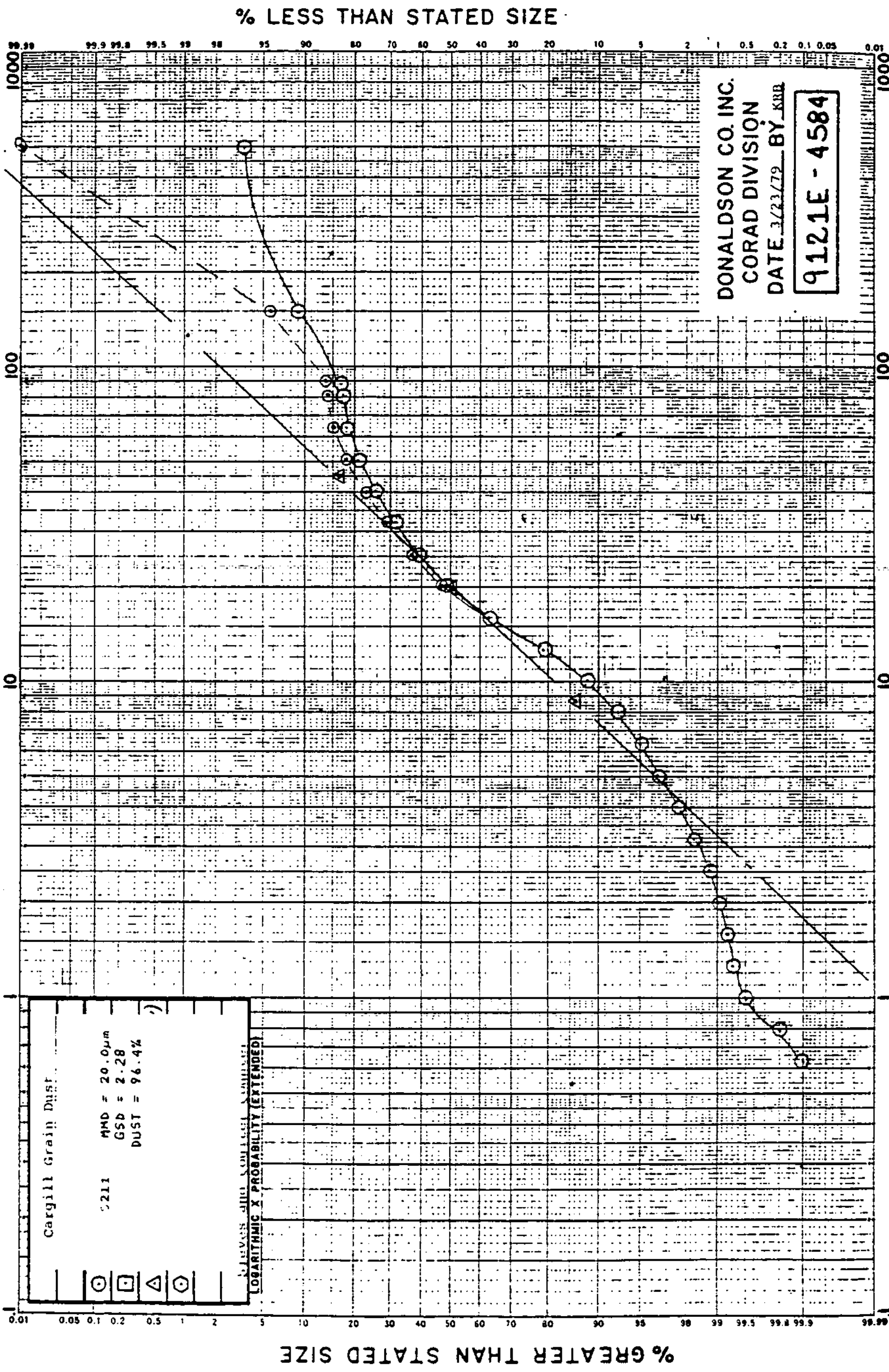
Cargill Grain Dust
558
MMD = 35.5μm
GSD = 2.27
DUST = 97.1%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 6-2-79 BY KRB
9121E-4700
00-922

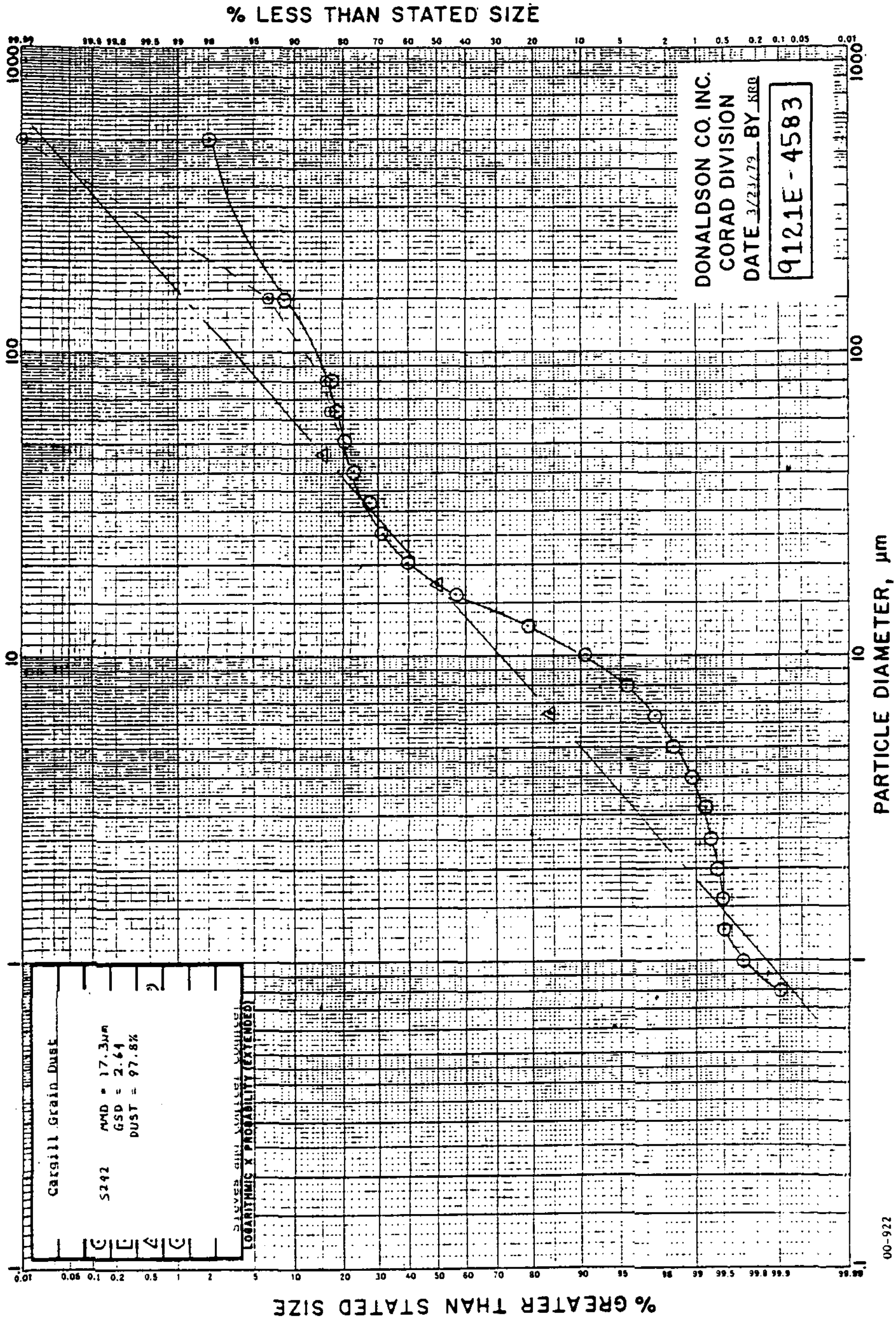


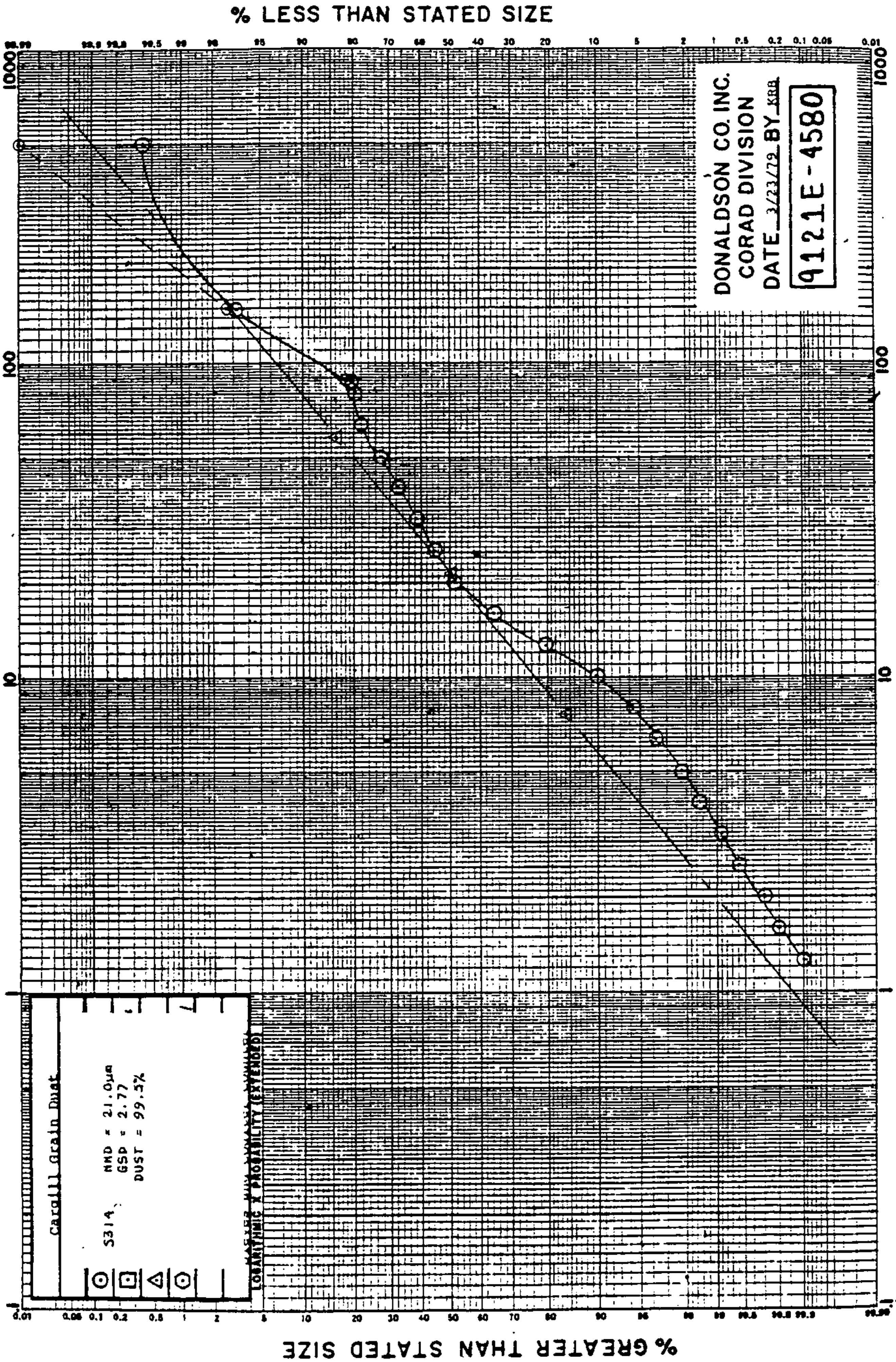
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE
BY KRB
9121E-4703
Cargill Grain Dust
559
MMD = 22.0µm
GSD = 2.64
DUST = 83.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

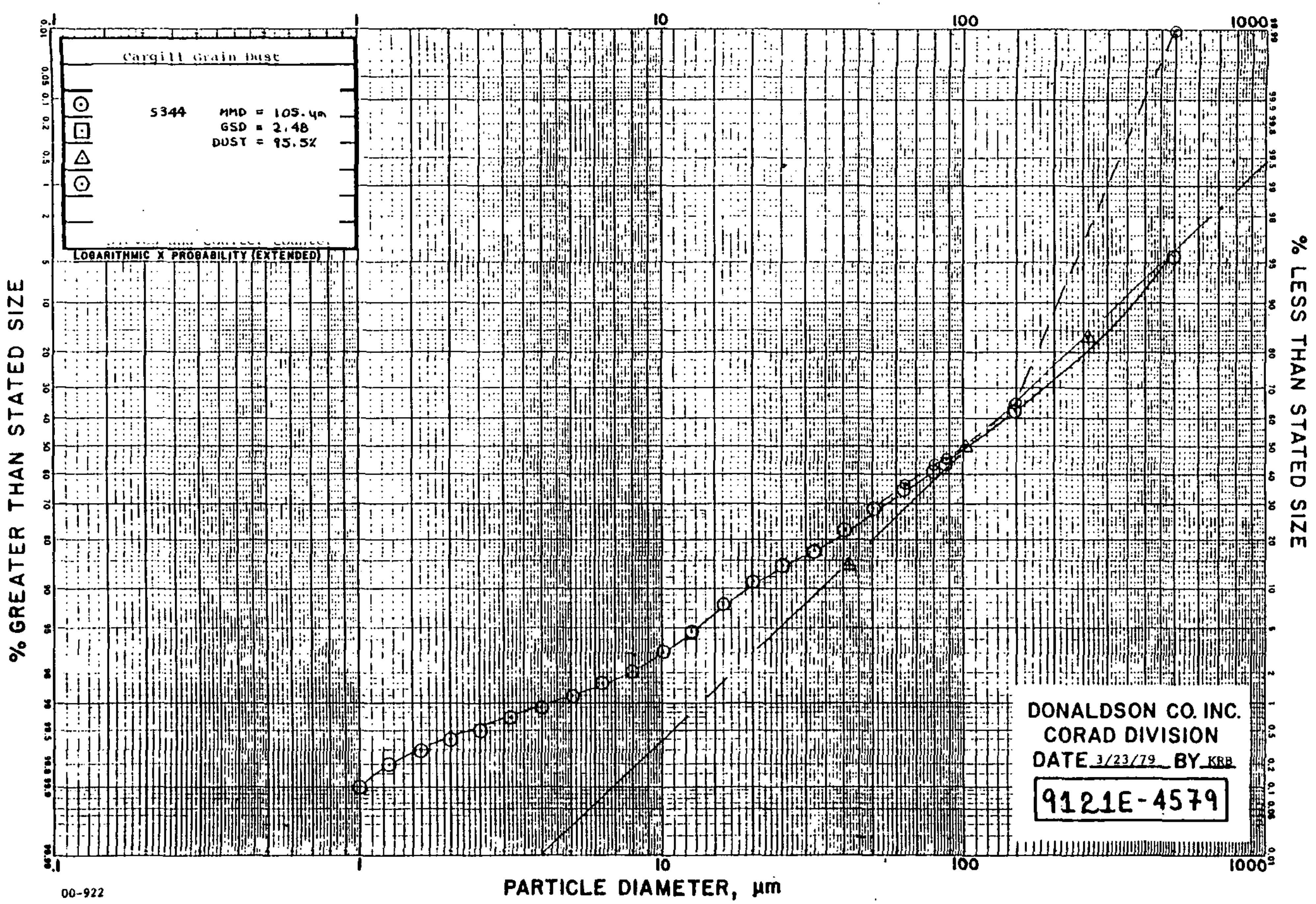

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE BY
4121E-4701
PARTICLE DIAMETER, µm
Cargill Grain Dust
S60
MMD = 26.0µm
GSD = 2.28
DUST ≈ 99.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


CargilE Grain Dust
5143
MMD = 55.0µm
GSD = 2.56
DUST = 85.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4582
00-922

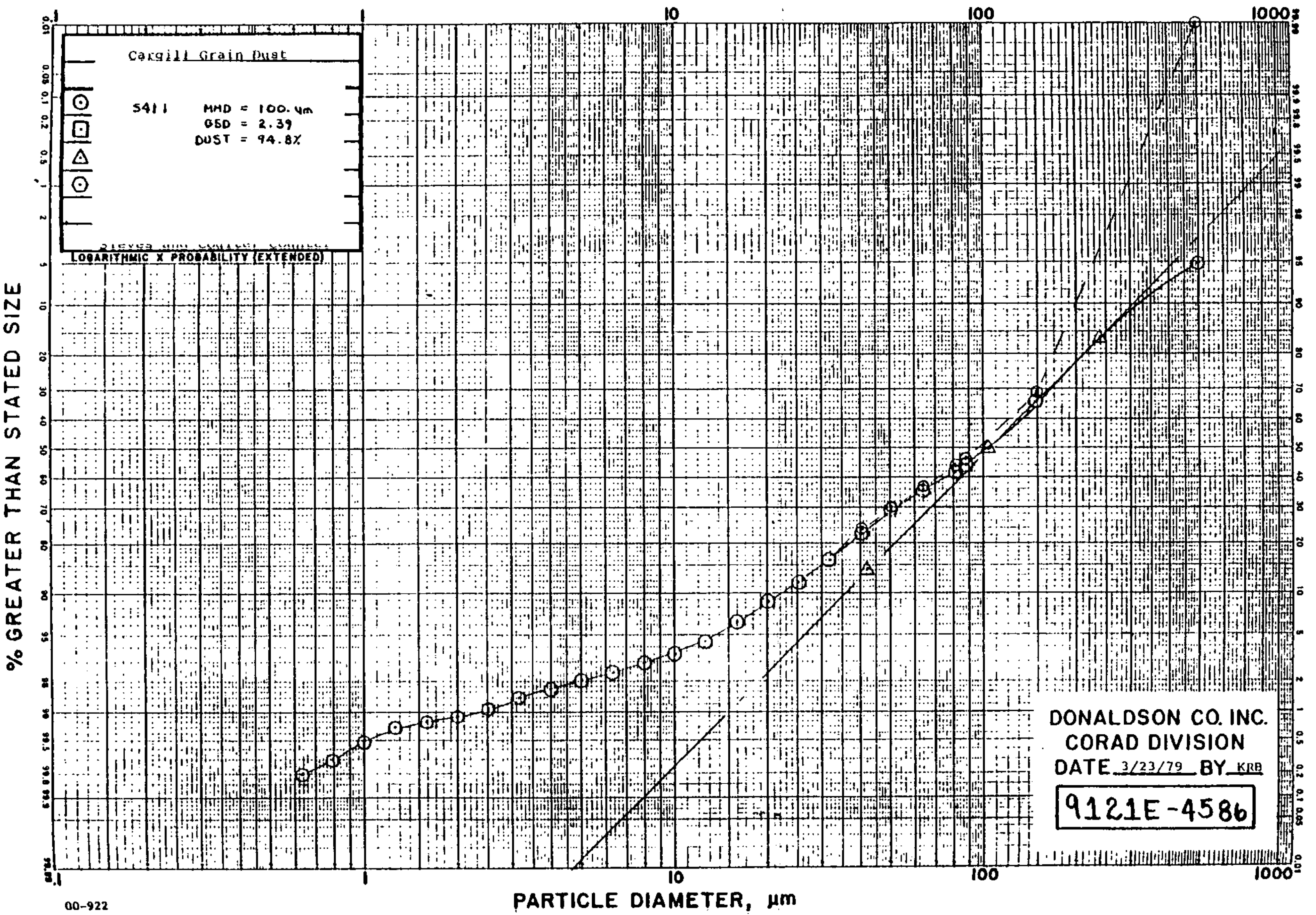

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E - 4584
PARTICLE DIAMETER, μm
Cargill Grain Dust
5211
MMD = 20.0μm
GSD = 2.28
DUST = 96.4%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/21/79 BY KRB
9121E-4583
PARTICLE DIAMETER, µm
Cargill Grain Dust
S242
MMD = 17.3µm
GSD = 2.64
DUST = 97.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

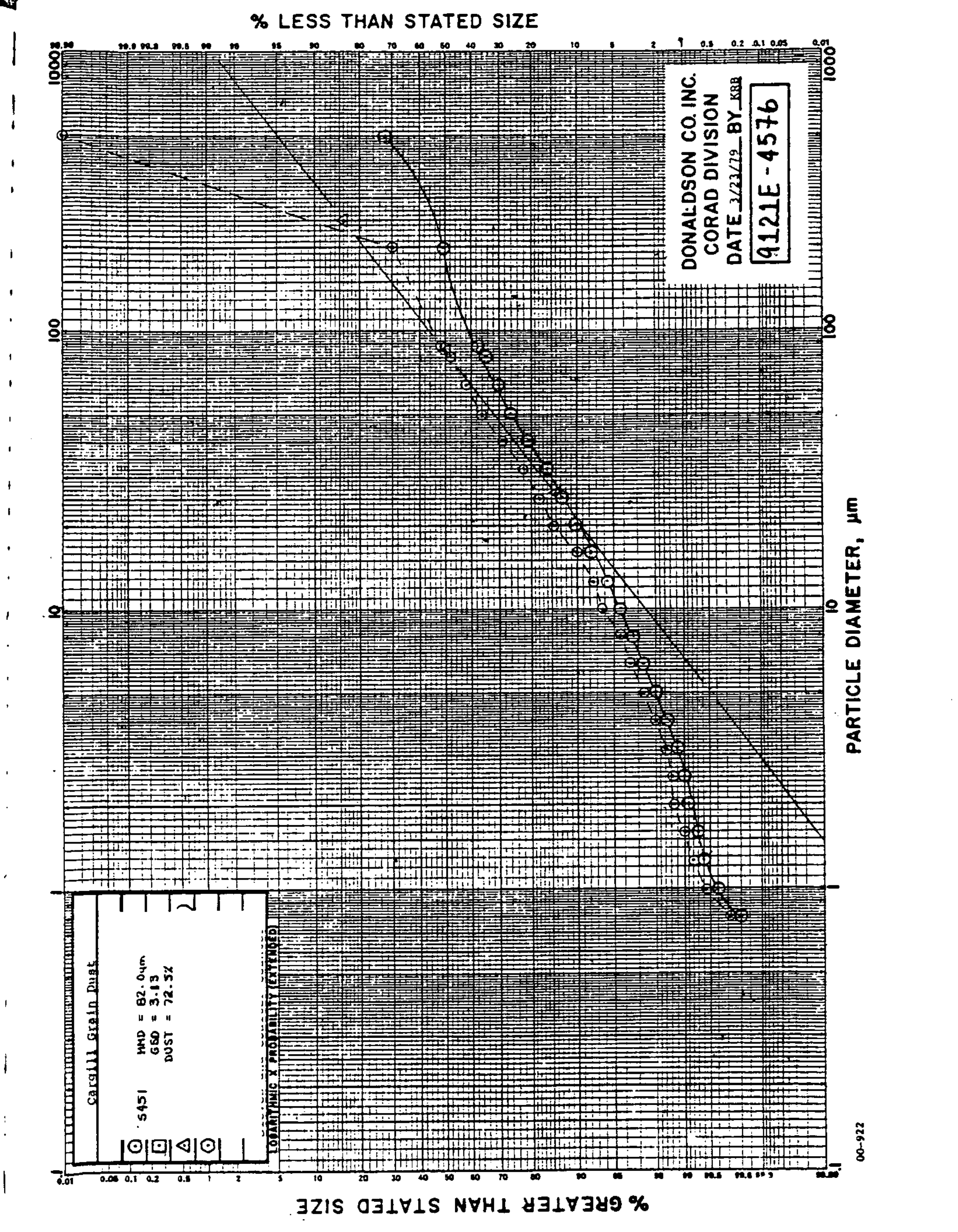

% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4580
Cargill Grain Dust
S314
MMD = 21.0µm
GSD = 2.77
DUST = 99.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

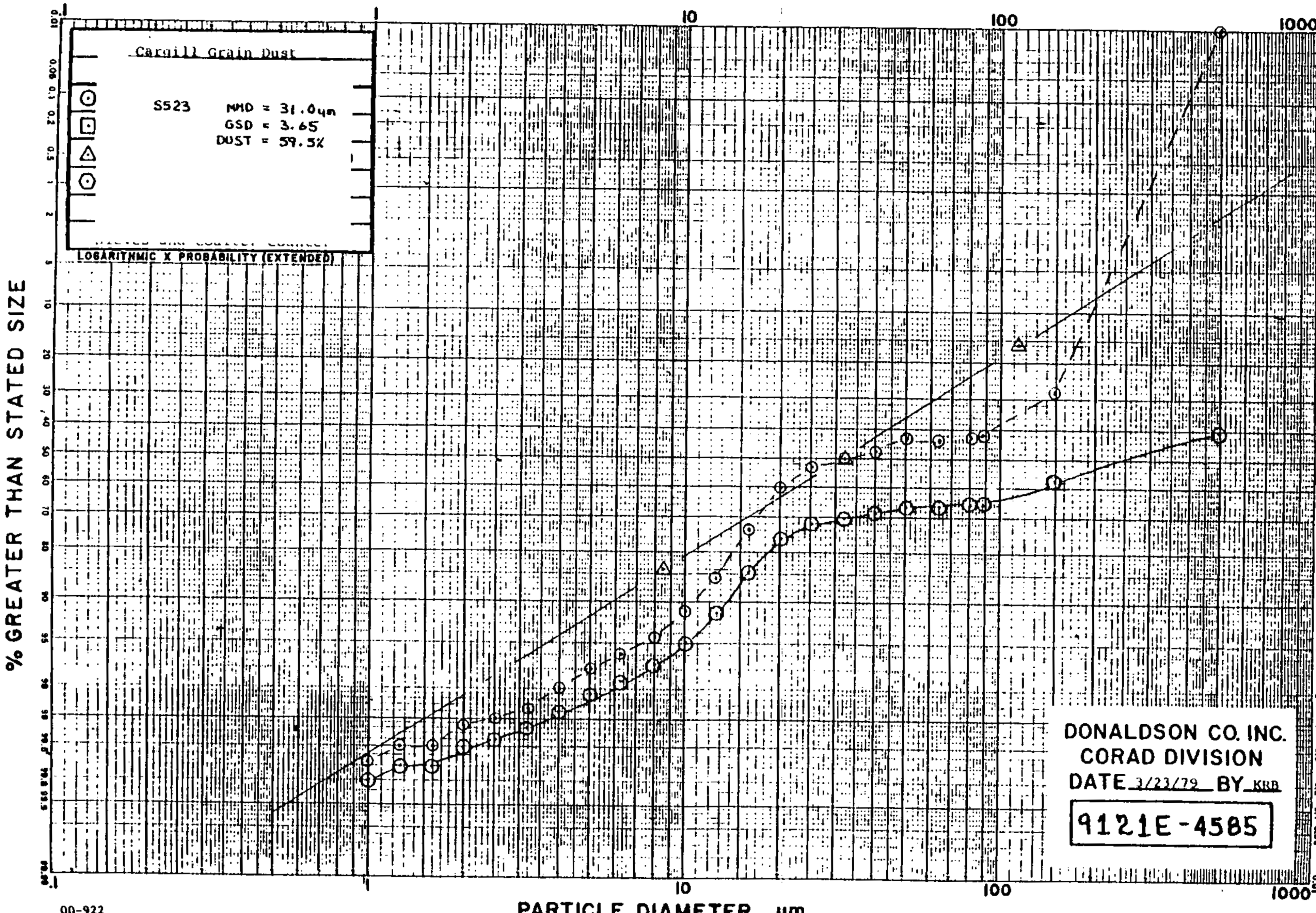


Cargill Grain Dust
5344 MMD = 105. µm
GSD = 2.48
DUST = 95.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4579
00-922

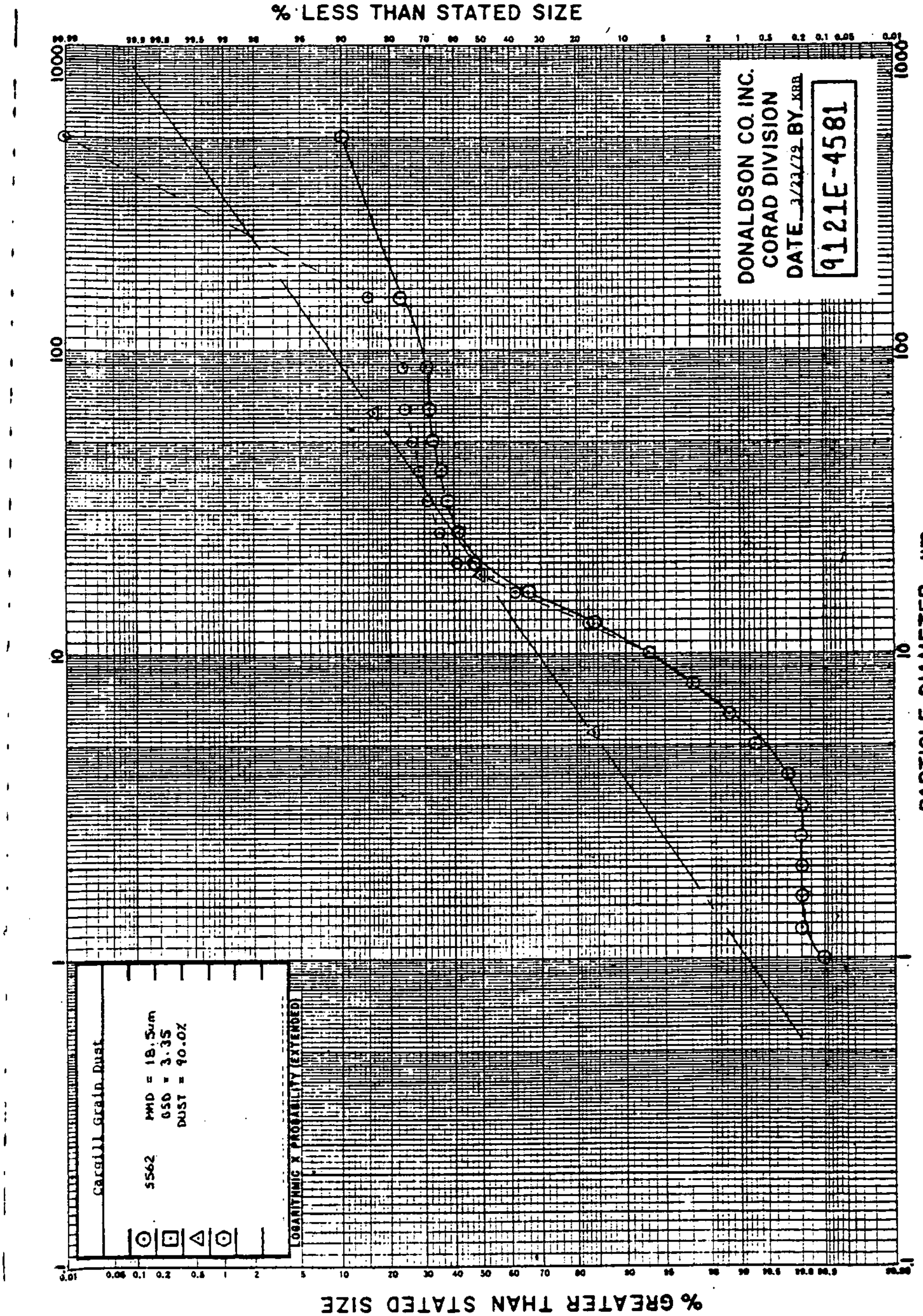


Cargill Grain Dust
5411 MMD = 100. μm
GSD = 2.39
DUST = 94.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4586
00-922

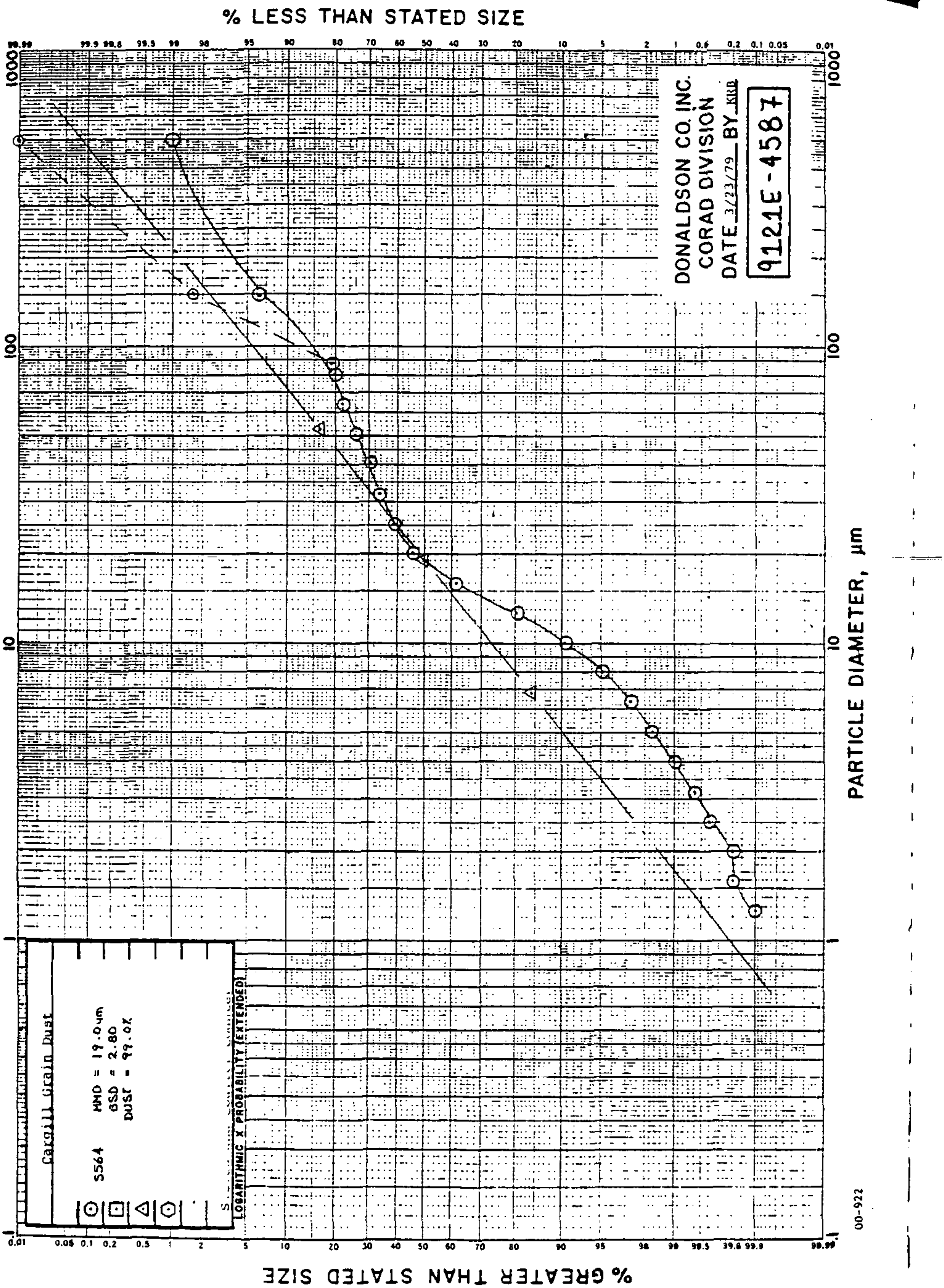

% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KBB
9121E-4576
PARTICLE DIAMETER, µm
Cargill Grain Dust
5451
MMD = 82.0µm
GSD = 3.13
DUST = 72.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

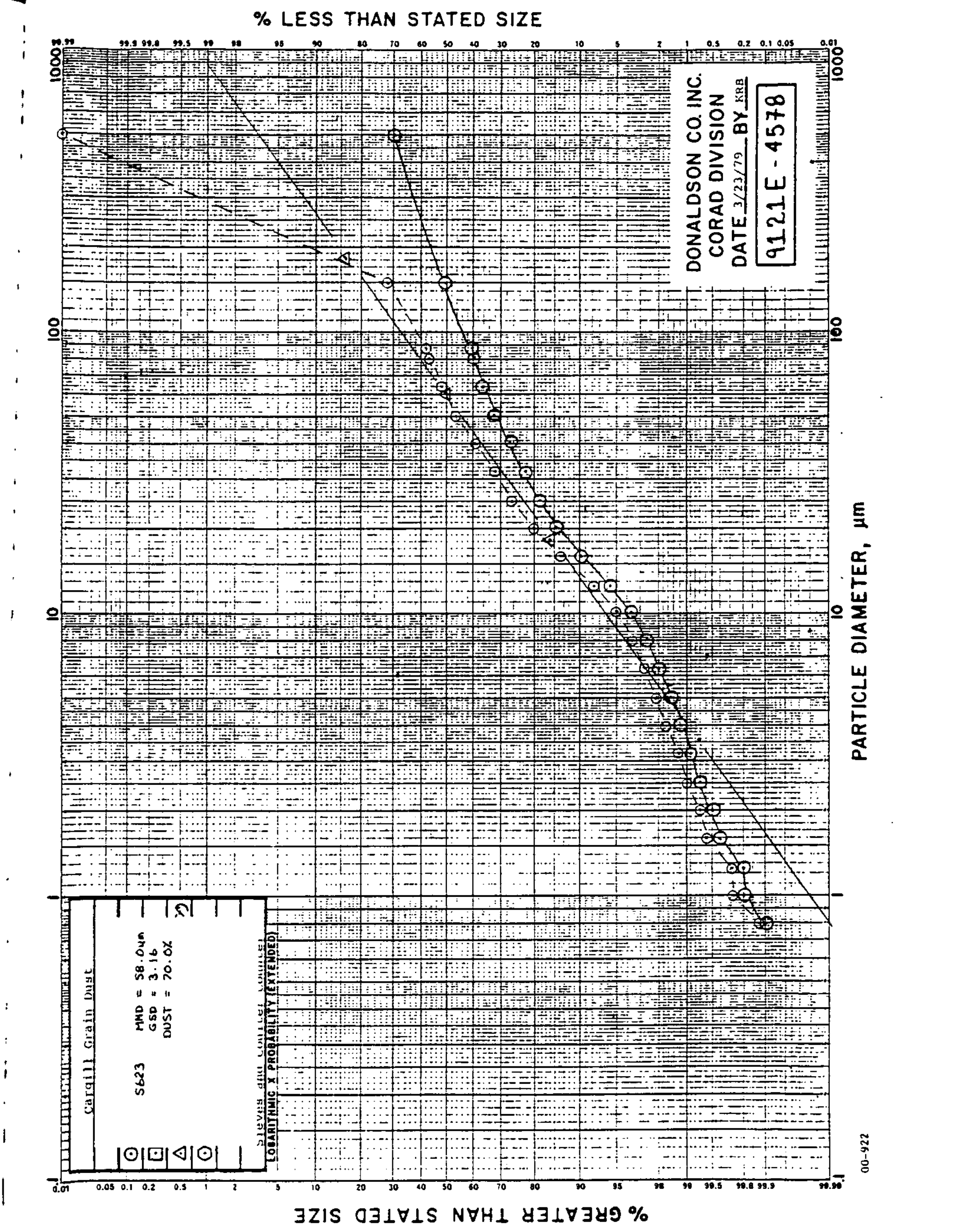


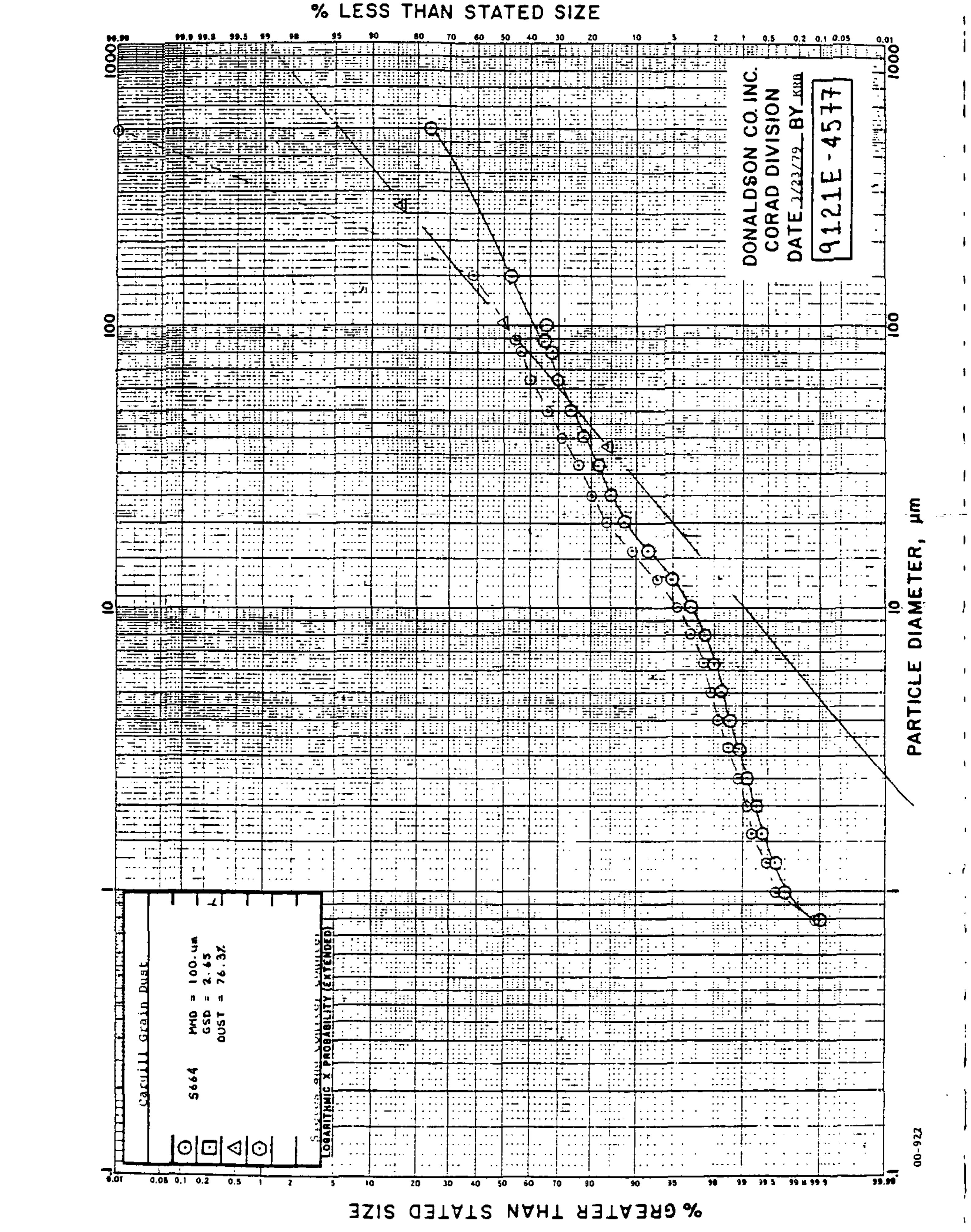
Cargill Grain Dust
S523
MMD = 31.0μm
GSD = 3.65
DUST = 59.5%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4585
00-922



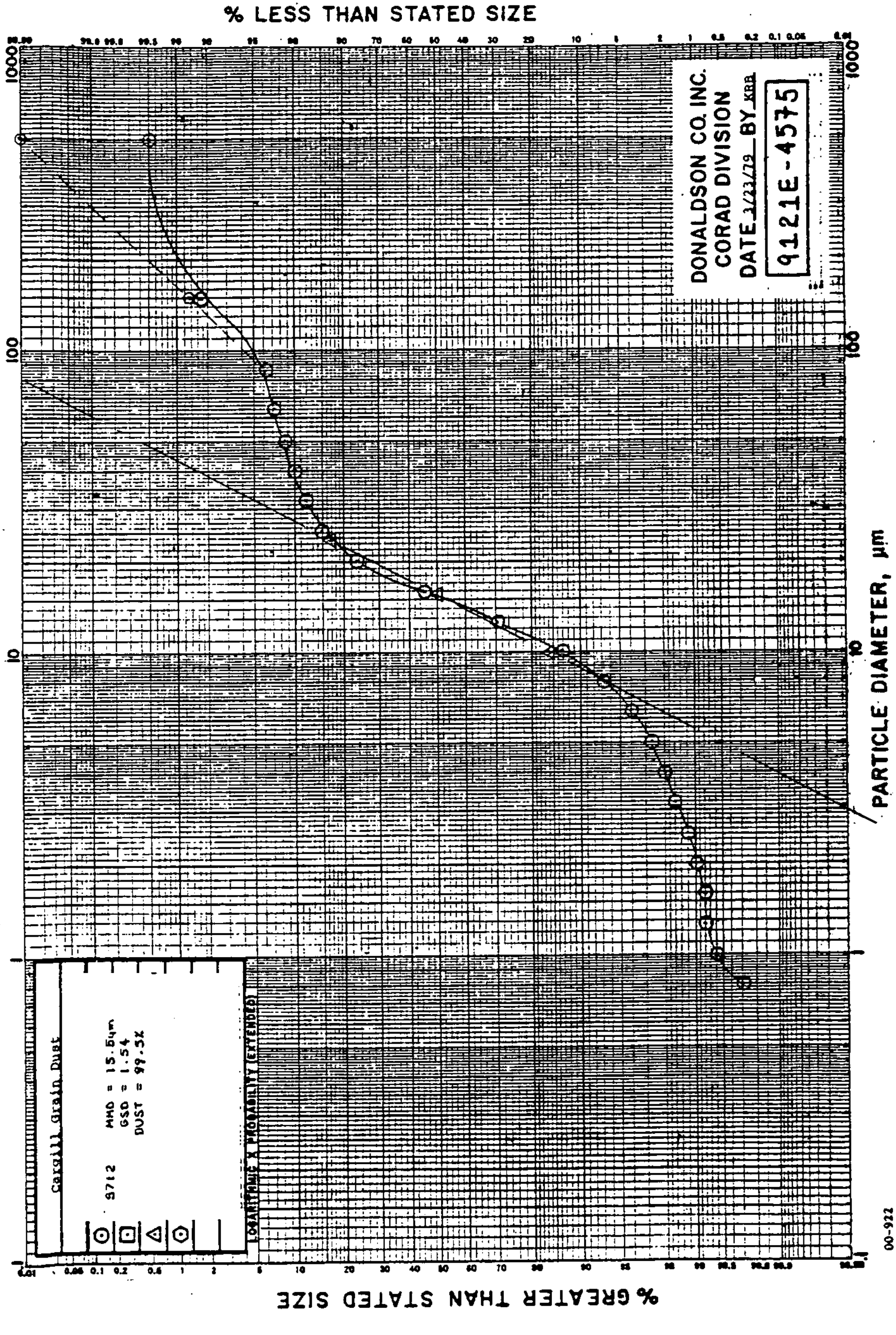
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4581
Cargill Grain Dust
5562
MMD = 18.5um
GSD = 3.35
DUST = 90.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

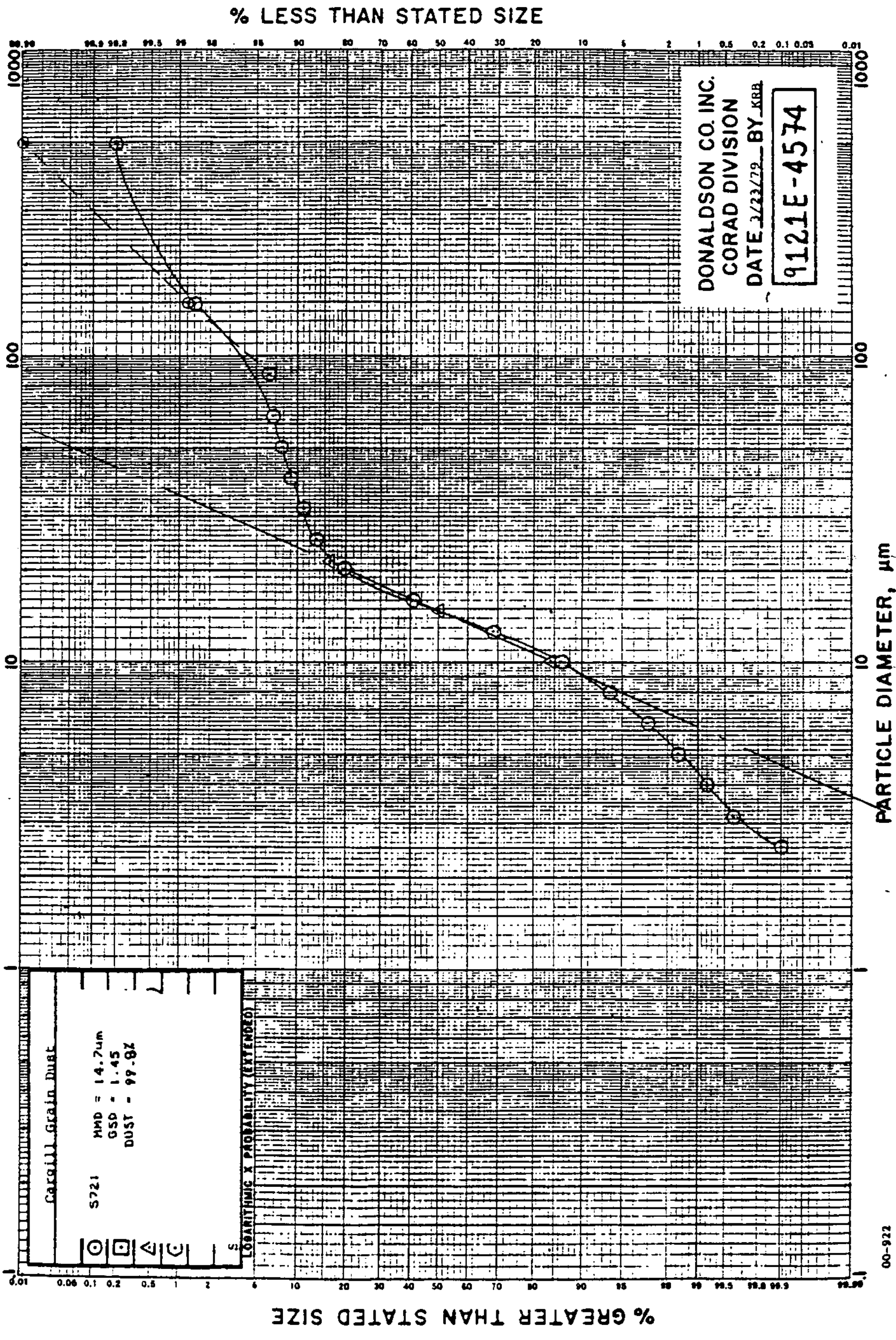

% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4587
Cargill Grain Dust
S564
MMD = 19.0 μm
GSD = 2.80
DUST = 99.0%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121 E - 4578
PARTICLE DIAMETER, µm
Cargill Grain Dust
S623
MMD = 58.0um
GSD = 3.16
DUST = 70.0%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 3/23/79 BY KRB
9121E-4577
PARTICLE DIAMETER, µm
Cargill Grain Dust
S664
MMD = 100. um
GSD = 2.65
DUST = 76.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 1/23/79 BY KRB
9121E-4575
PARTICLE DIAMETER, μm
Cargill Grain Dust
S712
MMD = 15.5μm
GSD = 1.54
DUST = 99.3%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 1/23/79 BY KRB
9121E-4574
PARTICLE DIAMETER, µm
Cargill Grain Dust
S721
MMD = 14.7um
GSD = 1.45
DUST = 99.8%
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

APPENDIX C. SUPPLEMENTAL STUDIES

This section consists of reports of research that was conducted after the main survey, but which relate directly to it.

Supplement I. Returning Dust to Bucket Elevators
Supplement II. Increasing Suction in Bucket Elevators
Supplement III. Cleaned Grain in Bucket Elevators

SUPPLEMENT I
FGIS DUST SURVEY

Dust Concentrations Inside Bucket Elevators Where Baghouse Dust is Returned to the Elevator Enclosure.

F. Wade 6/4/79

SUMMARY

Previous dust measurements in bucket elevators suggested that when dust systems return directly to bucket elevator enclosures, the concentrations inside the enclosures are higher than they would be if the dust were not returned. To study this effect more closely, the Norfolk Truck Receiving Leg and the Reserve Rail Receiving Leg were each sampled again under two modes of operation - returned (normal mode, dust from the baghouse is returned to the leg) and separate (baghouse dust is not returned). The results of these later tests show that keeping the baghouse dust separate had no measureable effect in the Reserve Rail Leg, but reduced concentrations to about half inside the Norfolk Truck Leg boot. Dust collection (pollution control) rates for both receiving systems were about 0.05 percent of the grain handled.

RESERVE RAIL RECEIVING LEG

Procedure:

1. A switching configuration was installed in the dust spout leading from the baghouse collector to the rail leg, so that the return dust could be diverted to a separate, portable container. The container was pre-weighed and weighed again at the end of the experiment.

2. Sampling was performed during the receiving of 200 or more cars of Midwest-origin corn (2 unit-trains). Three "pan" samples of grain were taken from the rail receiving conveyor belt during the period in which dust samples were taken from the leg. These pan samples were later sieved to determine fine (150 μm) and coarse (600 μm) dust content.

3. Dust concentrations were measured using Cargill's experimental sampler, according to the operating procedure described in earlier reports. Dust samples were collected in sets of four, the first with normal suction (dust control) at the leg boot and the other three at five minute intervals after the suction was shut off (at the blast gate). The following list is the order in which sets of samples were collected:

Location	Mode (baghouse dust)
head (pts 4,5,&6)	returned
head (4,5, & 6)	separate
boot (1 & 2)	returned
boot (1 & 2)	separate
middle (7, downside)	returned
middle (7)	separate

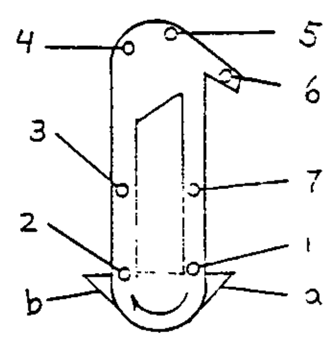
Results:

The following figure and table show where dust samples were collected from inside the Reserve Rail Receiving Leg and the highest concentrations found at each point during the sampling operations.

Sampling Location Guide

1 boot - downside
2 boot - upside
3 midway - upside
4 head - upside
5 head - top
6 discharge spout
7 midway - downside

a, b indicate feed location



Dust Concentrations Inside the Reserve Rail Leg

Date:	1/22/79	3/7/79	3/7/79
Grain:	corn	corn	corn
Mode:	returned	returned	separate
Sampling point	Highest Concentration, g/m^3		
boot, downside (1)	127	54	33
boot, upside (2)	460	237	229
head, upside (4)	79	92	126
head, top (5)	67	455	124
head, discharge (6)	110	135	152
middle, downside (7)	89	45	51

Dust Analysis of Grain (Pan) Samples From
Reserve Rail Receiving

	Sample 1	Sample 2	Sample 3	Average
Time: (3/8/79)	1:00 am	3:00 am	8:00 am	------
Weight	1107.7g	1012.7g	950.5g	1023.6g
Coarse dust (<600 μm)	2.5%	1.8%	1.5%	2.0%
Fine dust (<150 μm)	1.7%	1.1%	1.3%	1.4%

Dust Collection Rate of Rail Receiving Dust Control System (Baghouse)

Time period (grain being elevated	200 minutes
Grain elevating rate (estimate)	37,500 lb/min.
Total grain elevated	7,500,000 lb.
Weight of collected material	8,070 lb.
Weight of dust (est. 50%)	4,000 lb.
Dust collection rate	0.05 %

Discussion:

Comparing the results of the two samplings of March 7th, the concentrations at all but point 5 were found to be similar, with no particular improvement caused by separate handling of the bag-house dust return. The high value at point 5 (returned mode - 455 g/m^3) probably does not contradict the above conclusion, but indicates a measuring error or an otherwise unexplained event. Had it been significant, such high levels should have been measured at point 6; also, the next higher measurement at point 5 (returned), was 133 g/m^3 (similar to the highest measurement under the "separate" mode, 124 g/m^3).

Procedure:

1. Switching from "returned" to "separate" mode could only be done on a semi-permanent basis - tearing out the baghouse return spout connected to the leg boot (upside) and rebuilding the spout to reach a prtable container. The container was preweighed and weighed again after the experiment on the platform truck scale.

2. Sampling was performed during the unloading of about 100 semi-trailor trucks (800 - 1000 bushels each) over two days. During the first day the baghouse return spout was connected to the leg (returned). On the second day, the dust was diverted to the separate container (separate), during which time 50 trucks were unloaded - 30 soybeans (26,000 bushels) and 20 corn (16,000 bushels), totaling 2,460,000 lbs. No grain "pan" samples were collected, since grain lots varied with each dust sample.

3. Dust concentrations were measured using Cargill's experimental sampler - however, in a manner different from that of original survey in two respects. First, the sampler was modified, incorporating a cyclone ahead of the filter, to extend sampling time for high concentrations. Second, sample sets were reduced from four to two, as lack of dust control at the boot of the leg made fewer samples necessary. The order in which sample sets were collected are as follows:

Date	Location	Mode
3/30/79	boot (1 & 2)	returned
3/30/79	middle, upside (3)	returned
3/30/79	head (4, 5, & 6)	returned
4/2/79	head (6, 5, & 4)	separate
4/2/79	middle (3)	separate
4/2/79	boot (1 & 2)	separate

Results:

(See Reserve Rail Leg section for a guide to sampling points on the leg.)

Dust Concentrations Inside the Norfolk Truck Leg

Date:	12/7/78	3/30/79	4/2/79
Grain:	Intermittent lots of corn and soybeans		
Mode:	returned	returned	separate

Sampling Point	Highest Concentration, g/m^3		
boot, downside (1)	580	96	61
boot, upside (2)	600	200	58
middle, upside (3)	39	64	120
head, upside (4)	38	160	190
head, top (5)	52	92	84
head, discharge (6)	45	86	110

Dust Collection Rate of Norfolk Truck Receiving System

grain elevated	2,500,000 lb.
weight of dust collected	1,300 lb.
dust collection rate	0.05 percent

Discussion:

In the case of the Norfolk Truck Leg, there appears to be a reduction in concentrations caused at the boot by not returning the baghouse dust at the boot. No change was noticeable at the head. The general variation in concentrations through out the leg make the differences between the two modes less dramatic. The high levels measured during the original survey may have resulted from measurement errors during extremely short sampling times, a problem which was resolved by the sampler modification in the later equipment.

SUPPLEMENT II
FGIS DUST SURVEY

Reduction of Dust Concentrations Inside Bucket Elevators by Increasing Suction (Polution Control) at the Boot.

F. Wade 6/5/79

SUMMARY

It was shown in the main portion of this survey that high dust concentrations inside bucket elevators make them a severe explosion hazard. One solution is to reduce the concentration by drawing more air through the pollution control hood (s). This possiblity was studied in the shipping leg at the Savage terminal by measuring the dust concentrations inside the leg while varying airflow drawn through the hood at the boot. Dust measurements at suction rates of 600 ft^3/min (normal) and 750 ft^3/min (0.28 and 0.35 m^3/s) showed that concentrations at the boot were not reduced with additional airflow. Instead, concentrations appeared to increase at the head, perhaps by drawing dust-laden air in from the discharge spout. It can be concluded that existing pollution control is ineffective in reducing concentrations to below the minimum explosible concentration in the shipping leg at Savage and that moderate increases in airflow had no beneficial effect.

Procedure:

1. Dust control in the shipping leg at the Savage terminal (Figure 1) consists of a hood over the boot (between up and down casings) and two small suction points at the tail pulley bearings (floating), connected to a 12 inch (300 mm) diameter duct which combines with ducts from two other legs and leads to a booster fan exhausting to a negative - pressure baghouse. Suction was shut off at the damper nearest the shipping leg and was increased by shutting off other dampers upstream from the fan.

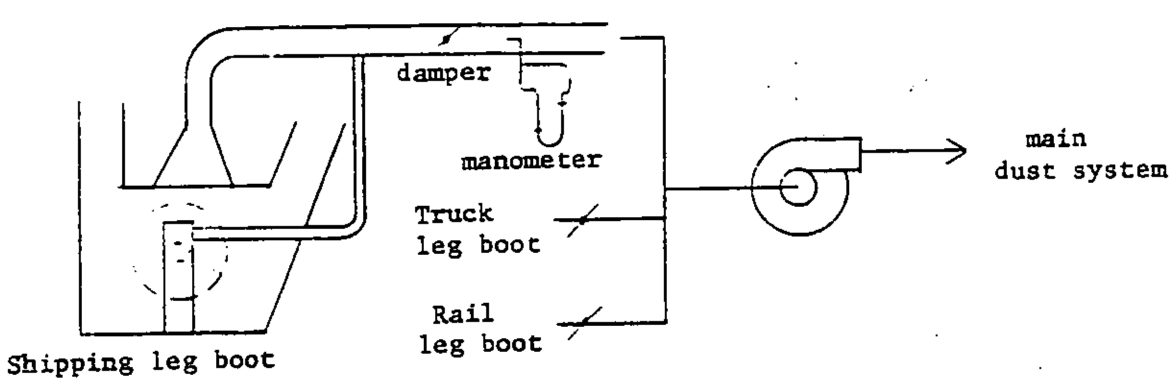


Figure 1. Diagram showing dust control in the shipping leg at Savage, MN

2. Airflow (suction) was measured in the shipping leg duct just downstream from the damper (10 to 15 ft. from the hood), along a straight section four feet in length. Measurements were made with a pitot tube and an inclined manometer (0-2.00 in., W.G.).

3. Sampling was performed during the loading with US No. 2 corn (3% BCFM). A pan sample was taken and later sieved over a US No. 30 sieve to determine approximate dust content of the grain.

4. Dust concentrations were measured using Cargill's experimental sampler, which was modified, as in Supplement I, by incorporating a cyclone between the hose and the filter. Two replicate measurements were made at each of eight points on the leg, numbered 1,2,3,4,5a,5b,6a, and 6b, to correspond to earlier numbering configurations (see Figure 2 for location of these points). Sampling was performed on two different days according to the following schedule:

Date	Location	Airflow
5/8	boot (1 & 2)	600 ft^3/min
	middle (3)	600
	head (4,5a,5b,6a,6b)	600
	head (4,5a,5b,6a,6b)	750
	middle (3)	750
	boot (2)	750
5/15	boot, downside (1)	600
		0
		750
	boot, upside (2)	750
		600
		0

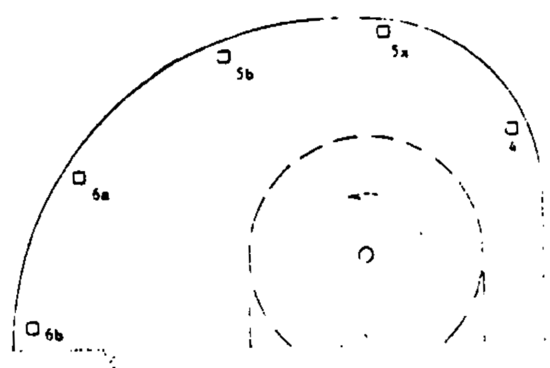


Figure 2. Sampling configuration of the shipping leg at Savage, MN

Results:

Point	Date	Concentration, g/m^3 at Indicated airflow, $ft^3/min.$ 0	600	750
Boot, downside (1)	5/15	44	66	21
		33	70	65
Boot, upside (2)	5/15	160	86	250
		155	89	210
Boot, upside (2)	5/8		170	270
			215	320
Midway, upside (3)	5/8		6	---
			2	---
Head, upside (4)	5/8		1	4
			1	2
Head, top (5a)	5/8		41	68
			53	210
Head, top (5b)	5/8		70	92
			62	130
Head, discharge (6a)	5/8		98	125
			97	200
Head, discharge (6b)	5/8		190	190

Dust Content of Corn

Pan sample weight	1004.2 g
Dust weight (US No.30 sieve)	1.4 g
	0.14%

Handling rate (18,000 bu/hr)	16,800 lb./min	
Dust handling rate (@ 0.14%)	24 lb./min	(11 kg/min)

Discussion:

The results show that increasing the airflow in the dust control system of this leg either increased the concentrations inside the enclosure or had no effect at all with variations caused by chaning amounts of dust in the grain, etc. In fact, what may occur in the head is that drawing air into the leg from the discharge spout and other openings may pull dust back towards the upside, as seen by the increased concentrations at points 5a, 5b, and 6a, as airflow was increased. From the basis of these results it appears unlikely that adding airflow (suction) at the leg boot will substantially reduce dust concentrations to safe levels, particularly as there appears to be more dust in the grain than is suspended in the air inside the casing at any given time. The pan sample yielded 0.14% coarse dust ($<600\ \mu m$); thus, 11 kg/min of dust was handled in the leg - three times the amount drawn off at the boot (3.4 kg/min @ 600 $ft.^3/min$, 200 g/m^3).

SUPPLEMENT III
FGIS DUST SURVEY

Dust Concentrations Inside Bucket Elevators Before and After the Grain is Cleaned

F. Wade 9/7/79

SUMMARY

It has been suggested by persons in the U.S. Department of Agriculture and by others that, in order to reduce explosion risks, grain should be cleaned at all stages of the U.S. marketing chain and that dust should not be added back to the grain. To determine what effect this policy has had for grain being received and cleaned at Cargill Grain Co., Ltd.'s export terminal at Thunder Bay, Ontario, dust concentrations were measured inside the boot and head enclosures of a receiving leg (bucket elevator) and a cleaner leg (after cleaning) while handling the same lots of wheat during three replicate tests. In the first two tests no differences were found, while in the third the cleaner leg had much lower concentrations than did the receiving leg. Dust control ducts were attached and operating at the boot and off the garner or explosion vent at the head of each leg, with no dust being returned to grain throughout the system. Two additional tests were performed on a shipping leg (one test with wheat and the second with barley) in which similar concentrations were found as those encountered in the receiving leg in earlier tests. These results seem to indicate that cleaning had little effect in reducing concentrations at this location. The general low levels (no concentrations exceeded 40 grams per cubic meter) may have been caused by earlier cleaning operations at other locations or by the slow speed at which the legs were running (less than 600ft/min).

Procedure:

The operations at the Thunder Bay terminal basically consist of receiving grain by rail (330 metric tons per hr), cleaning the grain (160 T/hr), and storing the grain until it can be shipped out (330 T/hr) by rail or "Laker". There are five separate systems which do the above, usually in a sequential arrangement. The receiving, cleaning, and shipping legs of "system 5" were selected and prepared for this study by installing 2 1/4 inch (57 mm) diameter sampling ports at the boot (point 2 according to earlier bucket elevator sampling configurations) and at the head (point 6). Two experimental samplers (described in the main body of this report) were prepared and positioned to operate, one at the boot and the other at the head of any of the legs.

During each of the first three tests, sampling was conducted simultaneously (duplicate samples - one minute each at 2 to 5 minute intervals) at the head and at the boot of the receiving leg, while an identified carload of wheat was being unloaded. Then, while this same lot was later being cleaned (Superior-type separators), sampling was conducted at the head and the boot of the cleaner leg. In tests 4 and 5, sampling was performed during the transfer of unidentified lots of wheat and barley through the shipping leg.

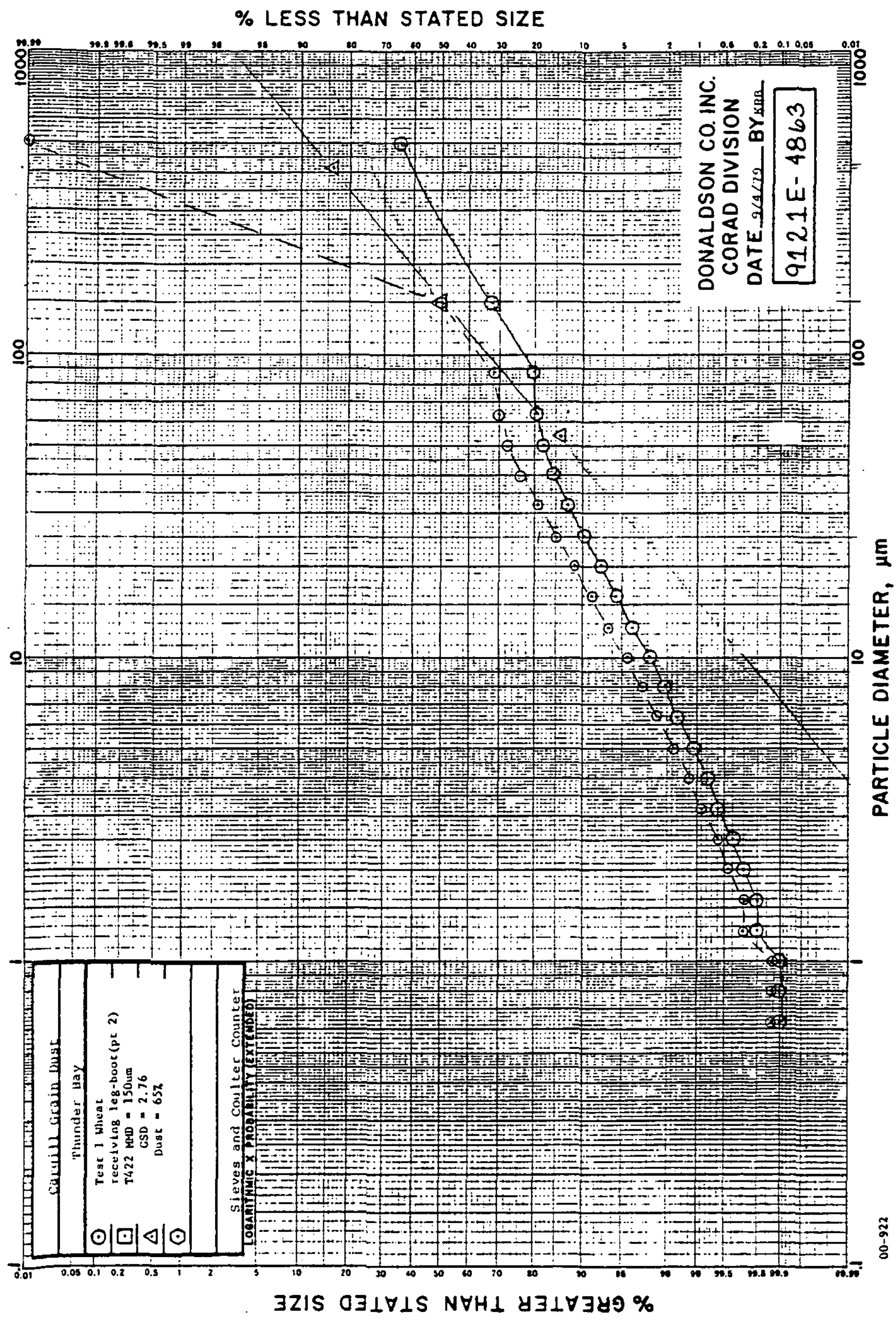
Particle size distributions were determined from several of the samples, according to the procedure described in the main report.

Results:

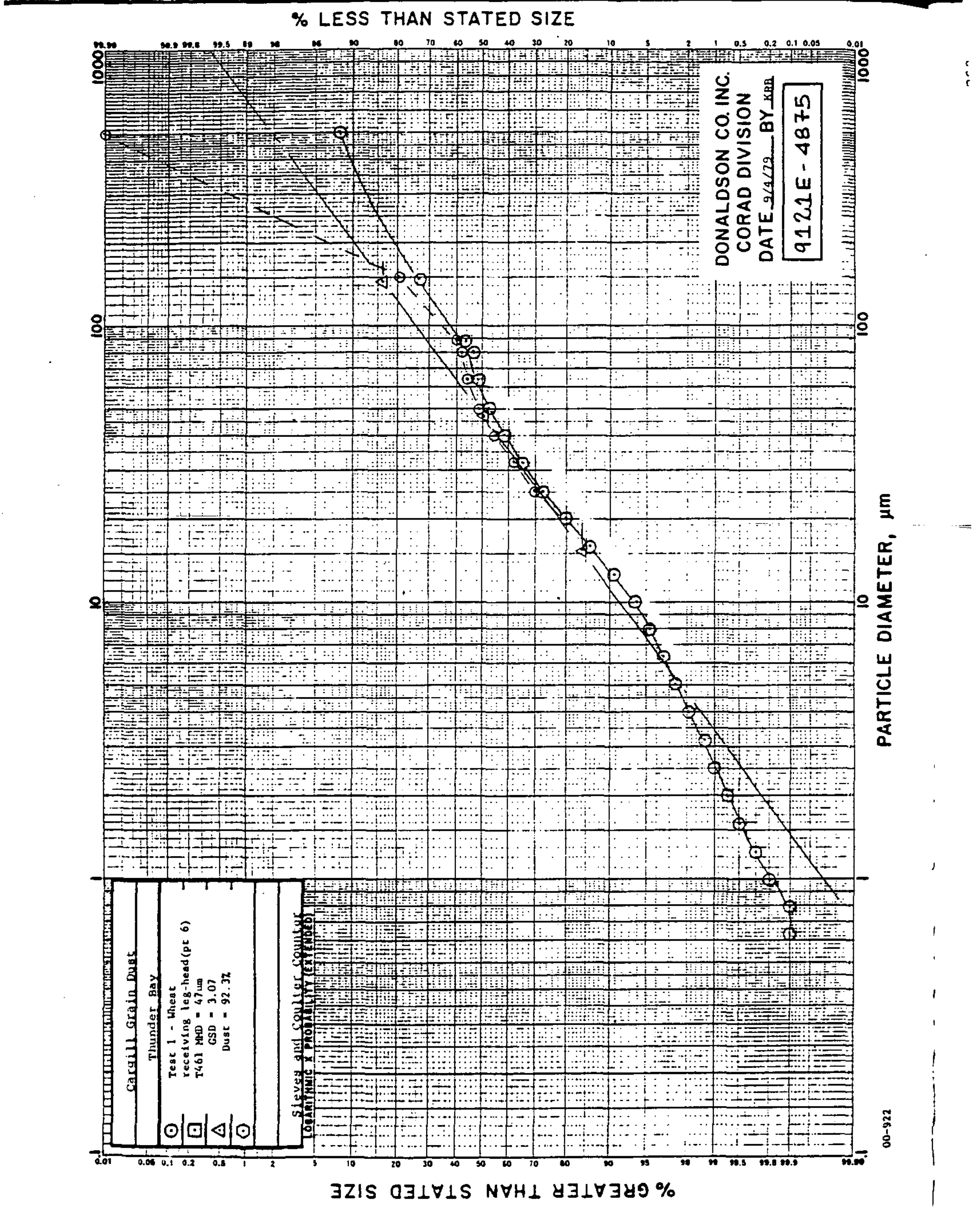
Test Number	Grain type	Bucket Elevator	Dust Concentration, g/m^3 boot(pt 2)	head(pt 6)
1	wheat	receiving	9	4
			12	4
		cleaner	12	4
			10	4
2	wheat	receiving	18	7
			13	6
		cleaner	33	8
			18	6
3	wheat	receiving	9	3
			16	6
		cleaner	3	2
			2	1
4	barley	shipping	14	13
			15	10
5	wheat	shipping	16	11
			13	9

Discussion:

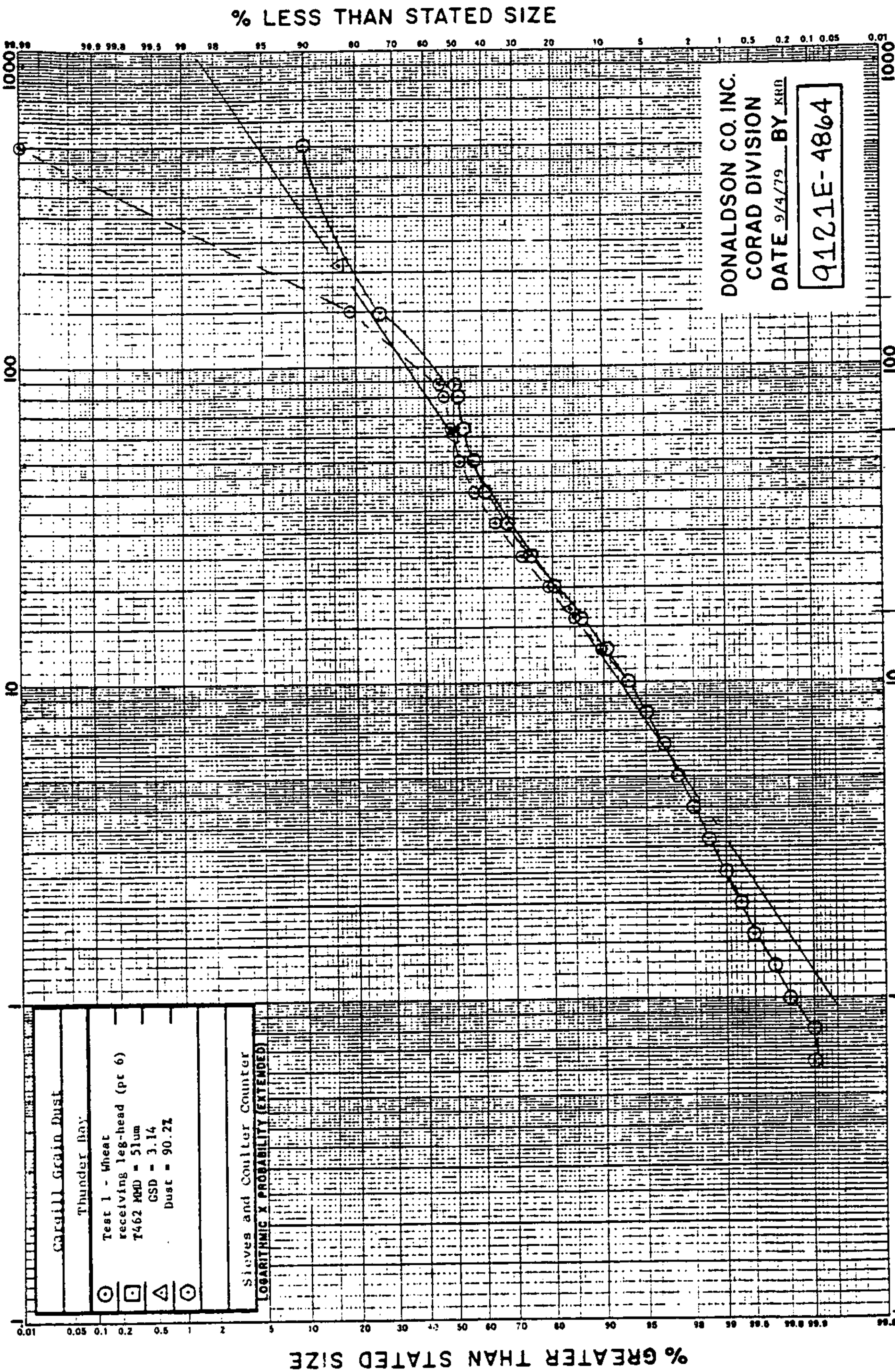
Tests 1 and 2 did not give any evidence that cleaning the wheat reduces the concentrations of dust inside handling equipment, whereas test 3 did show a large deduction. Tests 4 and 5 showed concentrations inside the shipping leg to be about the same as those found in the receiving leg, indicating that grain that has already been received and cleaned is as dusty as when being received. Although dust concentrations in general were found to be quite low, the merit of cleaning at other stations in the marketing system is not ascertainable because of differences between operating speeds of the legs at Thunder Bay and those in which dust was measured in the U.S. - 580 ft/min or less vs. 700 to 900 ft/min in the U.S. Particle size distributions were quite uniform, with no differences observed among samples from the receiving leg, the cleaner leg, or the shipping leg.

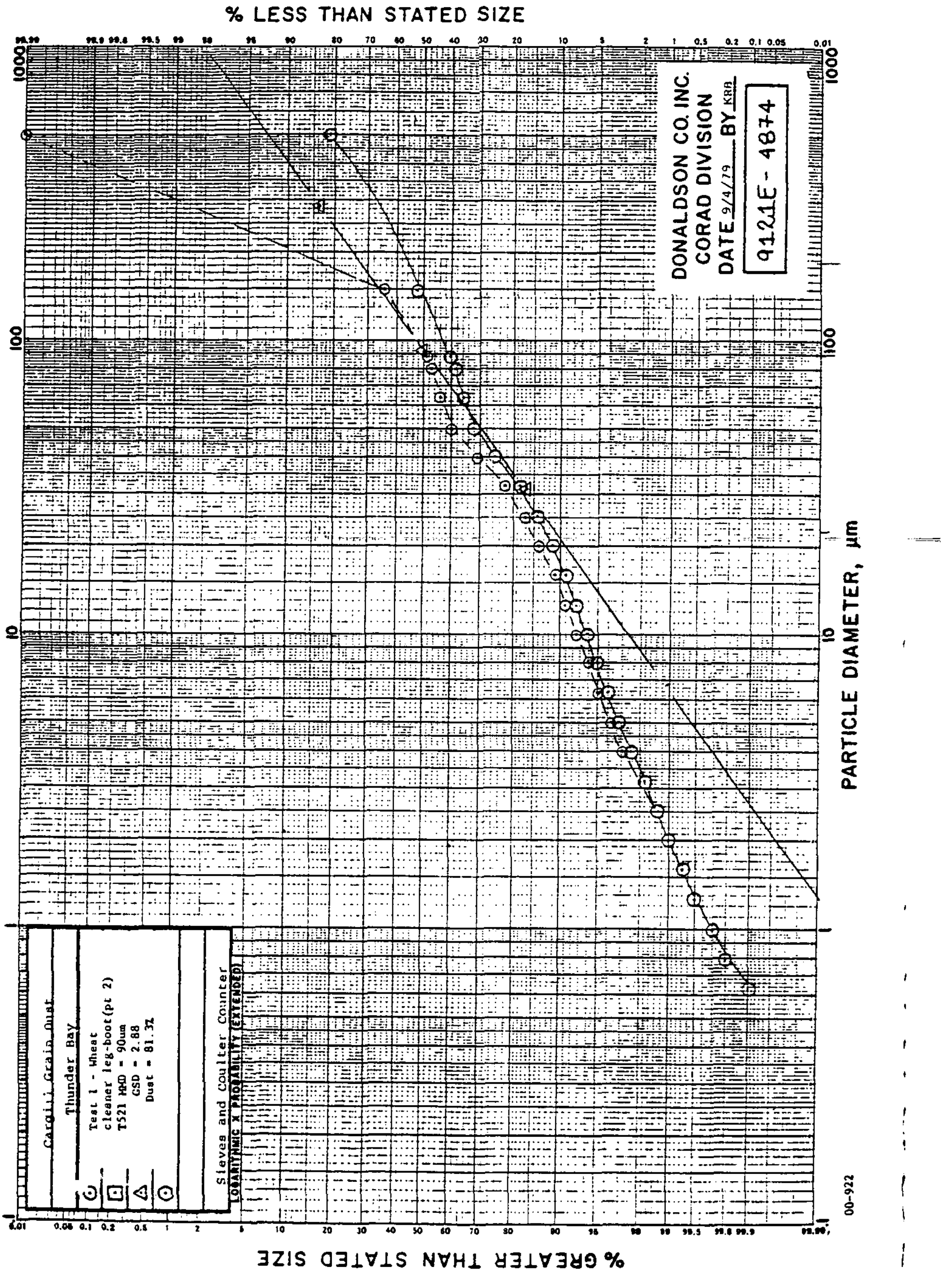


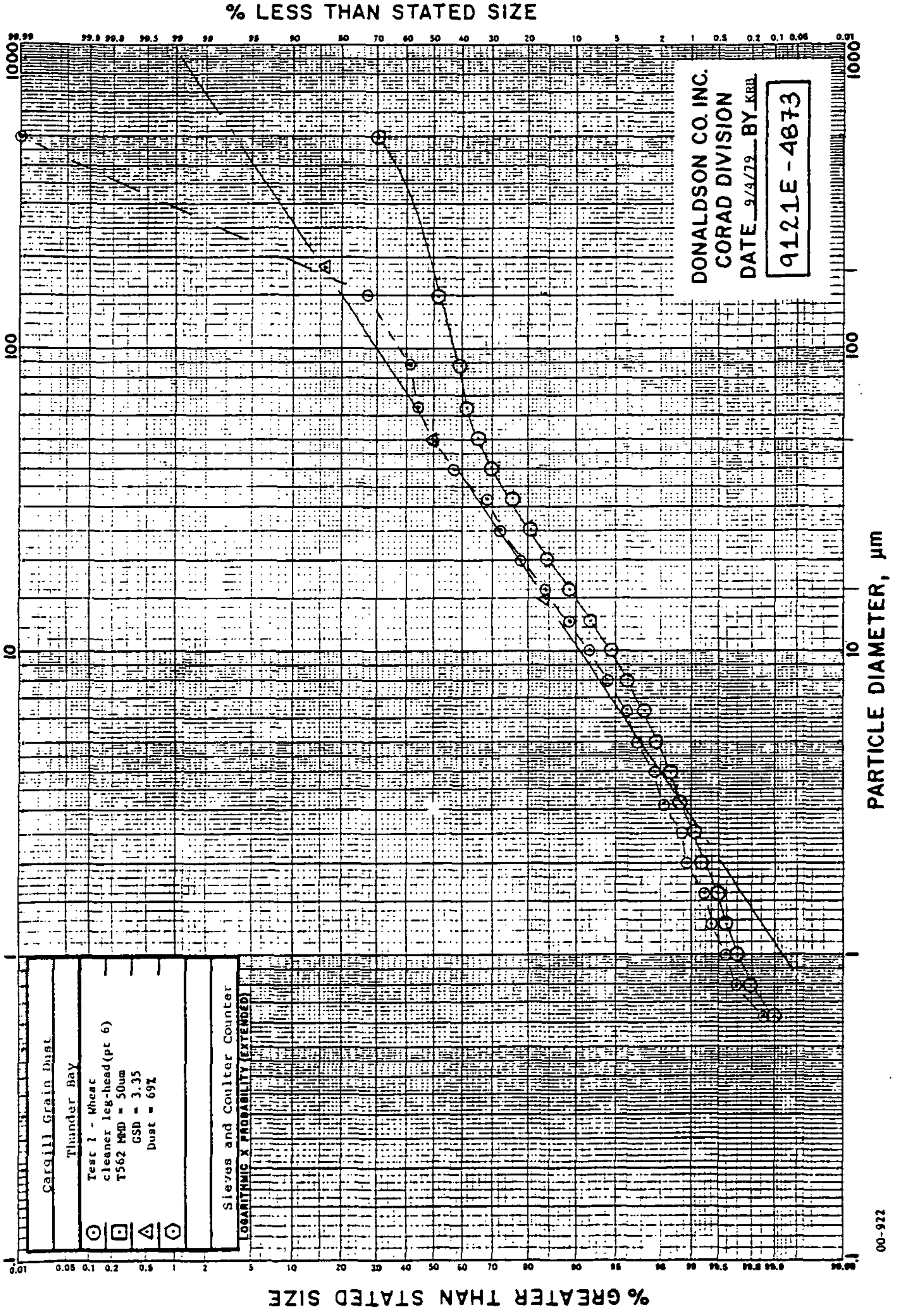
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KBB
9121E-4863
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 1 Wheat
receiving leg-boot(pt 2)
T422 MMD = 150um
GSD = 2.76
Dust = 65%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



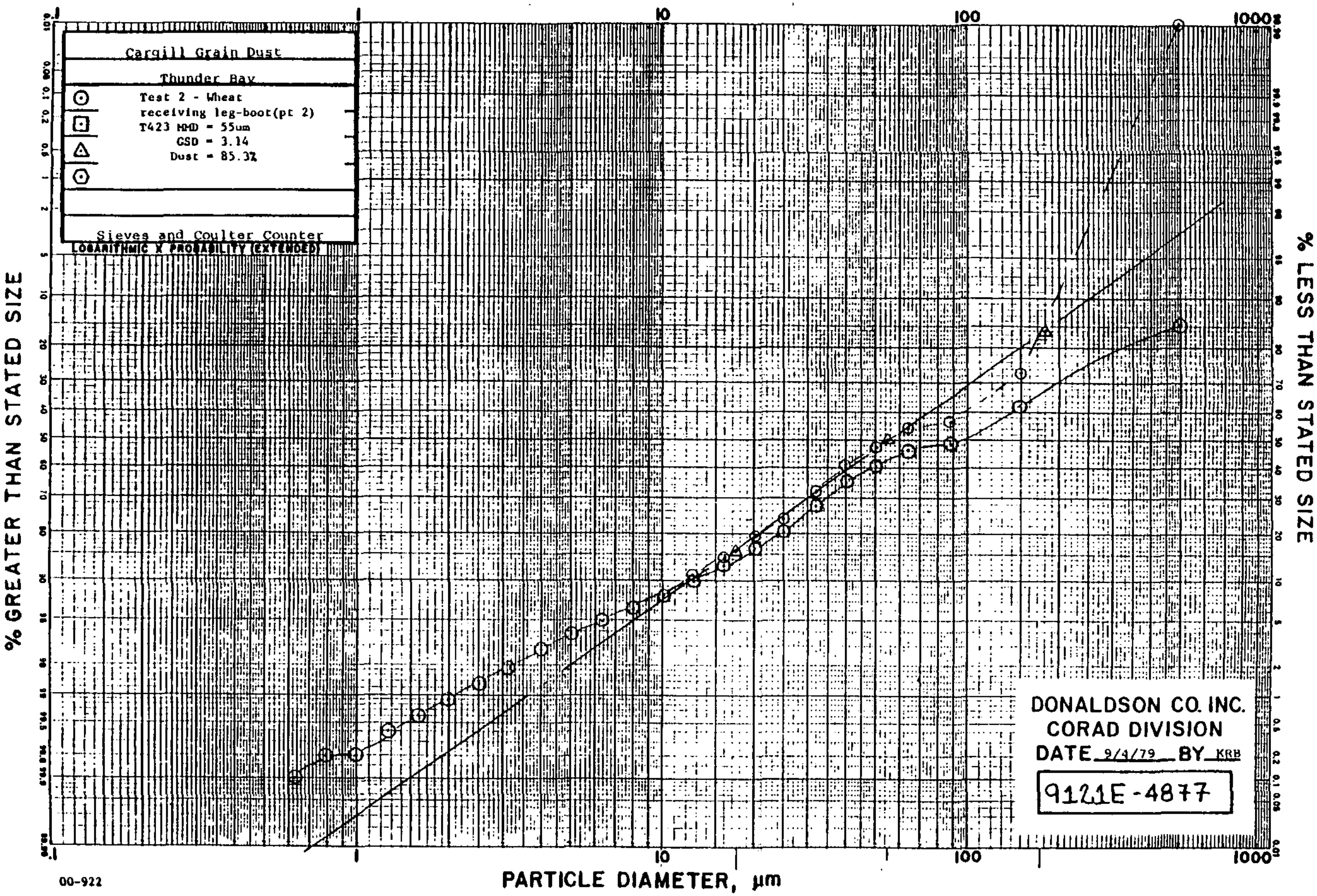
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4875
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 1 - Wheat
receiving leg-head(pt 6)
T461 MMD = 47um
GSD = 3.07
Dust = 92.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRH
9121E-4864
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 1 - Wheat
receiving leg-head (pt 6)
T462 MMD = 51um
GSD = 3.14
Dust = 90.2%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

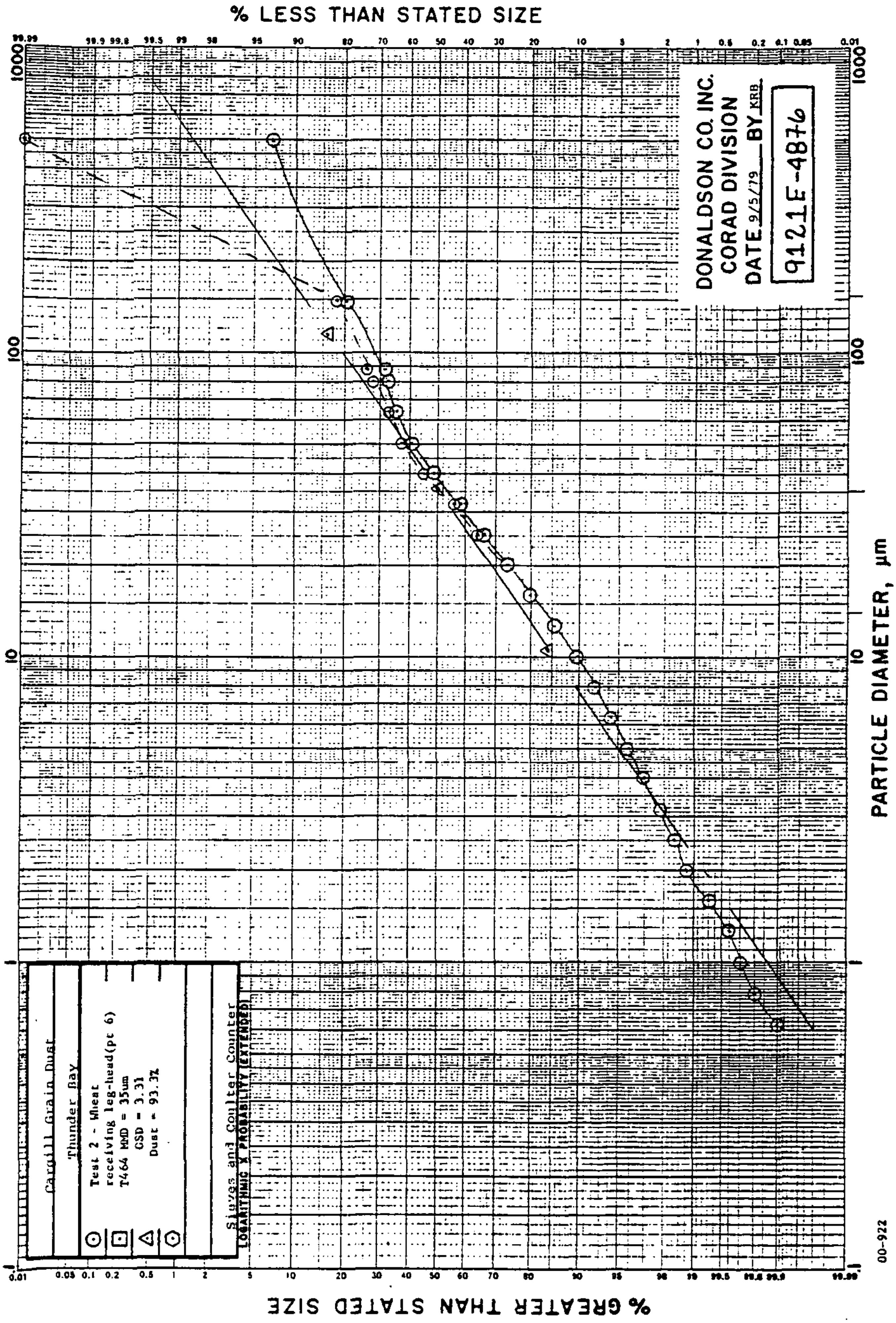

% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E - 4874
Cargill Grain Dust
Thunder Bay
Test 1 - Wheat cleaner leg-boot (pt 2)
T521 MMD = 90um
GSD = 2.88
Dust = 81.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



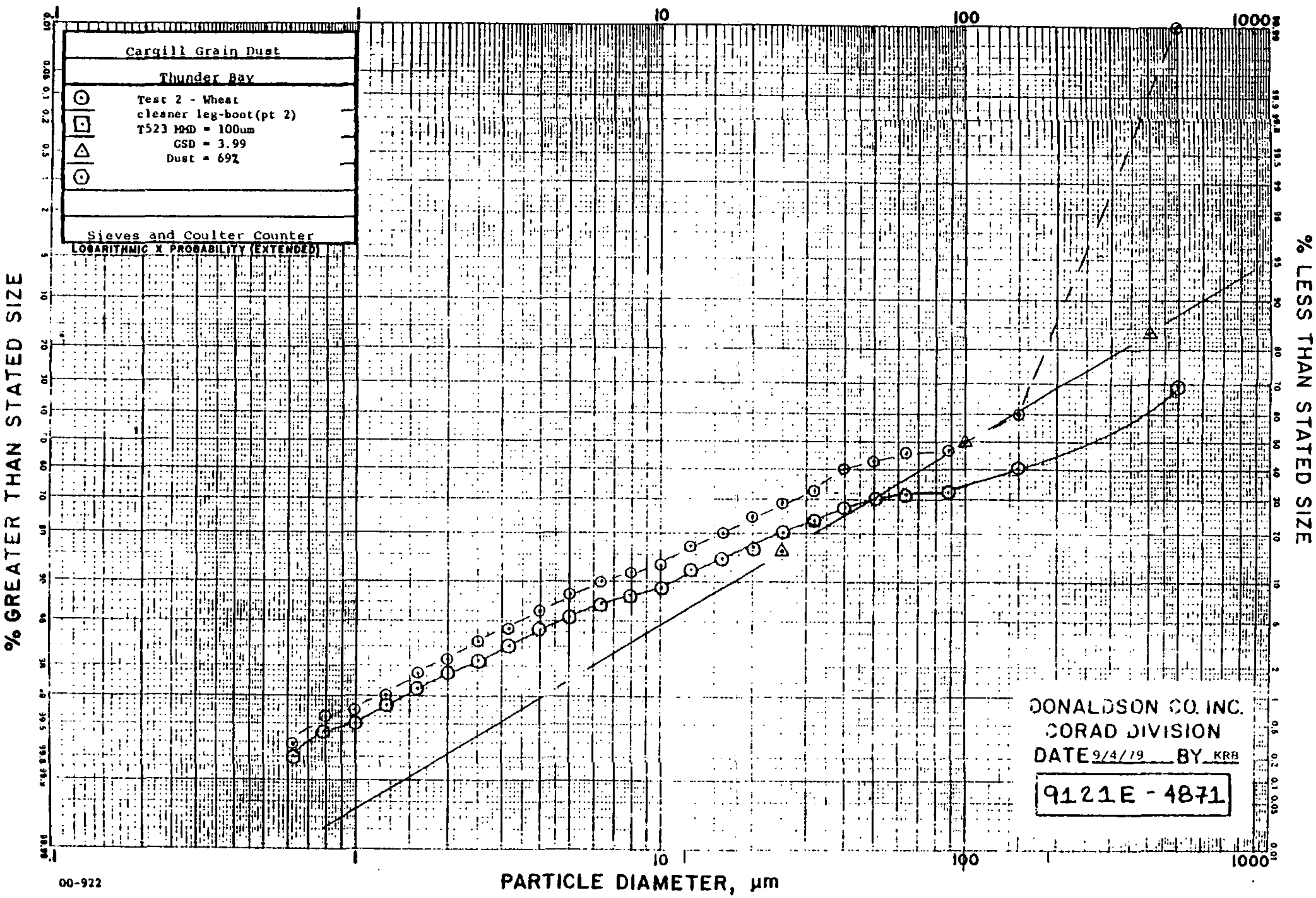
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4873
Cargill Grain Dust
Thunder Bay
Test 1 - Wheat
cleaner leg-head (pt 6)
T562 MMD = 50um
GSD = 3.35
Dust = 69%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



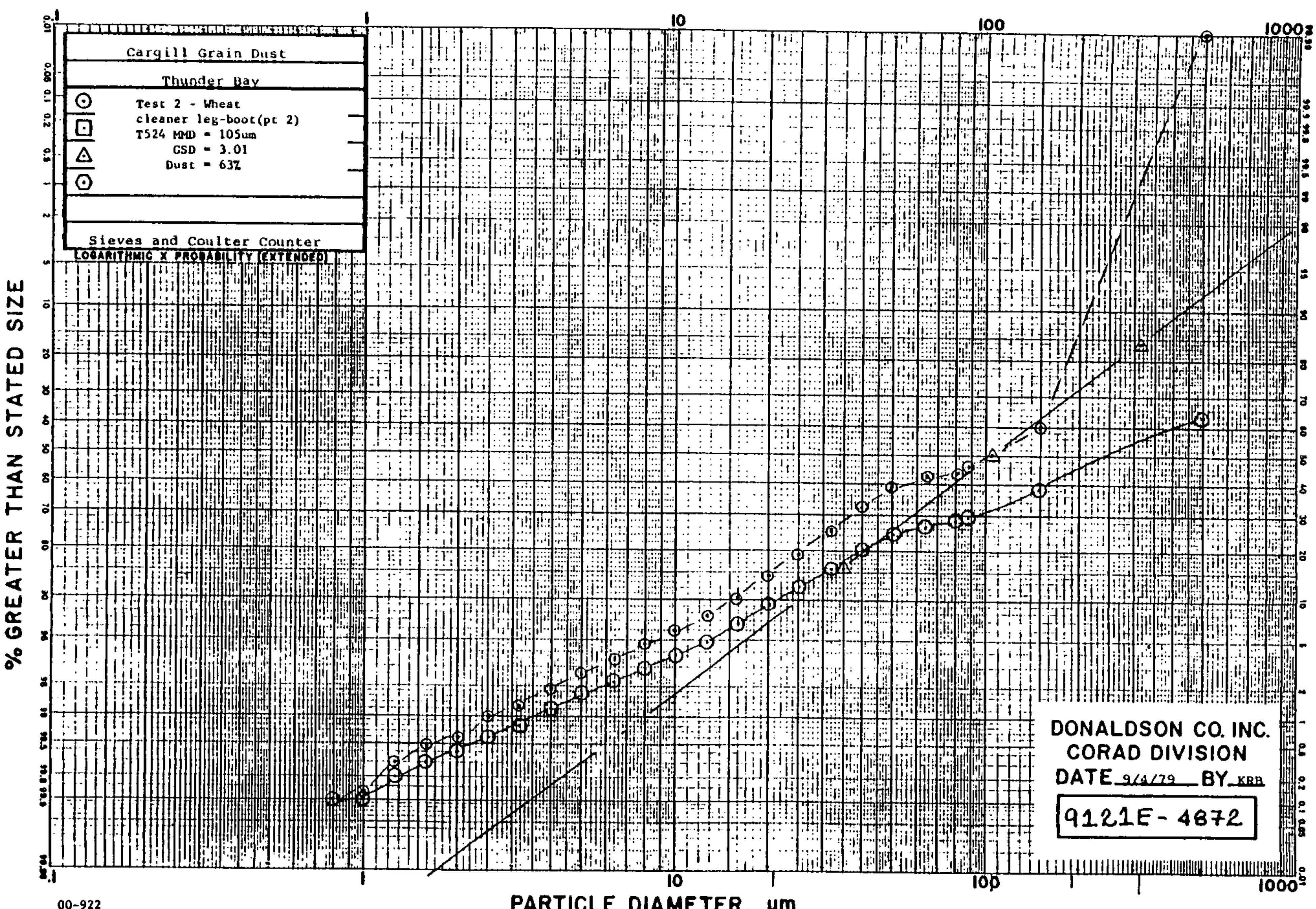
Cargill Grain Dust
Thunder Bay
Test 2 - Wheat
receiving leg-boot(pt 2)
T423 MMD = 55um
GSD = 3.14
Dust = 85.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
00-922
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4877



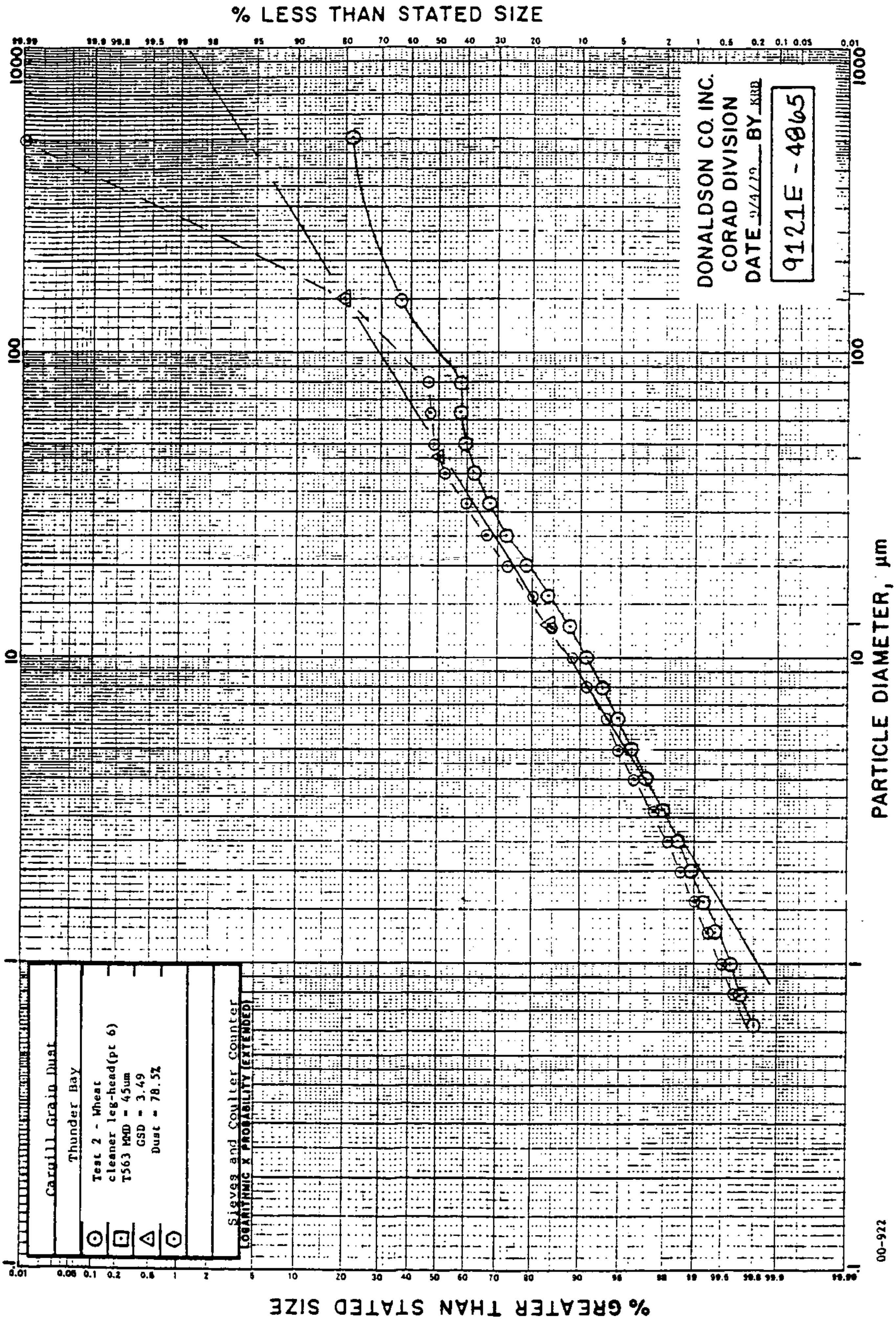
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/5/79 BY KRB
9121E-4876
Cargill Grain Dust
Thunder Bay
Test 2 - Wheat
receiving leg-head(pt 6)
T464 MMD = 35um
GSD = 3.31
Dust = 93.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



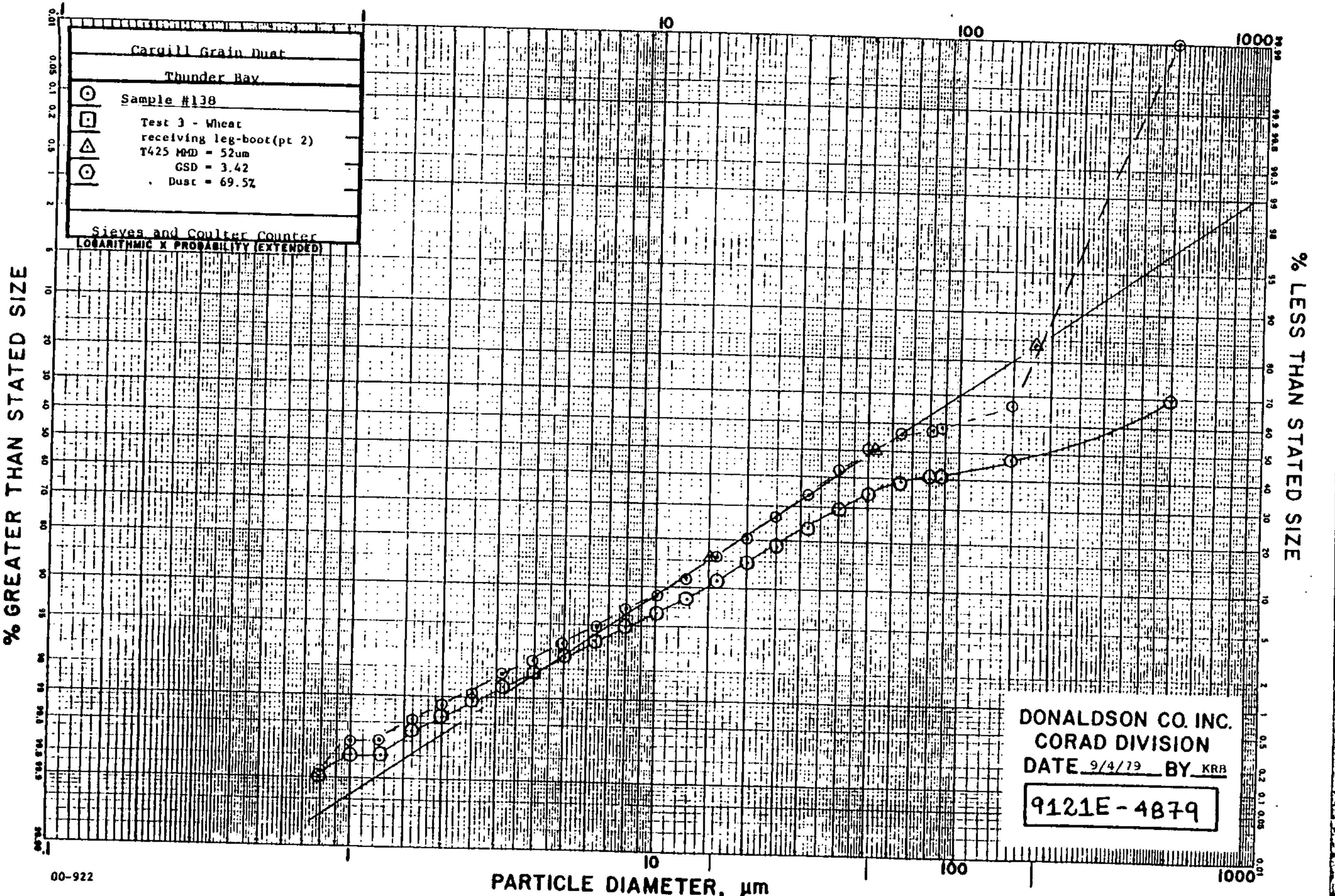
Cargill Grain Dust
Thunder Bay
Test 2 - Wheat
cleaner leg-boot(pt 2)
T523 MMD = 100um
GSD = 3.99
Dust = 69%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E - 4871
00-922

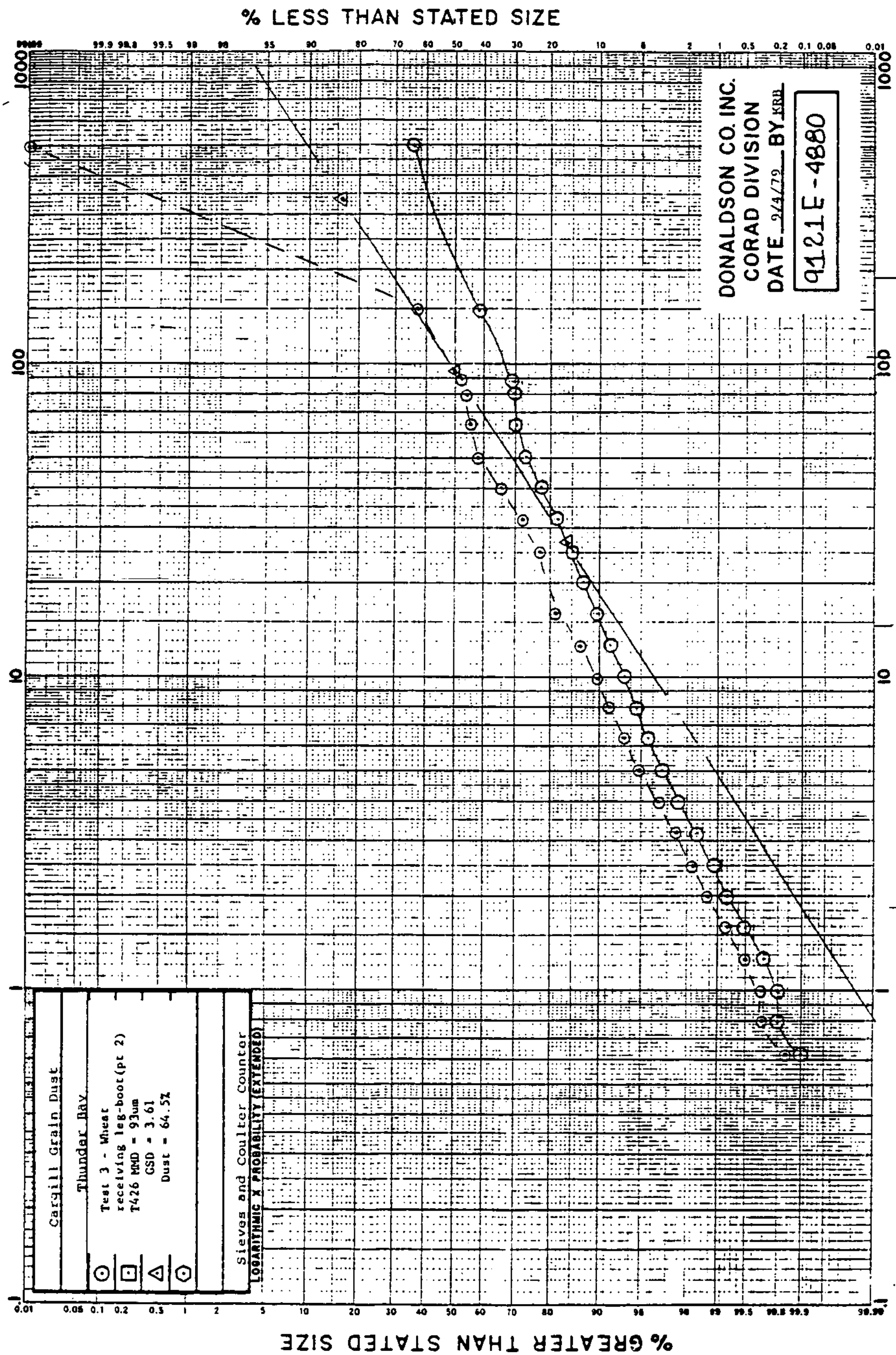


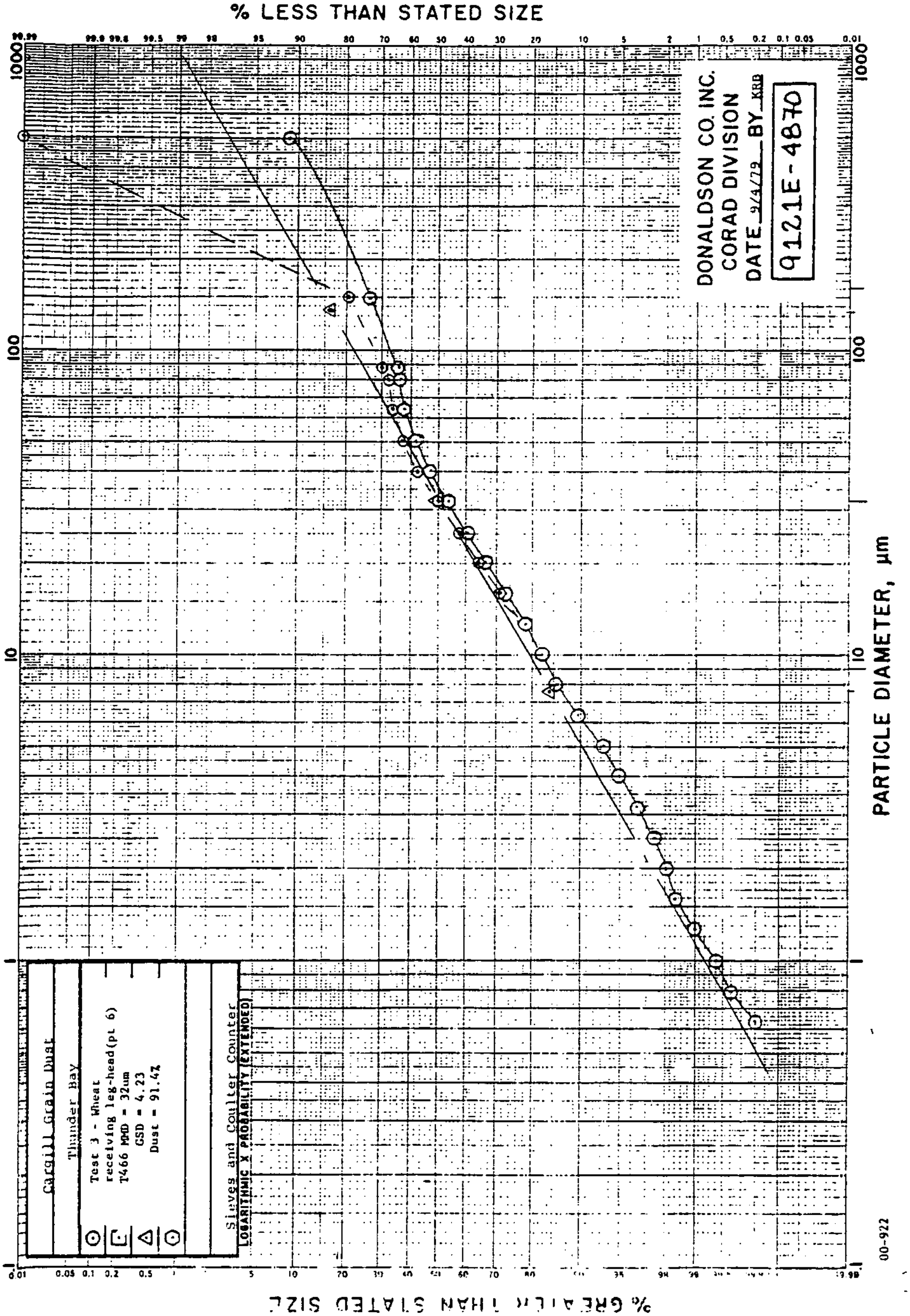
Cargill Grain Dust
Thunder Bay
Test 2 - Wheat
cleaner leg-boot(pt 2)
T524 MMD = 105um
CSD = 3.01
Dust = 63%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4872
00-922



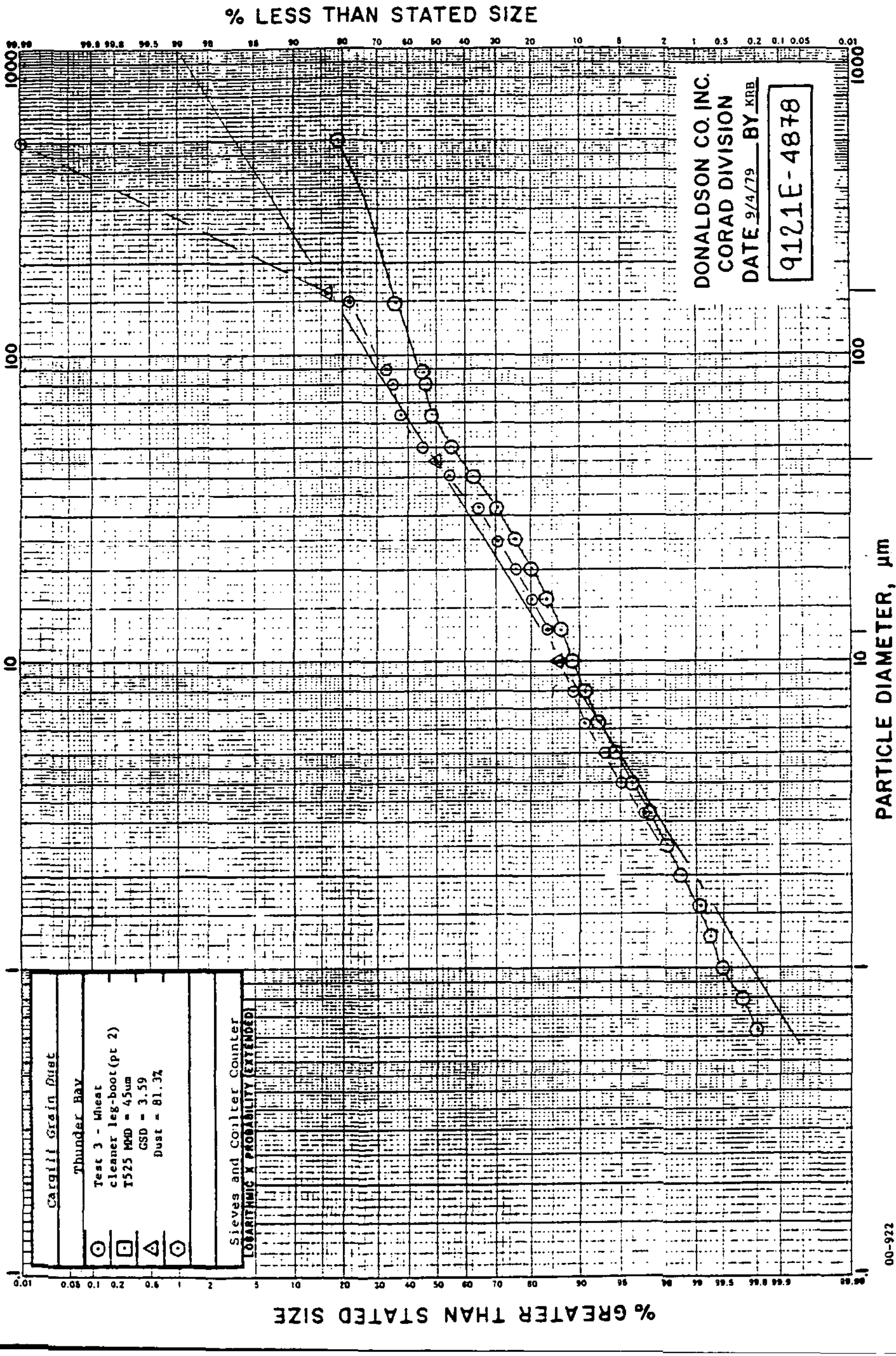
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E - 4865
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 2 - Wheat cleaner leg-head(pt 6)
TS63 MMD = 45um
GSD = 3.49
Dust = 78.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922


Cargill Grain Dust
Thunder Bay
Sample #138
Test 3 - Wheat
receiving leg-boot(pt 2)
T425 MMD = 52um
GSD = 3.42
Dust = 69.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4879
00-922

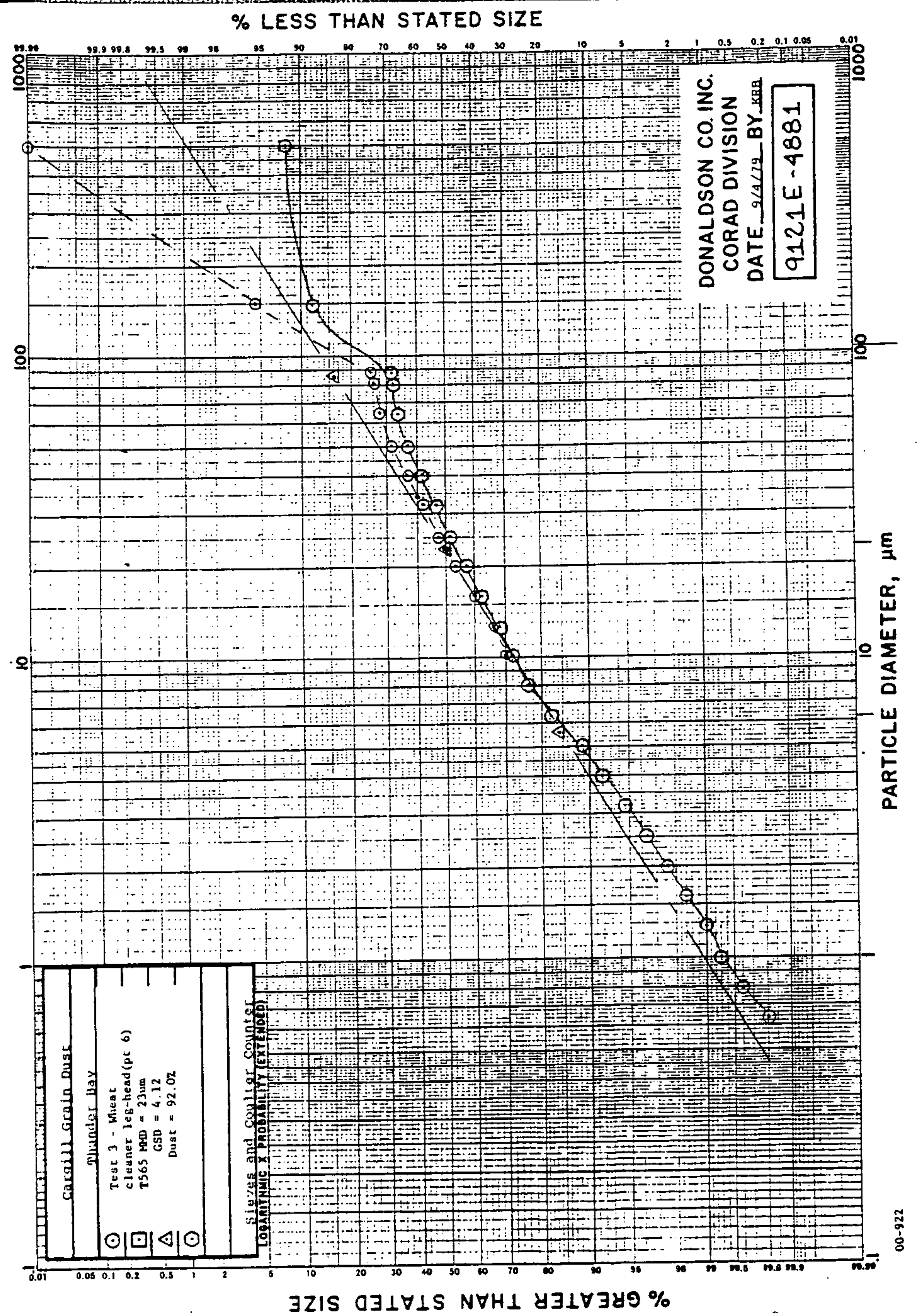

% LESS THAN STATED SIZE
PARTICLE DIAMETER, μm
% GREATER THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4880
Cargill Grain Dust
Thunder Bay
Test 3 - Wheat
receiving leg-boot(pt 2)
T426 MMD = 93um
GSD = 3.61
Dust = 64.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



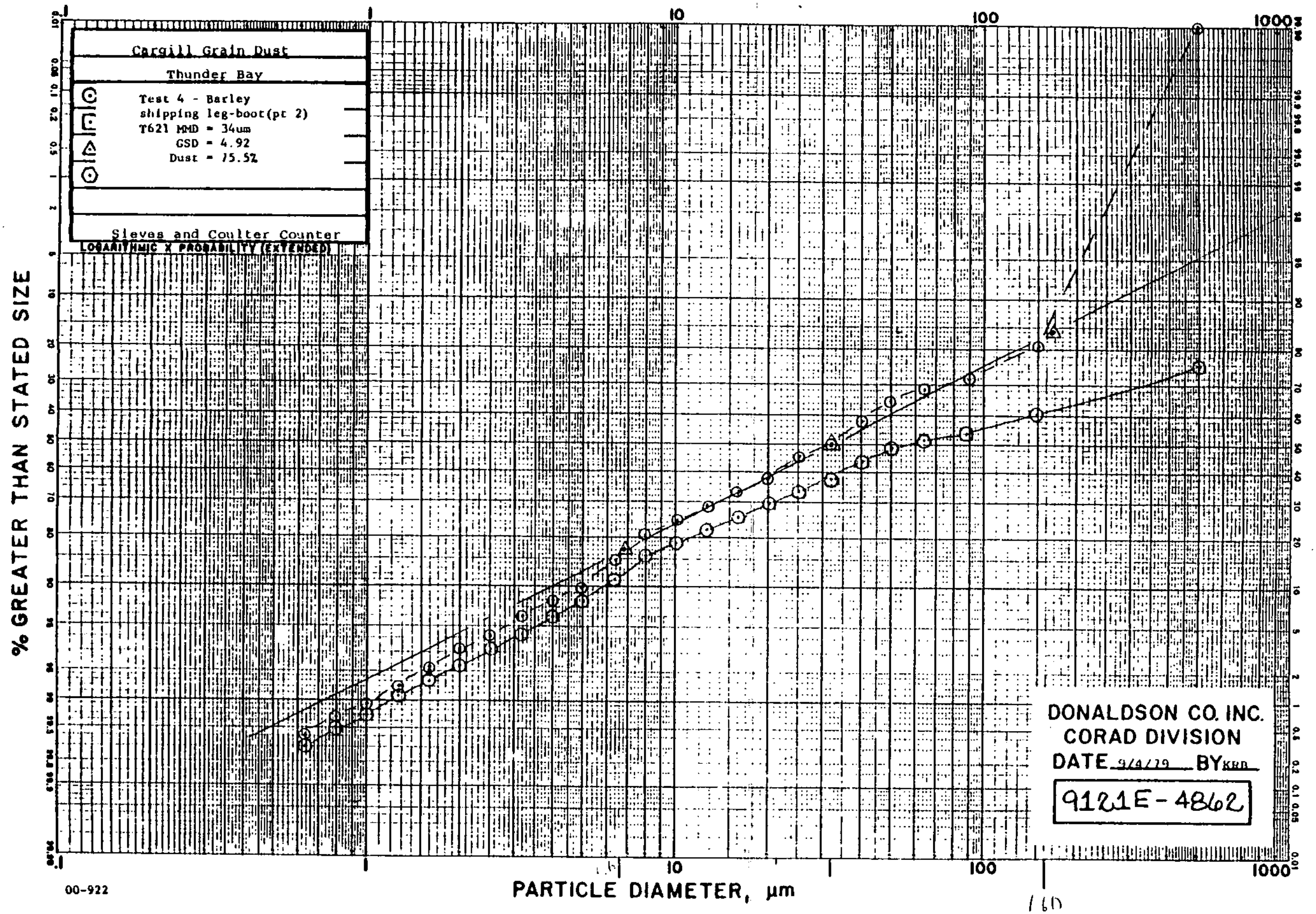
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4870
PARTICLE DIAMETER, µm
1000
100
10
Cargill Grain Dust
Thunder Bay
Test 3 - Wheat
receiving leg-head(pt 6)
T466 MMD = 32um
GSD = 4.23
Dust = 91.4%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

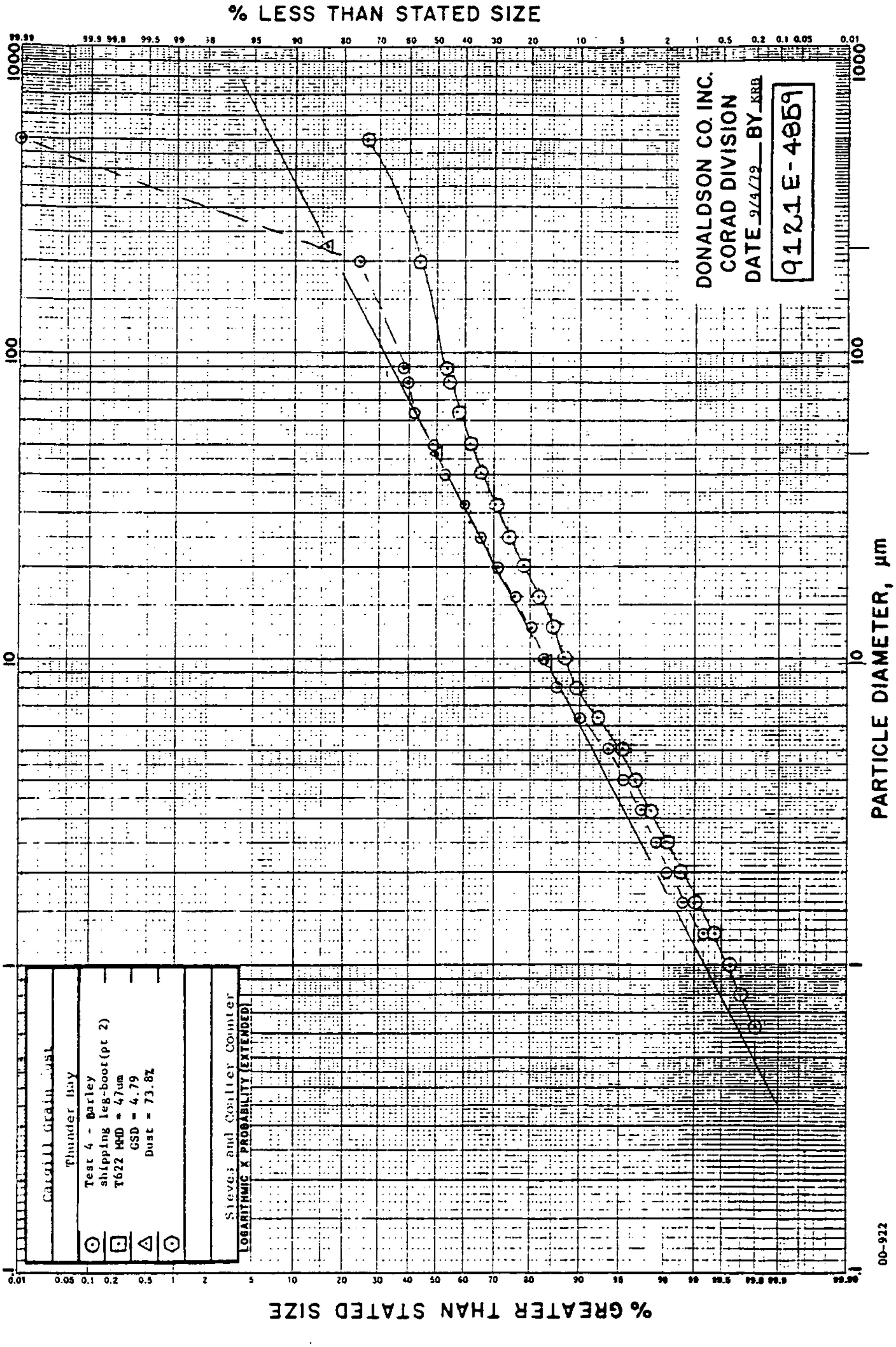


% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4878
Cargill Grain Dust
Thunder Bay
Test 3 - Wheat
cleaner leg-boot (pt 2)
T525 MMD = 45um
GSD = 3.59
Dust = 81.3%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922

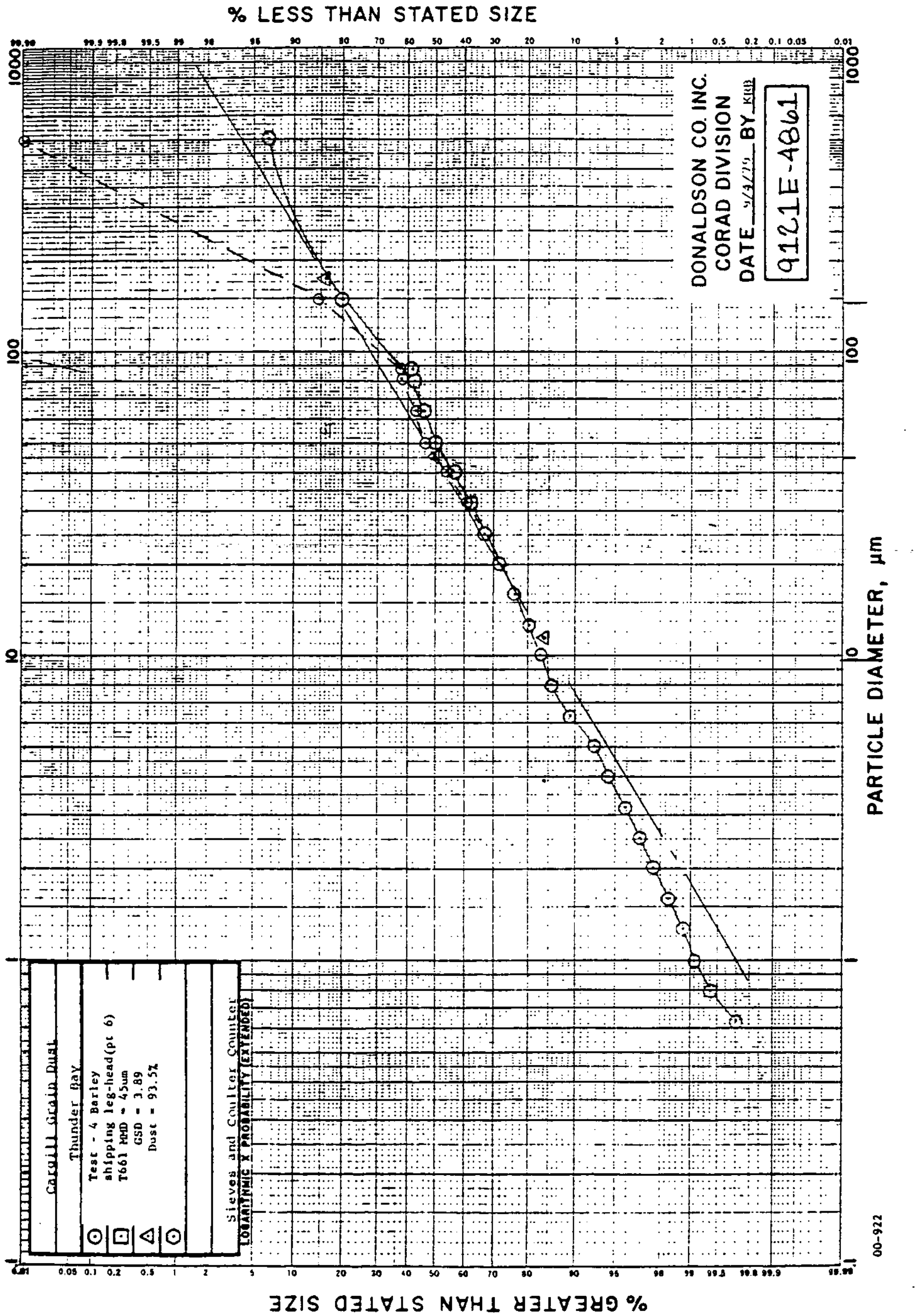


% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4881
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 3 - Wheat
cleaner leg-head (pt 6)
T565 MMD = 23um
GSD = 4.12
Dust = 92.0%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922

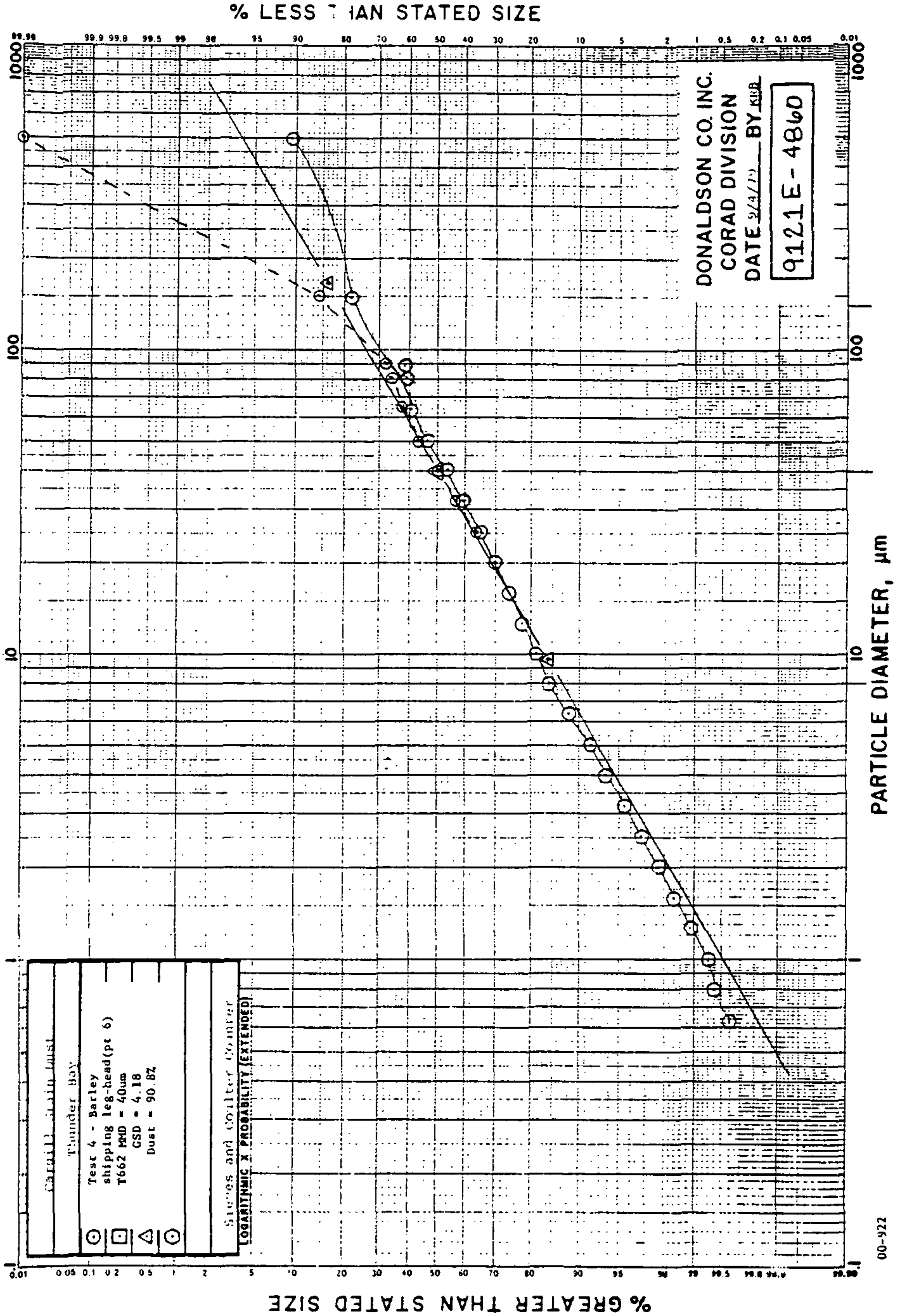

Cargill Grain Dust
Thunder Bay
Test 4 - Barley
shipping leg-boot(pt 2)
T621 MMD = 34um
GSD = 4.92
Dust = 75.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
.1
1
10
100
1000
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4862
00-922



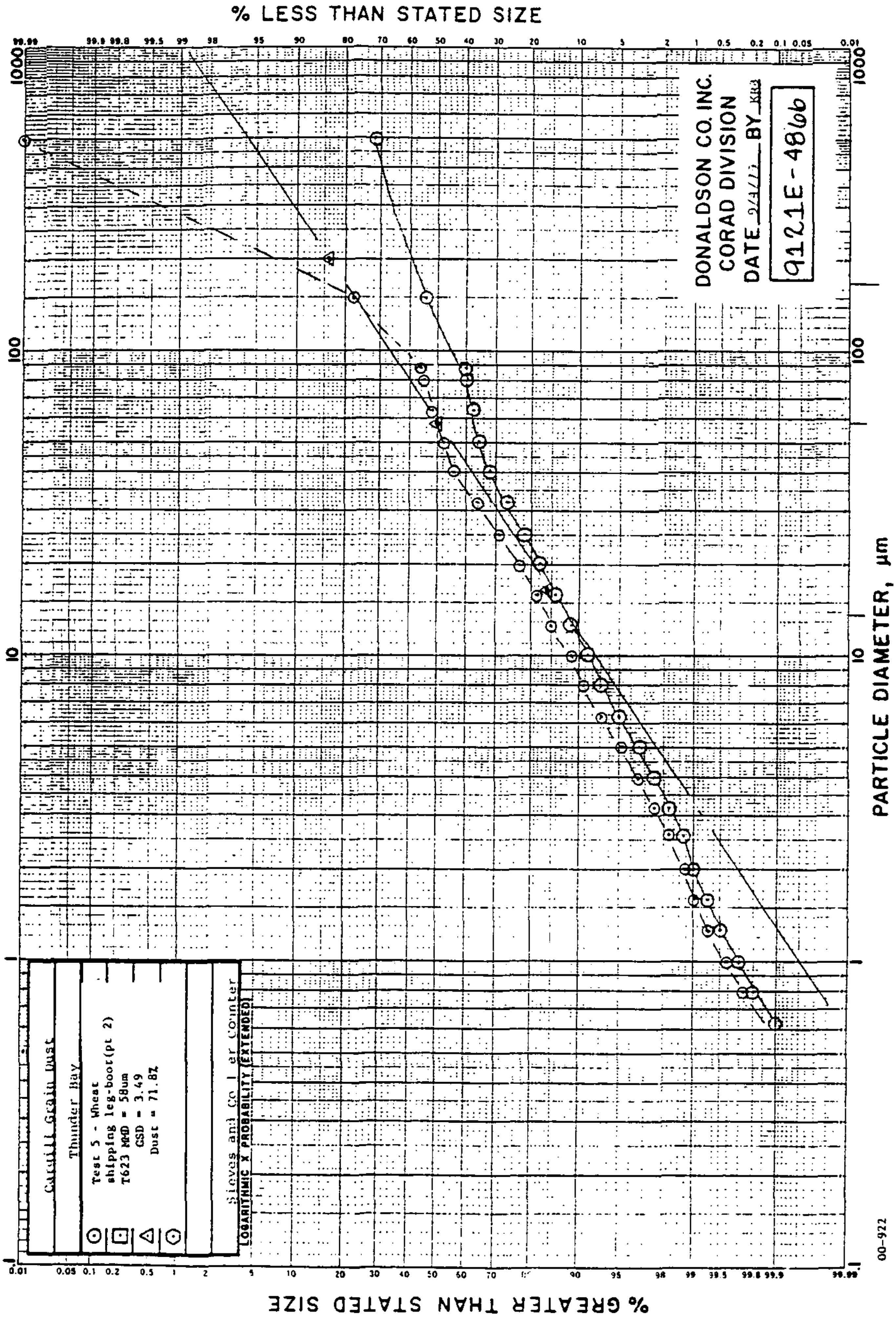
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121 E-4859
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 4 - Barley
shipping leg-boot(pt 2)
T622 MMD = 47um
GSD = 4.79
Dust = 73.8%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



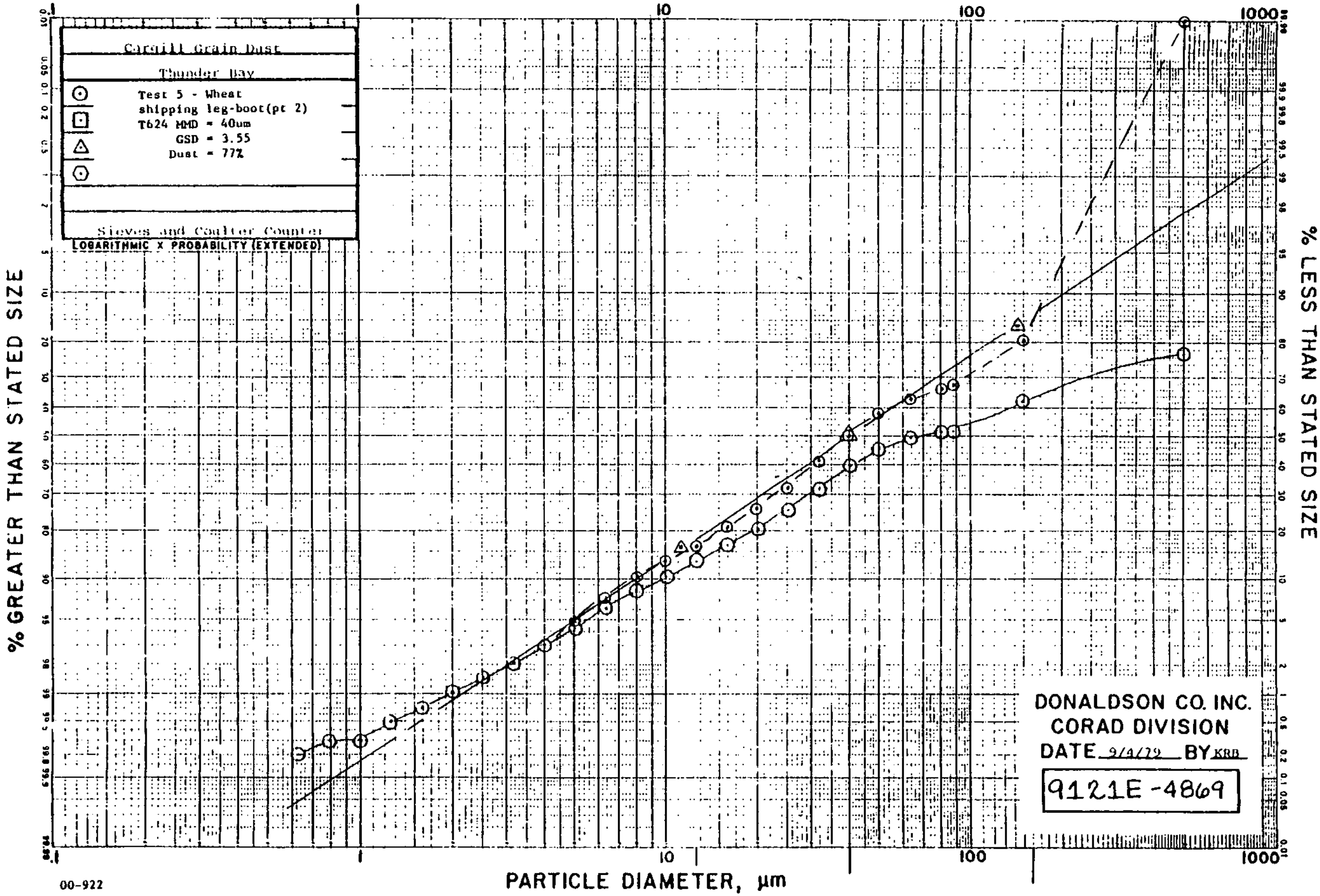
% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4861
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test - 4 Barley
shipping leg-head(pt 6)
T661 MMD = 45um
GSD = 3.89
Dust = 93.5%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



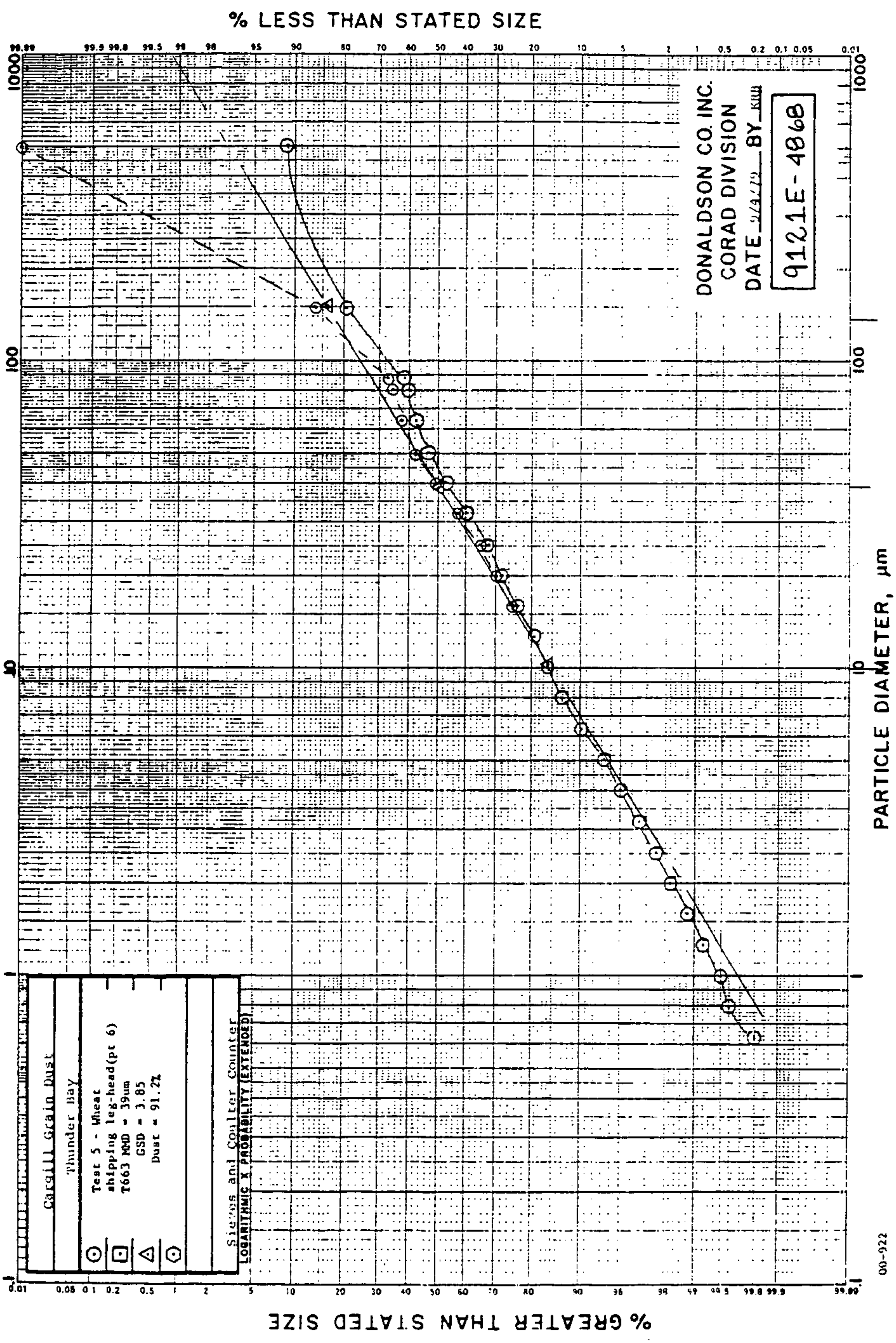
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 2/4/79 BY KUB
9121E-4860
Cargill Grain Dust
Thunder Bay
Test 4 - Barley
shipping leg-head(pt 6)
T662 MMD = 40um
GSD = 4.18
Dust = 90.8%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



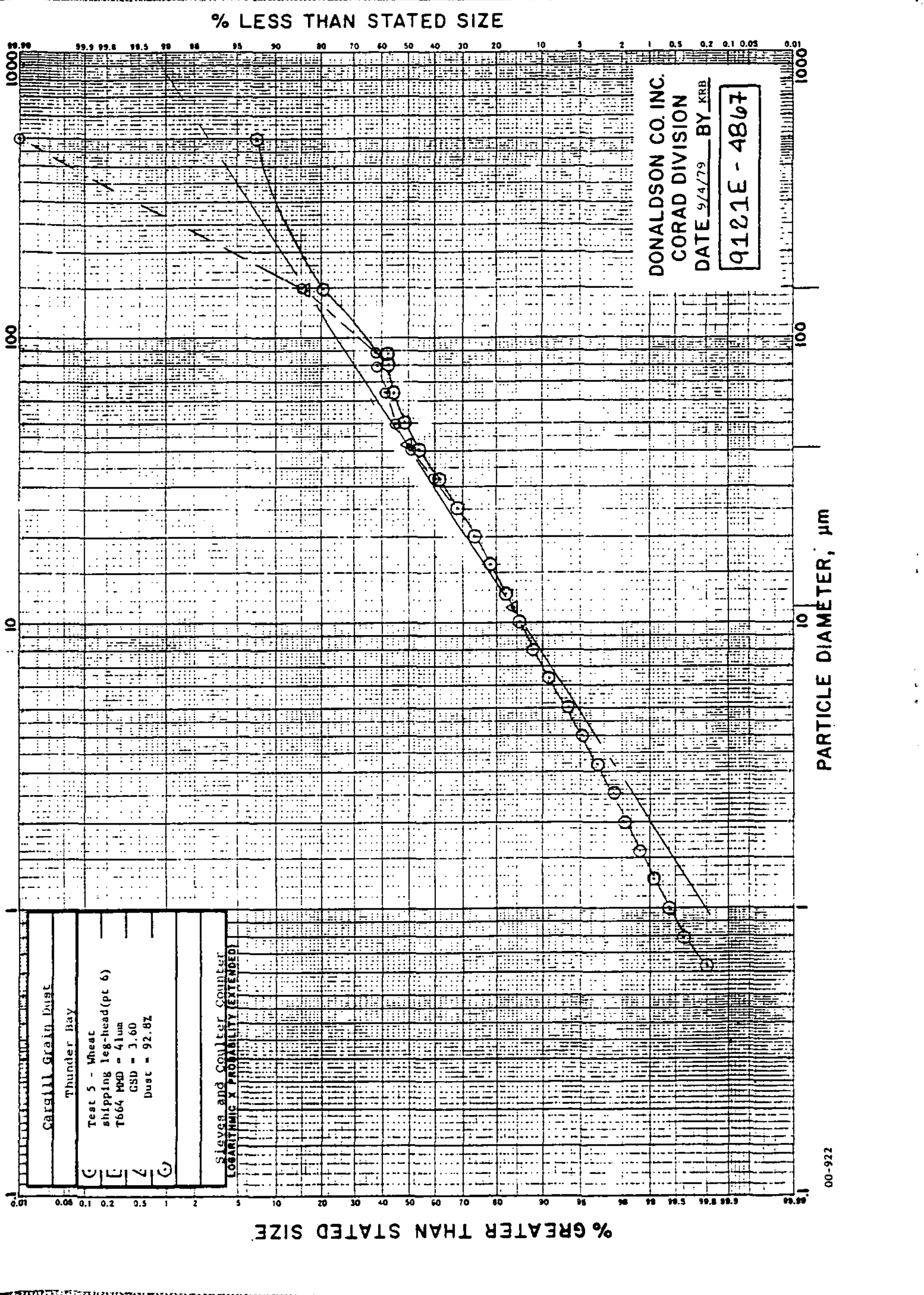
% LESS THAN STATED SIZE
% GREATER THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/77 BY KRG
9121E-4866
Cargill Grain Dust
Thunder Bay
Test 5 - Wheat
shipping leg-boot(pt 2)
T623 MMD = 58um
GSD = 3.49
Dust = 71.8%
Sieves and Co l er Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
00-922



Cargill Grain Dust
Thunder Bay
Test 5 - Wheat
shipping leg-boot(pt 2)
T624 MMD = 40um
GSD = 3.55
Dust = 77%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
% LESS THAN STATED SIZE
PARTICLE DIAMETER, µm
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E-4869
00-922



% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE BY
9121E-4068
PARTICLE DIAMETER, μm
Cargill Grain Dust
Thunder Bay
Test 5 - Wheat
shipping leg-head(pt 6)
T663 MMD = 39um
GSD = 3.85
Dust = 91.2%
Sievers and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922



% LESS THAN STATED SIZE
DONALDSON CO. INC.
CORAD DIVISION
DATE 9/4/79 BY KRB
9121E - 4867
PARTICLE DIAMETER, µm
Cargill Grain Dust
Thunder Bay
Test 5 - Wheat
shipping leg-head(pt 6)
T664 MMD = 41um
GSD = 3.60
Dust = 92.8%
Sieves and Coulter Counter
LOGARITHMIC X PROBABILITY (EXTENDED)
% GREATER THAN STATED SIZE
00-922