

**AIR DISPERSION MODELING  
AND THE REGULATORY PROCESS**  
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**Abstract**

Air dispersion modeling is becoming a significant part of the regulatory process in many states. Most states require all new facilities to obtain a permit prior to construction. Part of this permit application is to demonstrate that once the facility is in operation it will be in compliance with air quality standards for all regulated pollutants. Since it is impossible to measure air quality impacts of a future source, air dispersion modeling is used. In addition to being used in the initial permitting process, modeling could also be used to determine the impact of sources that wish to amend their abatement system, if this amendment will result in increased emissions. Also, any facility that receives a complaint will be evaluated to determine whether they are in violation of the air quality standards. At this point, the regulator could use air dispersion modeling to determine if the facility is in compliance. For all of these cases it is essential to have a model that will accurately predict the concentration of pollutants downwind from the source. One particular model being used for this purpose is the Industrial Source Complex (ISC) Screen2. However, the use of Screen2 results in inaccurate predictions of downwind concentrations. Therefore, a model that will accurately predict downwind concentrations when compared to ISC Screen2 is sought. This paper will describe a dispersion model that more accurately predicts downwind concentrations of particulates from agricultural operations. Both ISC Screen2 and the proposed model, Classical Gaussian Dispersion (CGD), are based upon the Gaussian diffusion equations.

**Introduction**

The U.S. concern for air quality can be traced back to 1955 when the 84th Congress passed Public Law 159. This law authorized the Federal government under the authority of the U.S. Department of Health, Education and Welfare "to get involved in all the phases of air pollution control". (DeMarrais, 1969) The Clean Air Act of 1963 gave the Federal government the power to control any pollution which could threaten the health and welfare of people. This Act also provided additional funding for the investigation of meteorological events related to air pollution problems. "The Air Quality Act of 1967 called for the designation of Air Quality Control Regions and

empowered state governments to adopt and enforce standards to control air pollution." (DeMarrais, 1969) The US EPA was created in 1970. Many states created State Air Pollution Regulatory Agencies (SAPRAs) in the early 1970's. The SAPRA for Texas was the Texas Air Control Board, more recently it is known as the Texas Natural Resource Conservation Commission (TNRCC). The process of regulating air pollution evolved into the following:

- (1) Federal enabling legislation passed the congress and signed by the President.
- (2) EPA personnel integrated federal legislation, issued guidance and delegated authority to SAPRAs, and provided insight to state air pollution regulatory processes.
- (3) SAPRAs obtained their enabling legislation from their respective state legislators and Governors. The SAPRAs sought delegation of regulatory authority from EPA utilizing State Implementation Plans (SIPs). Once a SAPRA was delegated authority, the SAPRA regulates air pollution from all sources in that state subject to oversight from EPA.
- (4) Under a congressional mandate, EPA reviewed the air pollution regulatory process. As a consequence of these reviews, periodic Federal Clean Air Act (FCAA) amendments were passed.

The two most recent and extensive acts are the Federal Clean Air Act (FCAA) of 1977 and 1990 (Cooper and Alley, 1994).

The 1990 FCAA amendments included a funding mechanism for SAPRAs. All major sources were requested to pay Title V emission fees of \$25 (plus) per ton of annual emissions. A major source is defined as one that emits more than 100 tons of a criteria pollutant in one year. The 4000 (plus) major sources in Texas would generate in excess of \$60 million per year. These funds must be used for air pollution regulation in the state. In addition, the FCAA amendments require all major sources to obtain a Federal Operating Permit (FOP). In order to comply with the FOP requirements, the TNRCC Air Quality Division had to expand from 400 employees to more than 1100.

The economic burden of Title V emission fees and FOPs increased the need to "quantify air pollutant concentrations and rates of release of pollutants into the air from sources". (Wright, 1994) Quantifying pollutant emission rates can be accomplished by source sampling. Source sampling is the "measurement of gas flow rate, physical characteristics, composition and pollutant concentration in exhaust gas streams leaving a process, factory, chimney, or ventilation system and entering the atmosphere". (Wright, 1994) A measurement of the impact of emission rates is ambient sampling. Ambient sampling refers to "the measurement of outdoor air pollutant levels, generally in attempts to characterize fairly broad area pollutant levels". (Wright, 1994) In order to compute the results of source sampling with ambient sampling or vice-versa, dispersion modeling

is required. Given measured emission rates, dispersion modeling can be used to evaluate downwind ambient concentrations. Given measured downwind ambient concentrations, dispersion modeling can be used to estimate emission rates.

The FCAA of 1970 required EPA to establish National Ambient Air Quality Standards (NAAQS) for criteria pollutants. The EPA developed a list of six criteria pollutants that have threshold values. This list consists of Sulfur dioxide, Ozone, Nitrogen dioxide, Carbon monoxide, Lead, and Fine particulate matter. Fine particulate matter refers to particles that are in the size range of 10 microns or less (PM10). The NAAQS for PM10 is  $150 \mu\text{g}/\text{m}^3$  - 24 hour average. The NAAQS are those standards that deal with concentrations of pollutants in the outdoor atmosphere (Cooper and Alley, 1994). "Each of the standards relates to a specific chemical element or compound except those for suspended particles." (Chow, 1995) Therefore, the areas targeted for compliance are set up to encompass communities throughout the United States. Most SAPRAs have monitoring stations in these areas that are operated on a 24 hour basis. If any one of these sampling periods yields a concentration higher than the NAAQS, this is considered an exceedance. Any areas that are found to be out of compliance are considered "nonattainment areas". Therefore, the main purpose of the NAAQS are to identify these nonattainment areas. A nonattainment area is one that has more than three exceedances of the NAAQS in three years. If four exceedances occur in one week, this area can be classified as a nonattainment area. The severity of nonattainment is determined by the number of exceedances. Once classified as a nonattainment area, all industry in that area will be subjected to reduced allowable emissions through the permitting process and will be required to install additional controls. This procedure is aimed at reducing the "ambient" level of pollutants in the area.

Permitting is necessary to ensure that facilities are operating within acceptable emission factor limits. (Goodin, 1981) The FOP program requires that all existing major sources must have a permit to operate. The FOP program also requires that any new major sources obtain a permit prior to construction. "Part of the permit application is to show that the new facility as completed and operating will not violate the air quality standards for each regulated pollutant. Since it is not possible to make measurements of resulting air quality for a facility that has not yet been constructed, air quality dispersion modeling is about the only way to estimate this future impact." (Turner, 1994)

All facilities with FOPs are required to have their permit reviewed every five years. In many states, the permitting process for a cotton gin involves engineering analyses only. (Figure 1.) These analyses are performed by a consultant

and/or permit engineers and involves determining allowable emission rates utilizing emission factors and/or process weight tables along with the gins processing rate. The performance characteristics of various air pollution abatement equipment is an integral part of the engineering analyses.

Some states are in the process of implementing a new permitting process. This process involves air dispersion modeling results in addition to engineering analyses. (Figure 2.) Once the permit application has been completed, the applicant is required to "conduct public notice of the proposed construction". (TACB, 1992) This information must be announced in the "public notice section of two successive issues of a newspaper of general circulation in the county where the proposed facility is to be located". (TACB, 1992) Following public notice, any interested parties "may submit written comments, including requests for public hearings". (TACB, 1992) If there is no public concern expressed or a request for a public hearing, the permit is granted. However, if a public hearing is requested, the applicant will need to have dispersion modeling results available to show that the facility as constructed will not violate air quality standards.

Once the permit has been granted, construction of the gin can take place. Any modifications in the ginning system that result in an increase in pollutant emissions must be reported to the SAPRA. Some states require prior approval by the SAPRA and subsequent permit amendments. An application for amendment must be submitted for engineering analysis. The remainder of the process is similar to that required in obtaining the initial construction permit. (Figure 3.) The future amendment process may include modeling in addition to the engineering analysis. (Figure 4.)

Enforcement is an essential element in the regulatory process. It is typically initiated by public complaints. Currently, if a complaint is made in relation to a cotton gin, a regulator must determine if the gin is in violation of the air quality standards. There are potentially two methods that can be used to determine whether a source of pollution (cotton gin) is in compliance with State Air Pollution Rules and Regulations:

(1) Opacity - The inspector can determine the opacity of all emitting points. It is assumed that the gin is not exceeding its permit allowable emission rate if no emitting point exceeds 20% opacity.

(2) SAPRA Judgement - In response to a complaint, the inspector may observe the operation and determine whether the gin is in compliance with appropriate rules and regulations. If in the inspectors judgement, the cotton gin is violating the nuisance standard, he or she may issue a notice of violation (NOV). The NOV will establish an appointment for a Formal Enforcement Conference (FEC).

The purpose of the FEC is to determine what the gin will be required to do in order to reduce their allowable emission rate.

If no violation is detected, the gin will continue to operate as usual. However, if a violation is detected, the gin will be forced to reduce their allowable emission rate. More effective and costly abatement devices will be required to reduce emission rates.. (Figure 5.) The future complaint process could adversely affect those grandfathered gins who did not need to have modeling results in order to obtain their initial permit. For example, once a complaint were reported, the regulator may use the gins permitted emission rates in a dispersion model to determine whether the gin is in compliance with air quality standards. This approach would replace the current methods of opacity or SAPRA judgement. (Figure 6.)

Since air dispersion modeling is becoming such a significant part of the regulatory process, it is essential to have a model that will accurately predict the concentration of pollutants downwind from the source. One particular model being used for this purpose is the Industrial Source Complex (ISC) Screen2, which is based upon Gaussian diffusion. (EPA, 1986) "The Industrial Source Complex (ISC) Dispersion Model combines and enhances various dispersion model algorithms into a set of two computer programs that can be used to assess the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. The ISC short-term model (ISCST) is designed to calculate concentration or deposition values for time periods of 1, 2, 3, 4, 6, 8, 12, and 24 hours. If used with a year of sequential hourly meteorological data, ISCST can also calculate annual concentration or deposition values. The ISC long-term model (ISCLT) uses statistical wind summaries to calculate seasonal (quarterly) and/or annual concentrations" (EPA, 12-1987) ISC was first developed in 1979. "The Industrial Source Complex (ISC2) dispersion models refer to restructured and reprogrammed versions of the original ISC models. The models were reprogrammed in order to improve the quality of the computer code, to improve the user interface, and to improve the end user documentation of the models." (EPA, 3-1992) In addition to ISCST and ISCLT, a simple model was created based upon the Industrial Source Complex. This simple model is known as Screen. "The Screen2 model includes several modifications and enhancements to the original Screen model, including updates to the code to ensure consistency with the dispersion algorithms in the Industrial Source Complex (ISC2) model." (EPA, 9-1992) Screen2 is known as a simple screening procedure. "The purpose of first applying a simple screening procedure is to conserve resources by eliminating from further analysis those sources that clearly will not cause or contribute to ambient concentrations in excess of short-term air quality standards or allowable concentration increments." (EPA, 10-1992)

All ISC programs are based upon Gaussian diffusion. The Gaussian model is the most popular basis for determining the impact of nonreactive pollutants (EPA, 1986). This model can be used to estimate the ground level concentrations downwind in the plume from a source with a specific emission rate. (Gifford, 1975) The Gaussian plume can be used to target a point source such as a factory smokestack and predict its concentration downwind. A coordinate system is incorporated where the origin is placed at the base of the smokestack with the  $x$  axis aligned in the downwind direction. "The contaminated air stream (normally called a plume) rises from the smokestack and then levels off to travel in the  $x$  direction and spread in the  $y$  and  $z$  directions as it travels. For Gaussian plume calculations the plume is assumed to be emitted from a point with coordinates  $(0,0,H)$  where  $H$  is called the effective stack height, which is the sum of the physical stack ( $h$ ), and the plume rise ( $\Delta h$ )." (De Nevers, 1995)

Turner (1994) listed the assumptions used in making air pollutant concentration estimates with dispersion models that are based upon the Gaussian model:

\* **Continuous emission rate** - The emission rate of pollutant in mass per time ( $Q$ ) is continuous and does not vary with time.

\* **Conservation of mass** - The mass of pollutant emitted from the source is assumed to remain in the atmosphere. None of the pollutant mass is lost at the ground surface through reaction, gravitational settling, or turbulent impaction. It is assumed that any of the released pollutant that is dispersed close to the ground surface by turbulent eddies is again dispersed away from the ground surface by other subsequent turbulent eddies (eddy reflection).

\* **Steady-State Conditions** - The meteorological conditions are assumed to persist unchanged with time over the period of transport (travel time) from source to receptor.

\* **Crosswind and Vertical Concentration Distributions** - It is assumed that the time averaged concentration profiles at any distance in the crosswind direction, horizontal, are well represented by a Gaussian, or normal, distribution and, similarly, concentration profiles in the vertical direction are also well represented by a Gaussian, or normal, distribution.

Several scientists have expressed opinions on the Gaussian Model assumptions: "Frequently the assumptions used in its derivation do not hold. An initial concentration of pollutant may exist. Emissions may vary with time. Pollutants may be absorbed at the ground. A wind field may change in time and space and vary with height. Inversion layers may exist. The diffusion constants are not necessarily constant, and those frequently used were experimentally determined as 10 min averages over open flat terrain. And diffusion may occur upwind at low wind

speed close to a source. Because of these conditions which may differ from those described by the assumptions used in deriving the Gaussian plume equation, care must be exercised in applying the Gaussian plume equation." (Veigle and Head, 1978)

"The dogmatic reliance on the overly simplistic Gaussian models in light of the greater success and generality of numerical approaches is a community-wide disgrace that has been perpetrated by "current wisdom" that is as archaic as the pre-computer computations which were used to develop the "wisdom". ... "It fails to emphasize that the Gaussian models are based on much more restrictive assumptions (e.g., straight line flow, no wind shear, constant meteorological conditions, etc.)." ... "It is hoped that the Review will serve in retrospect as the obituary for the overly simplistic Gaussian modeling that has forced over-conservatism on environmental planning and the resulting inefficiencies on industrial growth." (Skarlew, 1979)

One method to determine compliance with air pollution regulations is to measure the public exposure to criteria pollutants, and compare to a standard. Some SAPRA personnel are attempting to use the NAAQS as the property line emission limit (standard). If the property line concentration is greater than the NAAQS, the facility is not in compliance and must reduce its emission rate. To illustrate this for cotton gins, in which the primary pollutant is PM<sub>10</sub>, the predicted downwind concentration must not exceed 150 µg/m<sup>3</sup>-24 hour average. In most cases, regulators will assume an upwind or background concentration of 20 µg/m<sup>3</sup>. This means that the predicted concentration must be less than 130 µg/m<sup>3</sup> to be in compliance. The NAAQS were not intended for use in evaluating the effectiveness of controls. (Chow, 1995) They were originally intended to ensure that ambient concentrations of pollutants were at levels low enough to protect public health. Monitoring sites are operated in populated areas to determine ambient levels of pollutants. Cotton gins are generally located in rural areas. Consider the two potential scenarios (Figure 7 & Figure 8) where the NAAQS could be used for enforcement. The use of NAAQS as the property line emission limit for all situations inappropriate. Figures 7 and 8 depict two enforcement scenarios. The public depicted by the grade school in figure 7 is not affected by the emission of particulate from the gin. A policy of requiring the gin to reduce its emission rate so that the concentration at the property line is less than 130 µg/m<sup>3</sup> is not the intent of the FCAA. However, if the public were located on the property line (Figure 8) it is reasonable to impose a property line concentration limit of 150 µg/m<sup>3</sup>.

An alternative to imposing a property line emission limit utilizing the NAAQS could be to limit the public exposure at the nearest point downwind. With this policy, the allowable emission rate would be determined by utilizing

the NAAQS public exposure limit at nearest point of public exposure. In figure 7, this limit would be imposed 2.5 miles downwind. This policy would achieve the intended purpose of the NAAQS. This policy would be used in addition to establishing allowable emission rates using published emission factors a process weight tables.

Source Performance Standards could be used as an alternative to replace the process of using the NAAQS as an enforcement tool. These are federal standards that apply directly to emissions of pollutants from specific industrial sources and are written in terms of mass emissions per unit of time or unit of production. This type of standard is directly related to the current regulatory methods already in practice which utilize emission factors and process weight tables. Presently, in the Title 40 Code of Federal Regulations, there is a chapter on Standards of Performance for New Stationary Sources. These standards of performance are derived from actual field tests at a number of industrial plants, and are numerous because of the variety of sources. (Cooper and Alley, 1994) Although this particular chapter (40 CFR 60) is for new sources, a standard for cotton gins could be derived in the same manner. Once a standard is developed, it could be adopted into the Code of Federal Regulations for future use in permitting cotton gins.

The policy of using the NAAQS as a property line concentration limit places a severe burden on all industry and circumvents the permit allowables developed by the emission factor and process weight table methods. Since the NAAQS were developed for determining nonattainment areas, exceedances of the 150 µg/m<sup>3</sup> PM<sub>10</sub> standard downwind from a cotton gin, grain elevator, feedmill, rock crusher, asphalt plant, farm, or dirt road could result in a proliferation of nonattainment areas. The regulations for many facilities are based upon total suspended particulate (TSP) matter. In order to determine whether a gin is in compliance with the NAAQS, the PM<sub>10</sub> emission rate is required. For example, the current AP-42 emission factor for cotton gins is 2.24 pounds of dust per bale, which is based upon TSP. Most SAPRAs estimate that the fraction of PM<sub>10</sub> of particulate emitted by cotton gins is 50%. Herber (1988) reported that the fraction of PM<sub>10</sub> is 39%.

If some states do adopt the process of using ISC Screen2 to regulate cotton gins, other states will likely adopt this process also. "Increasing reliance has been placed on concentration estimates from models as the primary basis for regulatory decisions concerning source permits and emission control requirements." (EPA, 1986) According to the same EPA document, if a source is not clearly eliminated as a threat after the screening technique has been applied, then a more refined model must be used. If modeling is required, cotton ginners will be responsible for obtaining a consulting firm to model the source. The fee for having such modeling done could cost \$15,000. This could be an economic burden for cotton gins that may result

in many smaller gins going out of business. The downwind ground level concentration that is predicted with the current ISC Screen2 model appears to be overestimated by a factor close to 2.5. Any method used to model air quality should be conservative in nature. However, an extremely conservative prediction of property line concentrations used as a permitting tool could result in unjustified, mandated controls on an industry. This degree of conservatism is viewed as unnecessary in a model that is already conservative.

To use dispersion modeling in the permitting process will result in the following problems:

- (1) The current method of using ISC Screen2 results in inaccurate (excessively high) predictions of downwind concentrations;
- (2) SAPRA personnel are attempting to use the NAAQS as a property line emission limit. (The NAAQS were not developed for this purpose);
- (3) As a result of (1) above, the current methods of determining the permit allowable emissions from cotton gins are in jeopardy.

### Objectives

EPA (1986) states that, "it should be recognized that under some sets of physical circumstances and accuracy requirements, no present model may be appropriate. Thus, consideration of these factors should not lead to selection of an inappropriate model." "It should not be construed that the preferred models identified here are to be permanently used to the exclusion of all others or that they are the only models available for relating emissions to air quality. The model that most accurately estimates concentrations in the area of interest is always sought."

EPA (1986) states that, "The 1980 solicitation of new or different models from the technical community and the program whereby these models are evaluated, established a means by which new models are identified, reviewed and made available in the guideline. There is a pressing need for the development of models that more realistically simulate the physical and chemical process in the atmosphere and that more reliably estimate pollutant concentrations. Thus, the solicitation of models is considered to be continuous."

The goal of this research is to develop a model that can be used by SAPRA permit engineers whereby the results can be used to **support** the current methods of regulating air pollution from cotton gins. This research has the following specific objectives:

- (1) To develop a model that can be used to more accurately predict downwind concentrations when compared to ISC Screen2.
- (2) To determine an appropriate time average concentration equation that can be used to estimate the 24-hour concentrations of  $PM_{10}$ .

### Literature Review

In 1661, Evelyn (DeMarrais, 1969) suggested that industries locate their operations 5-6 miles outside of London so that better dispersal of the pollutants would occur before reaching London. The very early ideas of exchange or diffusion theories were "based on Fourier's treatment of the conduction of heat. Fourier's theory of conduction was first applied to the case of diffusion by the physiologist Fick. Thus, by analogy with Fourier's law of heat conduction, one may state Fick's law of molecular diffusion, *diffusion of material is in the direction of decreasing concentration and is proportional to the concentration gradient.*" (U.S. Weather Bureau, 1955) DeMarrais (1969) discussed work by Fick (1855) and Smith (1859), he recognized that Fick's law of molecular diffusion is known as Fickian diffusion and is also the basis for the K-theory of diffusion. Smith became the first modeler of atmospheric diffusion when he calculated the "average concentration of carbonic acid in the mixed layer of air over London".

Turbulence in the atmosphere, which varies greatly in time and space, performs a major role in the understanding of atmospheric diffusion. Turbulent motion is extremely complex, even in the controlled and simplified conditions of the laboratory or wind tunnel. When other complicating factors are added, which occur naturally in the open air, it is not surprising that the whole problem of atmospheric diffusion contains many features which are relatively uncontrollable. (Pasquill, 1962) "The spreading of a bent-over plume is due to factors other than simple molecular diffusion. Recall that any fluid in turbulent flow contains eddies (or swirls), which are macroscopic random fluctuations from the 'average' flow. The combined effect of many eddies of various sizes is to broaden and dilute the plume." (Cooper and Alley, 1994)

According to DeMarrais (1969), early major contributors to the field of atmospheric diffusion were Taylor (1915) and Richardson (1920). Taylor presented his theory on eddy motion while "Richardson discussed eddy diffusivity based on observations of the dispersal of smoke and parachutes". (DeMarrais, 1969) "In 1932, Sutton presented his theory of eddy diffusion. Using field experiments over long distances, he reported that the Fickian law did not hold; he assumed a Gaussian distribution." (DeMarrais, 1969) "Gaussian diffusion formulas appear in the early works by Roberts (1923). They were derived from K-theory, and were included in the papers by Sutton (1932) and Frenkiel

(1953), based on statistical theory. However, they were first used by Cramer (1957) and Hay and Pasquill (1957), as mathematical diffusion models to correlate empirical data." (Gifford, 1975)

In 1936, Bosanquet and Pearson "developed equations for calculating diffusion from a continuous line source and a continuous point source". In 1947, Davies "developed the equations of diffusion and boundary conditions with: 1) wind speed and diffusivity constant with height; 2) wind speed and diffusivity variable with height; 3) wind speed variable with height and zero lateral diffusivity; and 4) wind speed variable with height and appreciable lateral diffusion. He also introduced a lateral diffusion factor which provided an improvement to the Sutton equations of the 1930's." (DeMarrais, 1969) Throughout the 1930's, 40's, and 50's many papers were written that depicted several variations of atmospheric diffusion theories.

In 1957, Frenkiel presented "one of the earliest works demonstrating how a mathematical model of downwind dispersion could be used with a high speed computer". (DeMarrais, 1969) Since that time there have been numerous models developed that are operated with the use of computers, the majority of which are based upon the Gaussian diffusion equations. "The passage of the Clean Air Act Amendments in August 1977 has placed additional emphasis on air quality simulation modeling as an aid to assessing air quality impact. In May 1973 six air quality simulation models were placed on a nationwide computer network for execution by users. This system of programs was called UNAMAP (User's Network for Applied Modeling of Air Pollution). In March 1978, five air quality simulation models were added to UNAMAP." (Turner, 1979) "Industry and control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes. In the 1977 Clean Air Act, Congress mandated such consistency and encouraged the standardization of model applications. The Guideline of Air Quality Models was first published in April 1978 to satisfy these requirements by specifying models and providing guidance for their use. This guideline provides a common basis for estimating the air quality concentrations used in assessing control strategies and developing emission limits." (EPA, 1986)

Today there are over forty different models presented in the Guideline of Air Quality Models. One section in the guideline refers to screening techniques for stationary sources as an "acceptable approach to air quality analyses". These techniques can be used for new major or minor sources or modifications subject to new source review regulations, and existing sources of air pollution, including toxic air pollutants. The screening technique that is referenced is ISC Screen2. "A relatively large degree of 'conservativeness' is incorporated in that screening procedure to provide reasonable assurance that maximum concentrations will not be underestimated." (EPA, 1986)

Any method used to model air quality should be conservative in nature. However, an extremely conservative prediction of property line concentrations used as a permitting tool could result in unjustified, mandated controls on an industry. Therefore, it is essential that a model exist for the purpose of accurately predicting downwind concentrations when compared to ISC Screen2.

### Procedures

The following is a summary description of the instructions provided by the EPA in the document, Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised: (U.S. EPA, 1992)

The model operates with three files:

- (1) source information,
- (2) model options, and
- (3) meteorological data.

The source information required includes the following:

- \* Pollutant emission rate
- \* Stack height
- Stack gas temperature, stack inside diameter, and stack gas exit velocity
- \* Location of the point of emission with respect to surrounding topography, and the character of that topography
- Detailed description of all structures in the vicinity of the stack in question
- \* Similar information from other significant sources in vicinity of the subject source.

For meteorological data there are three different classes to choose from:

- (1) full meteorology,
- (2) stability class, and
- (3) stability class with selected wind speed.

ISC Screen2 can only be used to predict concentrations from a single point source. "Sources that emit the same pollutant from several stacks with similar parameters that are within about 100m of each other may be analyzed by treating all of the emissions as coming from a single representative stack." Screen2 is based on the following Gaussian dispersion equation for determining ground-level concentrations under the plume centerline:

$$C_{10} = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left(-\frac{1}{2} \frac{y^2}{\sigma_y^2}\right) \left\{ \exp\left(-\frac{1}{2} \frac{(z-H)^2}{\sigma_z^2}\right) + \exp\left(-\frac{1}{2} \frac{(z+H)^2}{\sigma_z^2}\right) \right\} \quad (1)$$

where

- $C_{10}$  = ten minute concentration ( $\mu\text{g}/\text{m}^3$ ),
- $Q$  = emission rate ( $\mu\text{g}/\text{s}$ ),

$\pi$  = 3.141593,  
 $u$  = stack height wind speed (m/s),  
 $\sigma_y$  = lateral dispersion parameter (m),  
 $\sigma_z$  = vertical dispersion parameter (m),  
 $z$  = receptor height above ground (m), and  
 $H$  = plume centerline height (m).

The first step of the modeling process is to calculate the normalized plume rise ( $u\Delta h$ ). To do so, the buoyancy flux parameter,  $F_b$  is calculated:

$$F_b = (g/4)v_s(ds)^2[(T_s - T_a)/T_s] \quad (2)$$

where

$g$  = acceleration due to gravity (9.806 m/s<sup>2</sup>),  
 $v_s$  = stack gas exit velocity (m/s),  
 $d_s$  = stack inside diameter (m),  
 $T_s$  = stack gas exit temperature (K),  
 $T_a$  = ambient air temperature (K) ( If no ambient temperature data are available, assume that  $T_a = 293K$ .),  
 and  
 $V = (\pi/4)(d_s)^2v_s$  = actual stack gas volume flow rate (m<sup>3</sup>/s).

To get the normalized plume rise ( $u\Delta h$ ):

$$\begin{aligned}
 u\Delta h &= 21.4(F_b)^{3/4} \text{ when } F_b < 55 \text{ m}^4/\text{s}^3 \text{ and} \\
 u\Delta h &= 38.7(F_b)^{3/5} \text{ when } F_b \geq 55 \text{ m}^4/\text{s}^3.
 \end{aligned} \quad (3)$$

The second step in the model is to obtain the actual plume rise ( $\Delta h$ ). These are calculated for a range of wind speeds ( $u = 1.0, 2.0, 3.0, 5.0$  and  $10\text{m/s}$ ) with the following equation:

$$u\Delta h = (u\Delta h)/u. \quad (4)$$

The third step is to compute the plume height ( $h_c$ ) that will occur during each wind speed by adding the respective plume rises to the stack height ( $h_s$ ):

$$h_c = h_s + \Delta h. \quad (5)$$

For a situation where the ambient temperature is equal to the exhaust temperature the plume rise is dominated by momentum. In this situation, the momentum rise is computed by two different equations and the one with the lower result is used. This will give the plume height. The two equations are for "Unstable or Neutral" and "Stable", respectively:

$$h_c = h_s + (3d_s v_s)/u \text{ and} \quad (6)$$

$$h_c = h_s + 1.5[(v_s)^2(d_s)^2 T_a / (4T_s u)]^{1/3} s^{-1/6}. \quad (7)$$

In Screen2 the concentration estimate ( $X$ ) can be found for each of the plume heights computed. This value is considered the maximum 1-hour ground-level concentration due to emissions from the stack in question. To obtain a concentration estimate for an averaging time

greater than one hour ( $X_p$ ), the 1-hour value ( $X$ ) is multiplied by an appropriate factor,  $r$ :

$$X_p = r X. \quad (8)$$

where

Averaging Time (r)	Multiplying Factor
3 hours	0.9 (+ .1)
8 hours	0.7 (+ .2)
24 hours	0.4 (+ .2)
Annual	0.08 (+ .02)

The preceding sequence of calculations are for a simple case that does not take into account downwash from buildings that might be in the near vicinity or the impact of elevated terrain. For these cases, the equations will differ slightly. (EPA, 1992)

Results obtained from modeling downwind concentrations of particulate from a cotton gin with ISC Screen2 are excessively high. A computer program referenced to as Classical Gaussian Dispersion (CGD), was developed to predict downwind concentrations in the plume. This allowed for direct comparison to ISC Screen2. CGD will follow the same procedures and calculations as those previously outlined from the EPA document, Screening Procedures for Estimating the Air Quality Impact of Stationary sources, Revised, with a couple of exceptions. The basis for both ISC Screen2 and the proposed CGD model is the Gaussian diffusion equation for determining ground level concentrations under the plume centerline. (Equation 1)

There are two differences in Screen2 and CGD. The differences are the dispersion parameter equations and the calculations used to obtain longer timed averages. However, CGD still compares quite well with Screen2. The major difference between the two models is that Screen2 predicts a 1-hour concentration while CGD predicts a 10-minute concentration.

The dispersion parameters  $\sigma_y$  and  $\sigma_z$  are integral parts of calculating concentration, as can be seen in Equation (1). Martin (1976) published the following dispersion equations:

$$\sigma_y = ax^b \text{ and} \quad (9)$$

$$\sigma_z = cx^d + f \quad (10)$$

where  $a, b, c, d,$  and  $f$  are constants that are dependent on the stability class and on the distance  $x$ . These are the dispersion equations that were used in CGD. These equations represent graphs of linear and near linear log-log plots. Screen2 uses the following, slightly different, dispersion equations:

$$\sigma_y = 465.11628 (x) \tan (TH) \quad (11)$$

where

$$TH = 0.017453293 (c - d \ln x) \text{ and} \quad (12)$$

$$\sigma_z = ax^b \quad (13)$$

Tests were run to compare the values of  $\sigma_y$  and  $\sigma_z$  obtained with the two different models.

The graphs used to derive the dispersion equations were developed from tests that were conducted in level, open terrain. The tests consisted of measuring short-time (10 minute) average concentrations. This means that the concentrations derived utilizing the dispersion equations shown above will give a 10 minute average. To obtain average concentration estimates beyond 10 minutes, Hino developed the following relationship (1968):

$$C_t = C_{10} (10/t)^5 \quad (14)$$

where

t = averaging time (min) and  
 $C_t$  = concentration for averaging time t  
 (Cooper and Alley, 1994).

The Hino Model has been validated for obtaining concentration estimates up to 5 hours. For example, once the CGD model has been used to predict the ten minute concentration ( $C_{10}$ ) from equation (1), Hino's relationship can be used to predict what the concentration estimate would be for averaging times of 1 to 5 hours. In Screen2, equation (8) is used to obtain a concentration estimate for a greater averaging time. This method multiplies the predicted value from Screen2 by an appropriate factor. The factor used is dependent on the desired averaging time. The factors vary for times of 3, 8, & 24-hours. These methods are the second way in which the two models differ. A method will be sought to extend Hino's relationship or develop a new one that will estimate a 24-hour concentration from the ten minute concentration ( $C_{10}$ ). Several equations may be used to accomplish this task. Research is being directed toward determining which equation and/or procedures would be the most appropriate to use.

### Cotton Gin Example

In order to make a direct comparison between ISC Screen2 and CGD, the following example was used: The source is a 28 bale-per-hour gin with all exhaust passing through forty 37-inch 1D-3D cyclones with a permit allowable emission factor of 1.12 pounds of PM10 per bale. This emission factor was calculated from AP-42. (EPA, 1985) The AP-42 emission factor for cotton gins is 2.24 pounds of dust (TSP) per bale. Utilizing the PM10 fraction of TSP of 50% yields a PM10 emission factor of 1.12 lbs per bale. The emission rate needed for ISC Screen2 and the proposed CGD model was calculated using the following equation:

$$ER = PR \times EF \times (454/3600) \quad (15)$$

where

ER = Emission rate (g/s),  
 PR = Processing rate (bales-per-hour), and  
 EF = Emission factor (lb/bale).

For this example, the emission rate (Q) was 4.1 g/s; the stack height was 10m; the stack inside diameter was 19 inches; and the stack exit velocity was 2037 feet per minute (yielding a flow rate of 1.89 m<sup>3</sup>/sec). Standard atmospheric conditions were assumed. The model option of "Rural" was selected and it was assumed that there were no structures in close proximity that would effect the concentration results.

Most gins do not operate continuously for 24 hours and there are times when the gin may be running but there is no material going through the system. The processing rate (PR) in equation 15 refers to the gins **rated capacity**. If a gin is rated for 30 bph but is typically operated at 20 bph, the regulator will calculate the daily emission rate based upon the 30 bph rated capacity. Hence, emission rates are typically overestimated. The following revised method is recommended:

$$ER = PR \times EF \times DO \times (454/3600) \quad (16)$$

where

ER = Emission rate (g/s),  
 PR = Processing rate (bales-per-hour)  
 EF = Emission factor (lb/bale), and  
 DO = Daily operation rate (hours/24 hours).

To illustrate the impact of this revised method consider the following example: A gin with a rated capacity of 28 bph operates for an average of 16 hours a day (DO = 16 hours/24 hours). The revised method will yield a daily emission rate of 2.6 g/s instead of the 4.1 g/s which is obtained using the regulators current method. Table 2 shows a range of emission rates (based upon an emission factor of 1.12 lbs of PM10/bale) that were obtained for gins rated at 10, 20, and 40 bales per hour and that operated for either 10, 16, or 20 hours a day. Table 3 shows the resulting concentrations obtained with Screen2 by utilizing these revised emission rates. The results shown are at 1000 meters downwind.

### Analysis of Various Abatement Control Strategies

Five alternative air pollution control systems (BBACT, BACTD0, BACTD1, BACTD2, and BACTD3) were defined. For each of the five gin plant categories, the associated investment costs resulting from the implementation of each air pollution control system was estimated. Each of these systems were developed on the basis that each system would achieve an associated level of air pollution control. The level of control represented by emission factors are dependent upon the specific equipment included in each design. There are different emission factors for picker and stripper type gins. (Table 4) The different emission factors are a consequence of the different air flow rates for gins processing picked cotton (7000 cubic



feet per minute (cfm) per bale per hour (bph) of capacity) and gins processing stripped cotton (8000 cfm per bph of capacity). (Ramaiyer and Parnell, 1996)

Baseline Best Available Control Technology (BBACT) consists of either 2D2D or 1D3D cyclones on all the centrifugal exhausts and fine mesh screens on the condenser drums of all axial flow exhausts. This design was defined in a policy document developed by the permit engineers and the industry engineers. This abatement strategy is assumed to have an emission factor of 2.24 lbs/bale . This number corresponds to 0.0373 grains /dry standard cubic foot (gr/dscf) for picker gins. (A. Ramaiyer, 1996)

Best Available Control Technology Design 0 (BACTD0) is an abatement strategy that consists of 1D2D cyclones on the axial-fan exhausts in the place of the covered condenser drums used in BBACT. The centrifugal fan exhausts have 1D3D or 2D2D cyclones. The 1D2D cyclones can be used for the axial flow exhausts because they are designed to operate at low pressure (<1.5 inches w.g). This cyclone was designed and tested successfully for this specific purpose (Simpson et al., 1995). This cyclone was also more effective as a dust abatement device for lint cleaner exhausts when compared to 1D3D or 2D2D cyclones. (A. Ramaiyer, 1996)

Best Available Control Technology Design 1 (BACTD1) is defined to include the following specific controls: Axial fans are replaced by centrifugal fans, 1D3D or 2D2D cyclones are utilized for all the centrifugal fan exhausts. The covered condenser drums are replaced by 2D2D cyclones. Particulate emissions are expected to be lower than BBACT because of the higher efficiency of cyclones compared to covered condenser drums. This strategy is currently being used by some gins in Texas. (A. Ramaiyer, 1996)

Best Available Control Technology Design 2 (BACTD2) is the fourth air pollution control system. It has a pre-separator/1D3D cyclone system on all of the fan exhausts. The axial flow fans are replaced with centrifugal fans. (A. Ramaiyer, 1996)

Best Available Control Technology Design 3 (BACTD3) is a strategy being used by some cotton gins. This design strategy makes use of a rotary drum filter on the cyclone exhausts that are connected to the unloading fan, the two push pull fans, and the trash fan exhausts. The remaining exhausts have the same controls as in BACTD1 (the axial fans are replaced by centrifugal fans, all the centrifugal exhausts have 1D3D or 2D2D cyclones). The rotary drum filter/cyclone system is included in order to study the economic feasibility of using rotary drum filters as air pollution control devices for cotton gins. (A. Ramaiyer, 1996)

The emission factors in Table 4 were utilized in Screen2 to predict the 1 hour and 24 hour concentration downwind at 1000 meters for the five different abatement strategies. The results shown in Table 5 are for a Stripper gin operating at 28 bph. The results shown in Table 6 are for a Picker gin operating at 28 bph.

To be in compliance with the NAAQS of  $150 \mu\text{g}/\text{m}^3$  - 24 hour average, regulators will assume an upwind concentration of  $30 \mu\text{g}/\text{m}^3$ . This would require the gin to have an emission rate that would result in a downwind property line concentration of  $120 \mu\text{g}/\text{m}^3$  - 24 hour average or less. Screen2 was utilized to model the five various abatement strategies. From these analyses it was possible to see how long a gin can operate on a bale/hour, bale/day, and hour/day basis and stay in compliance with the NAAQS. Regulators are using this procedure in some states to permit gins. The results shown in Table 7 are for Stripper gins to be in compliance with the limit of  $120 \mu\text{g}/\text{m}^3$  - 24 hour average. The results shown in Table 8 are for Picker gins that will be in compliance with the limit of  $120 \mu\text{g}/\text{m}^3$  - 24 hour average.

## Results

The following results were acquired with Screen2 and CGD. The models were run utilizing the six different stability classes. Each one of the stability classes is associated with a minimum and maximum wind speed. Results were obtained for each stability class at both the minimum and maximum wind speed. Each stability class was modeled for its respective minimum and maximum wind speed.

(1) The results obtained with Screen2 are one hour average concentrations - C (1hr). For stability class A, at a wind speed of 3 meters/second, the 100 and 1000 meter downwind concentrations were  $651.3$  and  $4.591 \mu\text{g}/\text{m}^3$ , respectively. For stability class C, at a wind speed of 10 meters/second, the 100 and 1000 meter downwind concentrations were  $486.1$  and  $20.35 \mu\text{g}/\text{m}^3$ , respectively. Table 1 shows the results of stability class A, C, and E concentrations calculated using Screen2.

(2) The results obtained with CGD are 10 minute average concentrations. For stability class A, at a wind speed of 3 meters/second, the 100 and 1000 meter downwind concentrations were  $645.7$  and  $4.538 \mu\text{g}/\text{m}^3$ , respectively. For stability class C, at a wind speed of 10 meters/second, the 100 and 1000 meter downwind concentrations were  $422.6$  and  $20.21 \mu\text{g}/\text{m}^3$ , respectively. Table 1 shows the results of stability class A, C, and E concentrations calculated using CGD.

(3) To estimate the 24 hour average concentration from the predicted values of Screen2, equation (8) was used with the multiplying factor of .4. Doing so yielded  $260.5$  and  $1.836 \mu\text{g}/\text{m}^3$  for stability class A at 3 meters/second (100 and

1000 meters respectively). For stability class C at 10 meters/second the values were 194.4 and 8.14  $\mu\text{g}/\text{m}^3$  for 100 and 1000 meters, respectively.

(4) To estimate the 1-hour and the 24-hour average concentrations for CGD, equation (14) was used. At 100 and 1000 meters, respectively, the concentrations for stability class A with a wind speed of 3 meters/second were 263.6 and 1.853  $\mu\text{g}/\text{m}^3$ . At stability class C with a wind speed of 10 meters/second the concentrations were 172.5 and 8.251  $\mu\text{g}/\text{m}^3$ .

(5) With Screen2, at 100 and 1000 meters, the  $\sigma_y$  values for stability class A at a wind speed of 3 meters/second were 27.2 and 208.75 meters, respectively. At stability class C with a wind speed of 10 meters/second, the values were 12.47 and 103.1 meters, respectively. The CGD model yielded  $\sigma_y$  parameters of 27.19 and 213 meters for class A, and 13.27 and 104 meters for class C.

(6) With Screen2, at 100 and 1000 meters, the  $\sigma_z$  values for stability class A at a wind speed of 3 meters/second were 14.59 and 453.9 meters, respectively. At stability class C with a wind speed of 10 meters/second, the values were 7.45 and 61.14 meters, respectively. The CGD model yielded  $\sigma_z$  parameters of 14.32 and 450.1 meters for class A, and 7.487 and 61 meters for class C.

(7) In Screen2, the calculated plume height for stability class A with a wind speed of 3 meters/second was 25.04 meters while for stability class C with a wind speed of 10 meters/second was 11.07 meters. In CGD, for the same conditions, class A plume height was 25.05 meters while class C plume height was 11.55 meters.

(8) For a 28 bph stripper gin with the highest level of abatement system (BACTD3) installed, Screen2 predicts a 24 hour average concentration of 216  $\mu\text{g}/\text{m}^3$ . (Table 5) For a 28 bph picker gin with the highest level of abatement system (BACTD3) installed, Screen2 predicts a 24 hour average concentration of 193  $\mu\text{g}/\text{m}^3$ . (Table 6)

(9) Utilizing Screen2 for regulatory purposes, a stripper gin that is equipped with BBACT can operate at 6.6 bales/hour or 158 bales/day and stay in compliance with the NAAQS. (Table 7) A picker gin that is equipped with BBACT can operate at 7.5 bales/hour or 180 bales/day and stay in compliance with the NAAQS. (Table 8)

(10) By use of cost factors developed by Ramaiyer and Parnell (1996) the initial investment required for the five abatement strategies discussed were calculated for both a stripper and a picker gin with a rated capacity of 28 bph. For a stripper gin to install a system consisting of BBACT it would cost \$141,120. (Table 9) For a picker gin to install a system consisting of BBACT it would cost \$125,440. (Table 10) The costs associated with upgrading the gin

from one abatement system to any higher level is also shown in Tables 9 & 10.

### Conclusions

Through comparison of the results obtained by modeling with Screen2 and those obtained with the CGD model, the following conclusions were made:

(1) The 1 hour concentration that SCREEN2 predicts is actually a 10 minute concentration.

(2) The 24 hour concentration that SCREEN2 predicts is actually a 1 hour concentration.

(3) The NAAQS should not be used for a property line concentration.

(4) Use of SCREEN2 to limit emissions from a cotton gin is inappropriate.

(5) To use the 10 minute concentration as a one hour concentration puts an unnecessary degree of conservatism in the Screen2 model results. Such conservative predictions will lead to downwind concentrations that are excessively high.

(6) The dispersion parameters utilized in CGD yield distances that are quite comparable to those obtained using Turner's dispersion equations. However, since the equations developed by Martin are clearly developed from Pasquill's log-log graphs, they are preferred over Turner's dispersion equations.

(7) The calculations for plume height in Screen2 and CGD are virtually the same and yield practically identical results.

(8) Even with the highest level of abatement installed for a 28 bph gin (which is associated with a cost of \$470,400) a gin still will not be in compliance with the NAAQS if Screen2 model is used as the regulatory tool. Therefore, CGD should be approved by EPA regions as an acceptable regulatory model for the purpose of calculating concentrations downwind from a cotton gin.

### Significance of Research

Dispersion modeling should exist for the purpose of determining whether a gin is in compliance (compliance meaning the gins downwind property line concentration is less than the NAAQS) with its permitted allowable emission rate. This emission rate should be calculated based upon a uniform process weight table (Parnell, 1996) or accurate emission factor. The available model, ISC Screen2, cannot be used to predict downwind concentrations accurately. Based upon ISC Screen2 Model results, the regulator justifies a limit on the number of bales ginned per day to a number such that the 24-hour average

concentration does not exceed 150 µg/m<sup>3</sup>. For example, in Arizona one particular 40 bale-per-hour gin is being limited to ginning 185 bales in one day. This means a gin that would normally operate 16-20 hours a day will only be able to operate 4-5 hours a day. The only gins that will be able to comply with the NAAQS are those that have excessive distance between them and their neighbor. Other gins would be forced to install control technology that is very expensive, and this still may not be sufficient. To use the current ISC Screen2 model could be an economic burden for cotton gins that may result in many smaller gins going out of business. Dispersion modeling should not be used to limit production unless there is a model that more accurately depicts the downwind concentration when compared to Screen2. The proposed model (CGD), **will** predict a more accurate concentration and therefore should be considered for use in place of Screen2.

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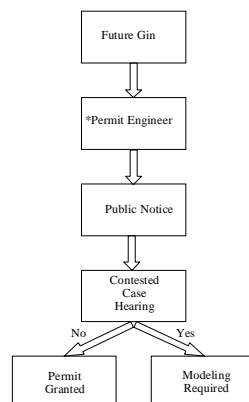


Figure 1. Current permitting process.

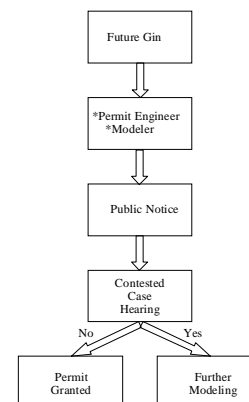


Figure 2. Future permitting process.

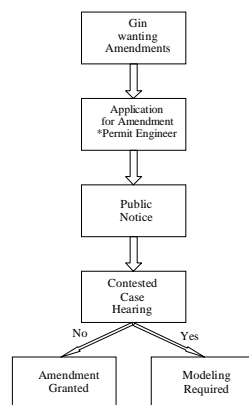


Figure 3. Current amendment process.

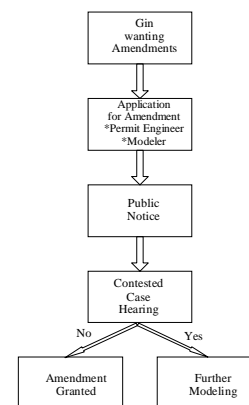


Figure 4. Future amendment process.

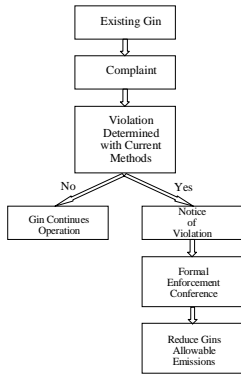


Figure 5. Current complaint process.

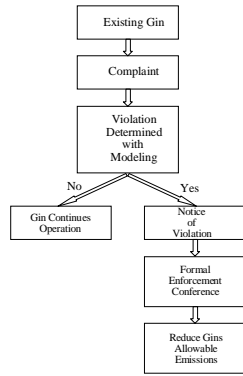


Figure 6. Future complaint process.

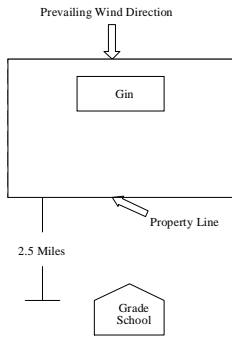


Figure 7. Scenario 1.

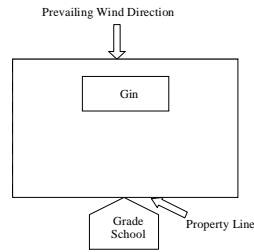


Figure 8. Scenario 2.

**Table 1.** ISC Screen2 Concentration compared to CGD Concentration. Concentration is in  $\mu\text{g}/\text{m}^3$  and Downwind Distance is in meters.

Stability class A; u = 1 m/s			Stability class A; u = 3 m/s		
Distance	Concentration		Distance	Concentration	
	Screen2	CGD		Screen2	CGD
100	768.3	740.8	100	651.3	645.7
200	614.2	615.1	200	259.8	261.6
300	331.7	308.4	300	121.4	110.8
400	185.4	158.8	400	64.44	54.48
500	107.0	89.95	500	36.38	36.38
600	62.93	55.42	600	21.16	18.60
700	40.81	36.47	700	13.35	12.20
800	31.03	25.27	800	8.955	8.441
900	26.96	18.23	900	6.293	30.87
1000	24.49	13.60	1000	4.591	4.538

Stability class C; u = 1 m/s			Stability class C; u = 10 m/s		
Distance	Concentration		Distance	Concentration	
	Screen2	CGD		Screen2	CGD
100	199.1	67.16	100	486.1	422.6
200	878.9	789.1	200	287.3	268.3
300	881.0	881.0	300	160.9	153.7
400	701.4	701.4	400	101.0	97.67
500	541.3	541.3	500	69.19	67.42
600	422.4	422.4	600	50.42	49.41
700	336.1	336.1	700	38.44	37.83
800	273.0	273.0	800	30.33	29.96
900	225.8	225.8	900	24.58	24.35
1000	189.7	189.7	1000	20.35	20.21

Stability class E; u = 1 m/s			Stability class E; u = 5 m/s		
Distance	Concentration		Distance	Concentration	
	Screen2	CGD		Screen2	CGD
100	10.47	.1193	100	60.68	40.16
200	363.2	236.0	200	489.7	488.2
300	946.3	835.2	300	601.4	594.0
400	1205	1162	400	536.1	533.0
500	1246	1231	500	450.3	448.0
600	1184	1181	600	374.9	374.0
700	1086	1088	700	314.1	314.3
800	980.4	986.2	800	265.9	267.2
900	880.6	889.0	900	227.7	229.7
1000	790.6	801.0	1000	197.1	200.0

**Table 2.** Emission Rates for Gins based upon an Emission Factor of 1.12 lbs PM10/bale.

	Daily Operation		
	10 hours	16 hours	20 hours
Rated Capacity 10 bales per hour	1.00 g/s	1.60 g/s	2.00 g/s
Rated Capacity 20 bales per hour	2.00 g/s	3.20 g/s	4.00 g/s
Rated Capacity 40 bales per hour	4.00 g/s	6.40 g/s	8.00 g/s

**Table 3.** Screen2 Emission Concentrations ( $\mu\text{g}/\text{m}^3$ ) at 1000 m downwind. Based on an Emission Factor of 1.12 lbs PM10/bale.

	Daily Operation		
	10 hours	16 hours	20 hours
Rated Capacity 10 bales per hour	283.4 $\mu\text{g}/\text{m}^3$	453.5 $\mu\text{g}/\text{m}^3$	566.9 $\mu\text{g}/\text{m}^3$
Rated Capacity 20 bales per hour	566.9 $\mu\text{g}/\text{m}^3$	907.0 $\mu\text{g}/\text{m}^3$	1134.0 $\mu\text{g}/\text{m}^3$
Rated Capacity 40 bales per hour	1134.0 $\mu\text{g}/\text{m}^3$	1814.0 $\mu\text{g}/\text{m}^3$	2267.0 $\mu\text{g}/\text{m}^3$

**Table 4.** Emission factors for Picker and Stripper Gins. (A. Ramaiyer, 1996)

Abatement Strategy	Picker Emission Factors (lbs PM10/bale)	Stripper Emission Factors (lbs PM10/bale)
BBACT	1.12	1.28
BACTD0	.90	1.03
BACTD1	.90	1.03
BACTD2	.60	.69
BACTD3	.47	.54

**Table 5.** Screen2 Emission Concentrations 1000 m downwind. Results are for a Stripper gin operating at 28 bale per hour.

	Emission Factor (PM10)	Concentration (1 hour)	Concentration (24 hour)
BBACT	1.28 lbs/bale	1275 µg/m <sup>3</sup>	510 µg/m <sup>3</sup>
BACT D0 &D1	1.03 lbs/bale	1060 µg/m <sup>3</sup>	424 µg/m <sup>3</sup>
BACT D2	.69 lbs/bale	680 µg/m <sup>3</sup>	272 µg/m <sup>3</sup>
BACT D3	.54 lbs/bale	539 µg/m <sup>3</sup>	216 µg/m <sup>3</sup>

**Table 6.** Screen2 Emission Concentrations for a 28 bph gin. Results are at 1000 m downwind for a Picker Gin.

	Emission Factor (PM10)	Concentration (1 hour)	Concentration (24 hour)
BBACT	1.12 lbs/bale	1134 µg/m <sup>3</sup>	454 µg/m <sup>3</sup>
BACT D0 &D1	.90 lbs/bale	907 µg/m <sup>3</sup>	363 µg/m <sup>3</sup>
BACT D2	.60 lbs/bale	595 µg/m <sup>3</sup>	238 µg/m <sup>3</sup>
BACT D3	.47 lbs/bale	482 µg/m <sup>3</sup>	193 µg/m <sup>3</sup>

**Table 7.** Stripper Gins that meet 120 µg/m<sup>3</sup> - 24 hour average with Screen2.

Emission Factor (PM10)	BBACT 1.28 lbs/bale	BACTD0 &D1 1.03 lbs/bale	BACTD2 .69 lbs/bale	BACTD3 .54 lbs/bale
Bales/hour	6.6	8.2	12.2	15.6
Bales/day	158	197	293	374
Hours/day (at 28 bales/hour)	5.6	7.0	12.2	1G